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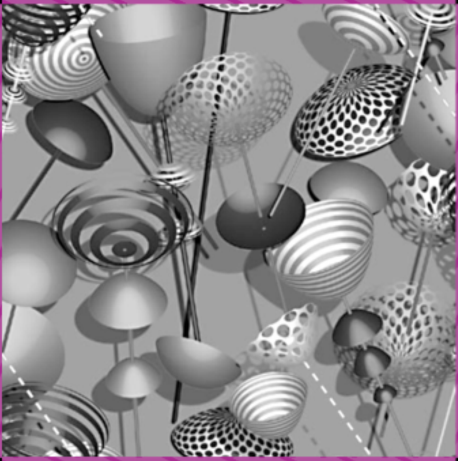

Textile design

Principles, advances and applications

Edited by A. Briggs-Goode and K. Townsend

The Textile Institute

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Textile design

The Textile Institute and Woodhead Publishing

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Foreword

This book *Textile design: Principles, advances and applications* is intended for a wide audience – textile design students, lecturers and professionals. It provides expert and up-to-the-minute information on a range of related topics that are insightful and far-reaching in their delivery.

Academics from universities worldwide have been consulted and here disseminate their knowledge on particular fields within the breadth and scope of textile design. While the majority of the experts are based in the UK, a wide cultural viewpoint is given – evidenced by three continents – Europe, Asia and Australia.

Inherent characteristics of fibres/yarns are discussed and various fabric construction methods are explained in detail including weaving and knitting, as well as nonwovens. In addition, methods of embellishment are covered in chapters on surface design and embroidery as well as dyeing and finishing treatments.

Case studies given demonstrate inspiring choices that span different expressions – one-off, artistic and production, commercial.

The book is logically divided into three parts – construction principles; surface principles and applications – namely fashion design and interior design. Each chapter begins by relaying the basics, making it ideal for students new to the area and acting as a reminder of the fundamentals for the lecturer/professional.

Also, concerns such as colour are given a voice while important and topical issues of sustainability are debated. More unusual industrial and technical textiles are investigated – expanding the field of textiles still further with their wide range of functional benefits.

Past and current innovations are explained while textile design's both near and far futures are contemplated and pondered.

This comprehensive book will arm its reader with in-depth knowledge – a must for the preparation of lectures, seminars, essays, dissertations, PhDs, conference papers and further publications. The book has been well edited with reliable, scrupulously researched texts, accessible writing and offers plenty of food for thought.

Sarah Braddock Clarke

Introduction

The focus of this book is to consider the current context of textiles from the perspective of design, manufacture, technological development and product application. The interconnections between these areas are described through discussion of historic and current developments as well as suggested future directions. Textile design is a complex field of practice which operates in a competitive, global industry. Textile designers are often unacknowledged in the process of design, obscured by the names of companies, brands and fashion designers. Therefore this publication attempts to bring clarity to the subject by revealing some of its hidden structures and interrelationships. It also seeks to capture the diversity of textile design through documenting technical and aesthetic considerations together with some of the traditional craft and advanced digital approaches currently applied by different sectors of the industry.

It is important for a publication of this nature to pose questions that challenge established practice and the authors featured here have all developed their own positions on the future of textiles. Each contributor has been selected for their specialist knowledge, but ultimately the shape and scope of this book has emerged from a shared passion and dedication to the field of textiles and fashion.

We have divided the chapters into the following three sections, Part I Principles: Fabric construction approaches to textile design; Part II Principles: Surface approaches to textile design and Part III Applications and advances, as described below.

Principles: Fabric construction approaches to textile design provides an overview of how most textiles originate from fibres and yarns and specifically how these are developed into woven and knitted structures. The section considers the fundamental knowledge required to enable a clear understanding of the constructed textile sector. In Chapter 1, 'Fibres, yarns and fabrics', Wilson considers the fundamental components of textiles, how they are categorised, produced and processed and provides a useful overview of the properties most likely to be encountered by the designer. It includes how ongoing research into new fibres is leading to the development of new materials and processes, in response to environmental issues. 'Woven textile design' by Redmore expands upon this context by detailing their formation, properties and applications. Innovation in craft and commercially woven fabrics is described through case studies. References to ecologically intelligent 'cradle to cradle' approaches and advances in jacquard and 3D weaving technology for scientific/medical contexts, point to the future of woven construction. In 'Knitted textile design', Francis and Sparkes outline the technology and its application in garment production by describing all the significant processes involved. The influence of technical advances (such as wholegarment, or 3D knitting) and hand crafted approaches are discussed in terms of current, ethical and future fashion trends. The various roles of a knitwear/knitted fabric designer are also clarified.

Principles: Surface approaches to textile design encompasses the subject areas of surface design, printed textiles, embroidered textiles, colour and dyeing and finishing, which are considered from the perspective of current commercial practice and future developments. 'Surface design' by Miles and Beattie focuses on the disparate approaches and processes which can now be applied to a broad range of surfaces as well as the potential coatings and finishes available to the designer. These developments have in themselves led to new designing strategies where links between science, technology, art and design are shifting previously held preconceptions about materials, applications and the role of the designer. 'Printed textile design' by Briggs-Goode and Russell discusses the current status of printed textile design, providing an introduction to its historical, technical and manufacturing contexts. They contextualise printed textiles in an historical timeline, describing different methods of textile printing as well as outlining the relationship between the 'print' and 'design' process. Contemporary principles and applications are considered and future trends within the sector proposed, with particular reference to the impact of digital technology. In 'Embroidered textile design' Miller discusses the ubiquitous nature of this application onto various clothing and household textiles through mass production. The chapter provides a comprehensive review of the contrasting stitching methods and styles, facilitated by traditional and new technologies and considers the design implications resulting from advances in digital (multi-head) embroidery. Chapter 7, 'Designing through dyeing and finishing' by Chakroborty, documents how colour is used in textile design to inform and enhance its surface appearance. Dyeing is evaluated as both an art form and commercial process, applied to contribute decorative and aesthetic value to cloth and clothing. The author discusses an extensive range of traditional and new dyeing and finishing approaches, describing how complex design effects are achieved. 'The use of colour in textile design' by Dickinson concludes the section with a complementary chapter which explores the importance of colour within contemporary textiles and fashion, from how it is perceived scientifically to its role as a communicator of trends. The author's consideration of colour in relation to technical, aesthetic and environmental issues provides the designer with important condiderations for future textile development.

Applications and advances is the largest section in the book and comprises seven chapters which provide examples of how textiles are applied within the industry, and significantly, how these applications are being influenced by tradition and technology. 'Colour and trend forecasting and its influence on the fashion and textile industry' focuses on how colour now informs the design process through its vital role in the development of textiles, garments and accessories. The chapter outlines the colour trend prediction industry; its inception, development, role in range planning and the development of seasonal colour palettes. Methods and strategies used to define new palettes are discussed in relation to industry timelines. Changes in consumer demands and new technology point to increased demand for changes in colour combinations and longevity. Chapter 10 'Sustainable textile design' by Sherburne considers a range of environmentally aware design practices and identifies how the industry can be influenced by considering several strategies to develop interpretations and alternatives based on life cycle analyses. The chapter underpins the unique role of the designer to affect change within this process.

In 'Fashion design', Jenkyn-Jones highlights how the role of the fashion designer is defined through the textiles, apparel and retail industries. It details the expertise and flexibility required to respond to changing technology and cultural trends, listing the new literacies required of the designer. The chapter concludes by questioning how fashion design education can inform responsive and responsible global relationships. Similarly, Jebbitt discusses 'Interior textile design' from a commercial industry perspective, providing insights into the professional practices of the printed and woven components, the key technical considerations for the designer and how the designer–manufacturer interface works. The author also informs the reader on the critical path, new trends, sustainability and includes case studies which effectively illustrate key concepts.

'The interaction between two and three dimensional design in textiles and fashion' by Townsend and Goulding discusses connections between the surfaces and structures of garments, the technical and aesthetic considerations faced by the designer. It identifies a range of design approaches to the integration of different styles of textiles with contrasting garment shapes and silhouettes. The chapter references significant historical and contemporary examples and includes figures from recent exhibitions and graduate design collections. No – waste approaches demonstrate how ethical considerations are influencing the ways in which designers apply textiles in fashion, while digital interventions are blurring the boundary between cloth and body.

In 'The design of technical textiles', Kettley describes how until recently this industry has focused on fabric function with little regard for the usual consumer requirements for aesthetics in garments and accessories. Now one of the fastest growing industries, a clear shift can be identified as designers work more closely with scientists and technologists to develop more pleasing and meaningful consumer products. The area is being driven by a passion and excitement about materials, processes and design concepts and is informing the future directions of textile design. Chapter 15, 'Designing future textiles', by O'Mahony provides an appropriate conclusion to the book, by helping the reader to fully appreciate how technology is driving the nature, performance and appearance of textiles. By considering the latest and most innovative fibre and fabric developments this chapter celebrates the creative impact of new materials and diverse applications that are revolutionising the use of textiles in design, art and architecture.

1
Fibres, yarns and fabrics: fundamental principles for the textile designer

J. WILSON, The University of Manchester, UK

Abstract: This chapter considers textile fabrics and their components – fibres and yarns. It looks at how fabrics and yarns are constructed and how fibres are produced and processed. It categorises fibres, yarns and fabrics and gives an overview of the properties of those most likely to be encountered. Ongoing research into fibres, yarns and fabrics means that new materials and processes are continually being developed – with environmental issues driving the development of more efficient processing technologies and new sustainable fibres.

Key words: fibres, yarns, fabrics.

1.1 Introduction

Fabrics are made from yarns and fibres. Fabrics may be made by a variety of processes including weaving, knitting, knotting and twisting yarns together and by bonding fibres together. Yarns are made from fibres, and fibres may be natural such as cotton and wool, or man-made such as acrylic and polyester.

Fabrics have many functions. They:

- clothe us;
- protect us – protective clothing worn by the emergency services and the forces;
- make us feel good;
- make our homes more comfortable – curtains keep in the heat and keep out the sun;
- dry us when wet;
- bandage and support injured limbs;
- are used in surgery – for artificial replacement ligaments and arteries;
- are used in many industrial applications – for conveyor and drive belts;
- are used in the construction of dams and motorways – geotextiles.
- The clothing or apparel market includes most garments that are worn. These can be classified by the wearer or by the type of apparel.

  By wearer:
  - menswear;
  - womenswear;
  - childrenswear.

  By type
  - sportswear;
  - casualwear;
  - formalwear.
- Specialised fabrics that go into protective clothing for fire-fighters, pilots, etc., are usually considered part of the industrial and consumer textiles market.

- Furnishing market or interior textiles includes:
  - curtains;
  - upholstery;
  - carpets;
  - wall coverings.
- Household textiles are those used in the home except furnishings and include:
  - sheets;
  - pillowcases;
  - towels;
  - blankets;
  - table cloths, etc.
- Industrial textiles include:
  - car tyre components;
  - medical textiles;
  - geo textiles;
  - filters;
  - conveyor belts;
  - safety belts;
  - parachute cords.
- Consumer textiles – these could be described as textiles not falling into the other categories and include:
  - tents;
  - back packs.

1.2 Basic principles of fibres, yarns and fabrics

The word textile comes from the Latin *texere* meaning to weave and was originally used only for woven fabrics; however, the term textile is now considered to cover any product that is manufactured from fibres, filaments or yarns.

Textile fabrics are structures that are made up of yarns or fibres in the form of a plane (essentially a flat or level surface) that is a structure which has a much greater surface area in relation to its thickness. Yarns and fibres are structures that are for the most part cylindrical and that are very long in relation to their diameter. Fibres are the fundamental units of yarns and as such are the fundamental components of fabrics. The Textile Institute's *Textile Terms and Definitions* (TT&D) defines a fibre as 'a unit of matter characterised by flexibility, fineness, and high ratio of length to thickness' (Beech *et al.*, 1986 page 94) and 'a fibre of indefinite length' (Beech *et al.*, 1986, page 96) is how TT&D defines a filament. Yarn is defined in TT&D as 'a product of substantial length and relatively small cross-section of fibres and/or filament(s) with or without twist' (Beech *et al.*, 1986, page 289).

The properties of any yarn are dependent on the properties of the component fibres and/or filaments and the structure of the yarn. The properties of any fibre or filament are dependent on its chemical and physical structure.

Yarns can be made from one fibre or from blends of fibres depending on what is required from the ultimate fabric in terms of performance, handle and appearance. They can comprise one single yarn for a single ply yarn or be made from a number of single yarns twisted or folded (plied) together for a multi-ply yarn. There are a variety of different systems to make yarns with regular and irregular profiles. Yarns with regular profiles are termed regular yarns while those with irregular profiles are termed fancy yarns.

Fibres have high length-to-diameter ratios. All natural fibres, apart from silk, are staple fibres; that is they have a natural length. Fibre lengths vary from 0.25 cm for cellulose pulp fibres and asbestos fibres, up to 12.5 cm or more for wool, and as much as 100 cm for flax. In cotton, the longer the staple length, the better the quality. For the most part natural fibres must be spun into yarns in order to be processed into useful textile materials. Manufactured or man-made fibres and silk are produced as continuous filaments. As such they may be used in continuous filament form or cut up into selected short lengths (staple) and then spun into yarns.

Fibres and yarns are made into fabrics by a variety of processes including bonding fibres together, weaving, knitting, twisting and knotting. Fabrics may be industrial textiles with detailed technical and performance specifications or for apparel, furnishings or household textiles where aesthetics may be as or even more important than performance. Fabrics may be coloured and patterned by dyeing, printing and by using coloured yarns in their construction and may have a finish applied to enhance appearance (e.g. brushing) or performance (e.g. flame proofing).

1.3 Main types of fibres, yarns and fabrics, and their production methods

1.3.1 Fibres

Fibres come from a variety of sources. They can occur naturally in plants such as cotton and hemp and on a variety of animals such sheep, goats, vicuna and camels or they can be created in a laboratory. Fibres can be classified in different ways including natural and man-made or as filaments and staple fibres.

Natural fibres

Natural fibres (Table 1.1) are any fibres that exist as fibres in their natural state. They can be categorised as protein (animal), cellulosic (vegetable) and mineral. Protein fibres are sheep's wool, speciality wools and silk. Speciality wools include goats' wool such as cashmere and mohair (from the Angora goat), wools from animals in the camel family including vicuna and alpaca, and angora from the Angora rabbit. Silk is the fibre that forms the cocoons produced by silkworms. Cellulosic fibres are cotton and speciality cellulosics include linen, ramie, jute, hemp, kapok and sisal. Flax (the fibre used to make linen yarns and fabrics), jute, hemp, and ramie are bast fibres obtained from the inner bark of plants, including flax (linen), cannabis plants (hemp), the Corchorus plant (jute) and from a member of the nettle family (ramie). Bast fibres are strong, soft, woody fibres. Organic cotton is from plants that have not been genetically modified and have been grown without the use of any synthetic chemical fertilisers or pesticides. Six naturally occurring fibrous silicates are called asbestos; asbestos is the only mineral fibre.

Table 1.1 Natural fibres

Natural fibres (all are staple fibres apart from silk which is a continuous filament)	Protein (animal) fibres	Sheep's wool	wool	
		Specialist wools/hair	Cashmere Mohair (from the Angora goat) Vicuna Camel Llama Alpaca Angora (from the Angora rabbit)	
		Silk	Tussah silk	Cultivated from 'wild' silkworms
			Cultivated silk	Farmed silkworms (sericulture)
			Organic silk	Farmed from silkworms which are allowed to emerge from the cocoon before processing
	Cellulosic (vegetable) fibres	Cellulosics	Seed	Cotton
		Specialist cellulosics	Bast (from the stem)	Flax Hemp Jute Ramie
			Leaf	Manila Sisal
			Seed	Kapok
			Fruit	Banana Coir Pineapple
	Mineral fibres	Fibrous silicates	Asbestos	

Man-made fibres

Originally developed in laboratories, man-made fibres (Table 1.2) are manufactured in industrial plants rather than occurring naturally. They can be classified as regenerated cellulosics – rayon, acetate and triacetate fibres; synthetics which include nylon fibres, polyester fibres, olefin fibres (polyethylene and polypropylene), acrylic fibres and elastomeric fibres (rubber and spandex); speciality synthetic fibres such as modacrylic and saran fibres; inorganic fibres which include glass, carbon and metallics; and protein fibres. Viscose is the most common type of rayon. It is produced in much greater quantity than cuprammonium rayon.

Microfibres are very fine synthetic fibres, finer than luxury natural fibres. The most common types of microfibres are made from polyesters, polyamides (nylon), or a mix of polyester and polyamide. The shape, size and combinations of fibres are selected for specific characteristics, including: softness, durability, absorption, wicking abilities, water repellency, and filtering capabilities.

Table 1.2 Man-made fibres

Man-made fibres (produced as continuous filaments)	Regenerated cellulosics		Rayon (Viscose and Cuprammonium) Acetate Lyocell Triacetate
	Synthetics	General use synthetics	Acrylic Nylon (polyamide) Olefin Polyester Rubber Spandex PLA (polylactide or polylactic acid)
		Specialist synthetics	Aramid Modacrylic Saran
	Inorganics		Carbon Glass Metallic
	Regenerated protein		Azlon

An item of clothing made from 100% microfibre will be much lighter and softer than one made from conventional fibres. Since the small filaments are packed closely together, fabrics made from microfibres are good barriers against the wind and, together with polyester's natural resistance to wetting, mean that fabrics are water repellent.

Extruded as continuous filaments man-made fibres are frequently cut into staple lengths so they can be spun. Traditionally, staple length only referred to natural fibres such as cotton, wool and jute. Silk is the only natural fibre which is a filament. Bi-component fibres are made from two related continuous filaments with different degrees of shrinkage; this result is a fibre which stretches due to the crimping. Hollow filament fibres are continuous filament fibres with a hollow centre which is created during the melt spinning process by extruding the fibres through a special spinneret or by introducing air or other gas in the polymer solution.

1.3.2 Yarns

Fibres and filaments are made into a variety of different yarns by a variety of different processes. Yarns can be categorised by their profile and by the way they are manufactured.

The first yarns were made from natural fibres such as wool and cotton and produced by hand. Essentially the process, called spinning, involved a process to remove impurities and lay the fibres reasonably parallel and then a process to tease out the fibres and give them some twist to create a yarn. For many thousands of years, fibres were spun using very simple tools, the spindle and distaff; fibres were attached to a distaff and then to a spindle which was dropped – spinning the fibres to give twist and form a yarn. The spinning wheel, which was still a hand process, was not generally known in Europe until the 15th century and it was not until 1764 and the beginning of the Industrial Revolution that yarns were mass-produced with the invention of the Spinning Jenny by James Hargreaves. This was improved by Samuel Crompton around 1779 with the development of his Spinning Mule.

Yarns can be classified as spun, filament, compound and fancy depending on the different processes used in their manufacture.

Spun yarns

Spun yarns (Table 1.3) are made from staple fibres (lengths of fibres) bound together, usually by twisting. Continuous filament fibres may be cut into lengths so they can be spun. The processes are ring-spinning, open-end spinning and air-jet spinning; each process giving different characteristics to the resultant yarn.

Ring spinning

Ring spinning is a system of spinning that uses a ring spinning frame that drafts rovings (fibres prepared into loose strands ready for spinning where the fibres have been laid parallel to some extent), twists the yarn, and winds it on the bobbin continuously and simultaneously in one operation. Ring-spun yarns have a higher proportion of fibres aligned parallel than other spinning systems. Carded yarns, combed yarns, woollen and worsted yarns are all types of ring-spun yarns. Carded and combed yarns are cotton or cotton blend yarns – combed yarns are made from longer cotton fibres and the fibres are more aligned than in carded yarns. Woollen and worsted yarns are made from wool or wool blends – worsted yarns are made from longer fibres than woollen yarns and the fibres are more aligned than in woollen yarns. The worsted process involves combing the fibres to give this better alignment.

Open-end spinning

Most open-end spun yarns are cotton or cotton blends, although some woollen yarns are friction-spun. The fibres are less well aligned than ring-spun yarns. They can be sub-divided into rotor and friction yarns depending on the method of processing. Rotor-spun yarns are more similar to cotton ring-spun yarns in terms of fibre alignment than rotor-spun yarns. Open-end spinning is faster than ring-spinning and friction spinning is faster than rotor spinning.

Table 1.3 Spun yarns

Ring-spun yarns	Carded Combed Woollen Worsted
Open-end spun yarns	Rotor Friction
Air-jet spun yarns	

Air-jet spinning

The rate of yarn production using this method is as high as ten times that of ring-spinning and twice as fast as open-end spinning. It is used for polyester and polyester/cotton blends. Air-jet spun yarns are made up of a core of relatively straight staple fibres held together by fibres wound round the core.

Filament yarns

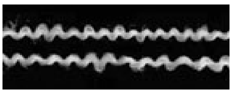
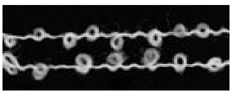
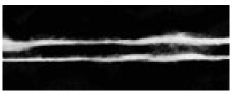
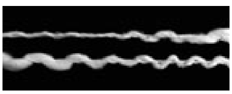
Silk yarn is produced by reeling off the silk fibre from the cocoons of the silkworm after the cocoons have been immersed in water. Man-made filament fibres are created by extruding the melts or solutions through a spinneret. Filament yarns are comprised of one or more continuous filaments which may or may not be twisted together.

To improve the handle (how the yarn feels to the touch) man-made filament yarns may be textured – that is the yarn is processed to make the profile more irregular. Fabrics which use textured yarns have increased bulk, opacity, moisture absorbency and thermal insulation properties than otherwise equivalent fabrics using filament yarns that have not been textured.

Fancy yarns

Fancy yarns (Table 1.4), also known as novelty or effect yarns, are yarns which have had irregularities deliberately introduced during manufacture. There is a whole range of different types of fancy yarns available – all producing different effects in any fabrics they are used in.

Table 1.4 Fancy yarns

Gimp	
Loop	
Slub	
Slub gimp	
Snarl	
Chenille	

Other yarn types

Compound yarns

A compound yarn is created by wrapping a covering yarn (covered yarn) or fibres (core-spun yarn) around a core yarn. Very often the core is a filament yarn while the covering strand is made from staple fibres.

Folded yarns

Folded yarns are yarns in which one or more single yarns are folded or twisted together making for example two-fold or two-ply yarns.

Cabled yarns

Cabled yarns are yarns made by twisting two or more folded yarns together.

1.3.3 Yarn count

The count number of a yarn indicates the length of yarn in relation to the weight. The linear density is measured rather than the width of a yarn to take into account irregular yarns.

Different systems of yarn count are currently in use: these either use a fixed weight (indirect) or a fixed length (direct). Fixed weight can be used with British and American weights and measures and metric weights and measures. Fixed length systems are based on metric weights and measures.

Indirect count systems

These fixed weight yarn count systems are used for numbering spun yarns. The count is the number of fixed length units that weigh 1 lb or 1 kilo. The more units of fixed length of a yarn weighing 1 lb or 1 kilo, the finer it is, and the higher the count number. With the metric system, 1 new metric (nm) always equals 1000 m/kg, regardless of the yarn fibre, 1/8s nm means 8000 metres would weigh 1 kilogram.

For wool yarns the count may be given as the number of 256-yard hanks that weigh 1lb (Yorkshire Skeins Woollen count –YSW) or as the number of 560-yard hanks that weigh 1lb (worsted count). For cotton yarns the count is the number of 840-yard hanks that weigh 1lb.

When a yarn is plied, that is, when two yarns of identical count are twisted together, the yarn is twice as thick, and therefore the length of yarn per lb is halved. The numbering of the yarn states both the count of the single component and the number of components that make up the ply.

2/8s nm means there are two 1/8s yarns plied together. This two-ply yarn will have an equivalent count of 1/4s; 2/10s cc (cotton count) – the length of this yarn that weighs 1 lb would be 10×840 divided by $2 = 4200$ yards; 1/5s cc (cotton count) – the length of yarn that weighs 1 lb would be $5 \times 840 = 4200$ yards

Direct count systems

The denier system (Beech *et al.*, 1986, page 70) is used to number continuous filament yarns, i.e. reeled silk and man-made extruded yarns such as rayon. It is based on a fixed yarn length to a variable weight and is measured in deniers. The denier count of a yarn states the weight in grams per 9000 metres. The coarser the yarn, the higher the denier count number becomes. Thus: 9000 metres of 30 denier yarn weighs 30 grams.

Tex is an internationally agreed fixed length system (that is the weight per unit length) of yarn numbering that applies to all types of yarns, regardless of the method of production. The tex count represents the weight in grams per 1 kilometre (1000 metres) of yarn (Beech *et al.*, 1986, page 251). For example, a yarn numbered 10 tex weighs 10 grams per kilometre. The tex number increases with the size of the yarn. The yarns are labelled according to an international code. The yarn count number is followed by the word 'tex'. The term 'folded' is used in preference to 'plied' yarn when two or more yarns are twisted together, and the direction of the twist is included in the formation. For example R 20 tex/ 2 S – two threads of 10 tex are folded in an 'S' direction, therefore the resultant count (R) will be 20 tex because the weight is exactly doubled.

1.3.4 Fabrics

Fabrics can be made by a variety of processes. Fabrics are classified as woven fabrics, knitted fabrics, twisted and knotted fabrics, nonwovens and compound fabrics.

Woven fabrics

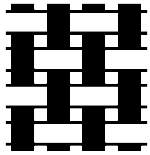
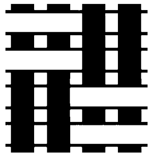
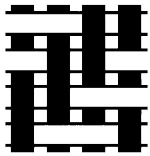
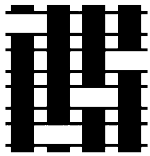
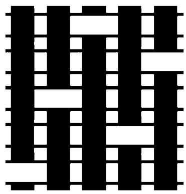
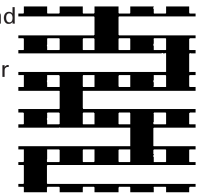
Woven fabrics are produced by interlacing two sets of threads, known as the warp and weft, at right angles to each other. The warp threads run parallel to the selvedge (the reinforced fabric edge) down the length of the cloth, and each warp thread is known as an 'end'. The weft threads run across the cloth from selvedge to selvedge and are called 'picks'.

The interlacing pattern of the warp and weft is known as the weave. The weave influences the appearance of the fabric, its handle, drape and its behaviour in use. A huge variety of different weaves can be created. The simplest woven structure is plain weave where warp threads interlace alternately with weft threads. Other basic structures include hopsacks, twills and satins (Table 1.5).

In general woven fabrics are made on a loom. A loom is essentially a system which allows the warp threads to be held taut and the desired weave raised in an appropriate order. The raising of some warp ends creates a space (the shed) which allows the weft to be inserted. For basic weaves the warp threads are usually woven on a loom which uses shafts to raise the warp threads as desired. The number of shafts on the loom determines the maximum number of different interlacing warp threads there can be in any fabric woven on that loom. For looms with only two shafts the shafts can be controlled by treadles.

Looms with more shafts, usually up to a maximum of 24, can be controlled by a mechanism called a dobby. A Jacquard mechanism allows more complicated structures to be woven as the warp ends are threaded through rods rather than

Table 1.5 Basic weave structures

Plain weave	The simplest weave structures with the highest number of interlacings possible	
Hopsacks	Variations of plain weave where two or more ends work together	
2/2 Twill	A weave giving a diagonal effect in the fabric. The angle of the diagonal line is dependent on the sett of the fabric; twills with more ends than picks per cm will have diagonal lines at more than 45°	
3/1 Twill	The structure used for most denims	
Warp satin	A predominantly warp-faced structure	
Weft satin	A predominantly weft faced structure; warp and weft satins are frequently used together; the smallest weave repeat size for a true warp or weft satin is 5 × 5	

shafts and this allows much greater flexibility in patterning. Examples of complex structures include leno fabrics and woven piles. As well as the structure in terms of the interlacings, the sett (the numbers of ends and picks per inch) will also have an impact on the appearance and the physical behaviour of a weave.

Other interlaced fabrics include braids. In these narrow-width constructions yarns interlace diagonally rather than at right angles to one another.

Knitted fabrics

Knitted fabrics are produced by interlacing loops of yarn and can be classified as weft knits and warp knits (Table 1.6). The knitting considered in this section is machine knitting.

Weft knitting is where the loops are formed one after another in a weft-ways direction as the fabric is formed. Warp knitting is where a set of warp yarns are simultaneously formed into loops. Weft knits can be categorised as being single, rib and purl structures. Warp knits can be further divided into tricot and Raschel structures.

Weft-knitting machines may be flat or circular. Circular knitting produces circular tubes. A row of knitting is termed a course and column of knitted loops is called a wale.

Weft knitting

The basic stitches in weft knitting are face loops, reverse loops, float stitches and tuck stitches. Transferring stitches to adjacent needles creates openwork effects (Tables 1.7 and 1.8).

- Single jersey fabrics are knitted on one bed of needles which means that the loops are all intermeshed in the same direction. Needles knit one at a time.
- Rib structures are knitted on two sets of staggered needles. This allows loops to be intermeshed in two different directions.
- Purl structures are knitted on machines which allow stitches in any one wale to be intermeshed in two directions.
- Interlock structures are knitted on machines which have two sets of needles aligned directly opposite each other. The machines are set up so that opposite needles cannot rise at the same time. This arrangement allows 'interlocked' structures which are more difficult to unravel that other weft-knitted structure to be created: 1×1 interlock, Punto di Roma and single piqué are commonly found interlock structures.
- Jacquard knits are colour-patterned fabrics which can be produced on single jersey and rib machines. The advent of computerised electronic knitting machines in the early 1970s and their subsequent development to allow individual needle control and selection has allowed detailed large patterns to be created.

More recent developments in knitting are electronic 'whole garment' machines which now allow three dimensional knitting. Entire garments can be knitted in one piece eliminating yarn waste and minimising the making up processes required after knitting.

Warp knitting

In warp knitting each needle is supplied with a yarn and all needles knit together producing a complete course (row) at once.

- Warp knits are flat fabrics rather than tubular.
- Tricot knits are made up solely of knit stitches and are used mainly for underwear, nightwear and lingerie.

Table 1.6 Knitted structures

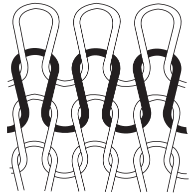
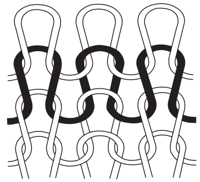
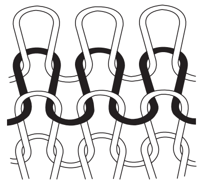
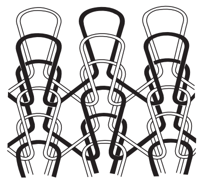
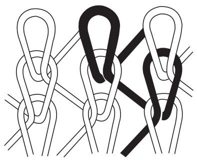
Weft knitting	Knitting where the loops are formed one after another in a weft-ways direction as the fabric is formed	Single jersey	Structures knitted on one bed of needles with the loops are all intermeshed in the same direction	
		Rib	Structures knitted on two sets of staggered needles. This allows loops to be intermeshed in two different directions	
		Purl	Structures knitted with double-ended needles which allow stitches in any one wale to be intermeshed in two directions	
		Interlock	Structures knitted on two sets of needles aligned opposite to each other. This allows loops on the front and the back to be intermeshed or interlocked	
Warp knitting	Knitting where a set of warp yarns are simultaneously formed into loops		Tricot	Structures made solely of knit stitches
			Raschel	Structures in which in-laid yarns traverse from column to column of loops up the fabric

Table 1.7 Basic weft-knit stitches

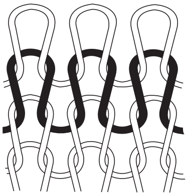
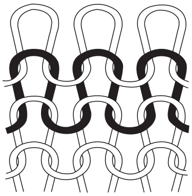
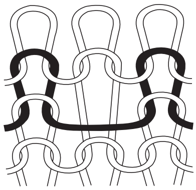
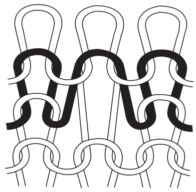
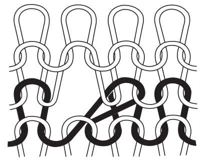
Face loops	Reverse loops
	

Table 1.8 Basic weft-knit structures

Float/miss stitch	Tuck stitch	Transfer stitch
		

- Raschel knits are essentially structures in which columns of loops connect in-laid yarns which traverse from column to column up the fabric. Raschel knits tend to be open structures and are frequently used for net curtaining fabrics.

Twisted and knotted fabrics

Twisted and knotted fabrics are created by intertwining (twisting and winding) yarns. Twisted and knotted fabrics include lace, some nets, rugs and carpets.

Lace

Lace is a fine openwork fabric made by looping or twisting. Lace-like structures can also be made by knitting, crocheting and embroidering.

Nonwoven fabrics

Nonwoven fabrics (Table 1.9) are composed of webs of fibres. The webs are bonded together to make a fabric by a variety of methods. These include entangling the fibres as in felting and needlepunching, bonding with adhesives, stitching together or some other means.

Compound fabrics

Compound fabrics (Table 1.10) are made by joining layers of fabric or by joining a fabric and a layer of another component such as yarn, fibres, vinyl, or film. A variety

Table 1.9 Nonwoven fabrics

Staple fibre webs	These include felt fabrics, needlepunched fabrics and spunlaced fabrics
Felt fabrics	Nonwovens created by entangling fibres by the application of heat, moisture and agitation. Woven and knitted fabrics can be felted to create effects
Needlepunched fabrics	Nonwovens created by entangling fibres by the action of barbed needles
Spunlaced fabrics	Nonwovens created by entangling fibres by the action of high-velocity water jets
Stitch-bonded fabrics	Nonwovens in which one component is a series of stitches and the other a web of fibres, yarns or a fabric

Table 1.10 Compound fabrics

Quilted fabrics	Fabrics consisting of a filler material sandwiched between two fabrics
Tufted fabrics	Fabrics which have a yarn pile (of loops or tufts) inserted into a backing fabric. The pile stands vertical at 90° to the backing fabric
Flocked fabrics	Fabrics which have flock (very short or pulverised fibres) attached to a base fabric – usually by an adhesive. The resultant fabrics have a velvet-like feel
Coated fabrics	Fabrics which have had a layer or layers of a coating fabric applied
Laminated fabrics	Fabrics which comprise layers joined together by an adhesive or by the adhesive properties of one of the layers

of techniques such as stitching, fusing or bonding with adhesive are used to hold the layers together. Compound fabrics include quilted fabrics, tufted fabrics, flocked fabrics, coated fabrics and laminated fabrics.

1.4 Main properties and characteristics of fibres, yarns and fabrics

The performance of any textile structure depends on its properties and characteristics. These are dependent upon a combination of factors including component properties (fibres and yarns), as well as the geometrical arrangement of fibres in yarns and of yarns in fabrics.

Different end uses will require different levels of performance from fibres, yarns and fabrics in terms of resistance to deformation (stress and strain), elongation and extensibility, elastic recovery (degree of return to the initial state after extension), stiffness, abrasion resistance, flexibility, moisture regain (the weight of moisture in a material expressed as a percentage of the oven-dry weight), heat resistance, combustibility, resistance to light, etc.

As there are so many variables which affect the properties and characteristics of fibres, yarns and fabrics, it is impossible to fully cover these in a chapter like this. What follows therefore is intended only as a general guide.

1.4.1 Key properties

Table 1.11 explains the key properties of textile materials.

1.4.2 Fibre properties

These are dependent on chemical composition, cross-sectional area and shape, length, crimp and surface contour of the fibre. Different fibres react differently when exposed to mechanical forces, water or other solvents, heat, radiation, chemical solutions and biological organisms.

Every fibre will have a characteristic structure and this structure is very important in determining the strength or weakness of a fibre and the way it does or not absorb water. All textile fibres are made from long chain molecular structures known as polymers. What the molecules are made up of, however, will be different from fibre to fibre. A co-polymer consists of two or more different chemical units joined together to form a chain. Acrylics are co-polymers. Cellulose in cotton consists of carbon, hydrogen and oxygen molecules joined together in a chain. Cotton and linen are both cellulosics but the chain molecules in flax are more highly oriented (that is they lie reasonably parallel to each other) than in cotton and it is this which explains why flax is stronger than cotton and also why cotton extends more than flax. As well as being joined along the chain, fibres will have some sideways joining of molecules or cross-linking. This prevents fibres sliding over each other. In wool the cross linking is such that it makes the wool springy and gives it good recovery from creasing. Cotton and viscose fabrics are frequently treated with resins to introduce cross links between the molecules and improve crease recovery.

Areas in fibres where the molecules are packed together in an orderly manner are said to be crystalline, while areas where the molecules are more randomly arranged are non-crystalline. All fibres have both crystalline and non-crystalline areas but the ratio of crystalline to non-crystalline areas will vary from fibre to fibre. The extent of crystallinity in a fibre has an impact on water absorption. Non-crystalline areas are more easily penetrated by water because of the larger spaces between the molecules. Viscose, for example, absorbs more moisture than cotton as

Table 1.11 Key properties of textile materials

Abrasion resistance	The degree to which loss of appearance through surface wear, rubbing, chafing, and other frictional actions is withstood
Absorbency	The ability to take up water
Air permeability	The ease with which air passes through; air permeability measures the warmth of blankets, the air resistance of parachute cloth, the wind resistance of sailcloth, etc. as measured on standard testing equipment
Colour fastness	The resistance to colour changes under specified conditions such as exposure to ultraviolet light, bleaching, etc.
Crease retention	The ability to retain pleats or creases deliberately placed in a fabric
Crocking resistance	The ability of a fabric to withstand transferring its colour to another surface when rubbed

Table 1.11 Continued

Dimensional stability	The degree to which a textile retains its shape in use – such as washing and dyeing
Drapeability	The manner in which a fabric hangs or forms folds; fabrics that fall smoothly into several soft folds are said to be highly drapeable
Dyeability	The ability to be dyed
Effect of heat	The impact of heat
Effects of sunlight	The impact of sunlight and ultraviolet light
Elastic recovery	Ability to return to original shape after stretching
Elasticity	The ability to stretch
Flammability	The degree to which a fibre, yarn or fabric burns
Handle	The feel when touched – descriptors of hand include pliable – stiff, soft – hard, stretchy – non-stretchy, springy – limp, rough – smooth, crisp, harsh, slippery, cool – warm, clammy and sleazy
Heat resistance	The extent to which useful properties are retained during exposure to heat
Insulation properties	The degree of resistance to transferring heat
Lustre	The sheen (reflectance of incident light); lustre depends on surface contour; filaments are normally more lustrous than staple fibres and satin weaves are normally more lustrous than other weaves
Moisture absorbency	The ability to absorb moisture; fibres, yarns and fabrics may be hydrophilic (absorbing water) or hydrophobic (avoiding water)
Moisture regain	The weight of moisture in a material expressed as a percentage of the oven-dry weight; moisture regain is an important element in whether or not a fibre, yarn or fabric is prone to static electricity which causes a fabric to cling; high regain and fabrics are less prone to static
Resilience	The ability to return to the original state after being deformed over a prolonged period; important aspects of resilience are wrinkle resistance, recovery from wrinkles, loft (compressional resistance), crease retention and shape retention
Pilling	A surface fault when bunches of fibres form in small balls on the surface of a fabric
Snagging	A snag is a yarn or part of a yarn that catches and is displaced from its desired position so that it sits above the fabric; knit fabrics because of their open loop structure have a greater tendency to snag than woven fabrics
Stain resistance	The ability to resist being discoloured by substances accidentally brought into contact such as red wine and chocolate
Washability	The ease of washing; fibre composition of a yarn or fabric is the element which most determines washability
Water repellency	The ability to shed environmental water
Water resistant	Fabric that resists the penetration of water; the compactness of a fabric's structure is an important factor in how resistant a fabric is
Water repellent	A fabric that provides a complete barrier to water; some water repellent fabrics are also breathable
Water vapour permeability or breathability	The rate of diffusion of moisture through a fabric
Wickability	The ability to disperse water by capillary action
Wrinkle resistance	The ability to resist bending and the formation of creases

it is less crystalline. The moisture absorption of a fibre is important when it comes to dyeing as to carry the dye into a fibre it needs to be carried by water. A fibre such as polyester is more difficult to dye than viscose or cotton as it does not easily absorb water.

Manufacturing processes for man-made fibres can be varied to produce differences in structures to meet specific requirements, for example by varying how man-made fibres are manufactured it is possible to produce fibres having high or low crystallinity.

Cotton fibres can have the shape of their cross section altered by soaking them in caustic soda and then neutralising them in acid. This process swells the fibres making them much more cylindrical and giving them their characteristic lustre. Mercerised cotton, as cotton treated in this way, is known is also stronger and has an increased affinity for dyes.

There is no one fibre which has all the properties required for most end uses. Wool fibres are comfortable, luxurious with a soft handle, relatively hard wearing and strong, lightweight, have good insulation properties, are wrinkle-resistant and absorbent however for easy washing special treatments are required to alter the wool fibres.

As well as changing processing methods and applying special processes to improve fibre performance fibres can be blended so that the subsequent blend combines the properties of both fibres.

Properties of natural fibres (Tables 1.12 and 1.13)

With the exception of mineral fibres, all natural fibres have an affinity for water in both liquid and vapour form. This strong affinity produces swelling of the fibres connected with the uptake of water, which facilitates dyeing.

Unlike most synthetic fibres, all natural fibres are non-thermoplastic; that is, they do not soften when heat is applied. At temperatures below the point at which they will decompose, they show little sensitivity to dry heat, and there is no shrinkage or high extensibility upon heating, nor do they become brittle if cooled to below freezing. Natural fibres tend to yellow upon exposure to sunlight and moisture.

All natural fibres are particularly susceptible to microbial decomposition, including mildew and rot. Cellulosic fibres are decomposed by some bacteria and fungi. Cellulose mildews and decomposes rapidly at high humidity and high temperatures, especially in the absence of light. Wool and silk are also subject to microbial decomposition by bacteria and moulds. Animal fibres are also subject to damage by moths and carpet beetles; termites and silverfish attack cellulose fibres. Protection against both microbial damage and insect attacks can be obtained by chemical modification of the fibre substrate; modern developments allow natural fibres to be treated so they are resistant to such attacks.

Man-made fibres

The key properties of man-made fibres are shown in Tables 1.14 and 1.15.

Table 1.12 Key properties of wool, silk, cotton and flax

	Sheep's wool	**Silk**	**Cotton**	**Flax**
	Made from the fleece of sheep. There are estimated to be 40 different breeds of sheep which produce around 200 different types of wool. Merino wool is high quality wool from pure-bred Merino sheep	Animal fibre from the silk worm; most silk is collected from cultivated worms; Tussah silk, or wild silk, is a thicker, shorter fibre produced by worms in their natural habitat	Fibres which grow as 'bols' round the seeds of the cotton plant Organic cotton is from plants that have not been genetically modified and have been grown without the use of any synthetic chemicals such as fertilisers or pesticides	A bast fibre from the plant stem; made into linen yarns and fabrics
Fibre length	20–200 mm	Filaments of 400–700 metres	10–55 mm	30–100 cm
Fineness	Varies fine to coarse	Very fine	Fine	Moderately fine to coarse
Strength	Relatively weak fibre but strong in yarn due to crimp	Moderately strong	Strong and durable	Very strong
Resilience	Exceptionally good – crease resistant	Moderate to good	Fair – creases relatively easily	Poor – creases easily
Abrasion resistance	Good	Good	Moderate to good	Moderate
Dimensional stability	Poor – felts when wet	Good resistance to stretch and shrinkage	Fabric may shrink during laundering	Will not stretch or shrink
Moisture absorbency	Good	Good	Very good	Poor
Effects of sunlight	Prolonged exposure will cause degradation	Considerably weakened by sunlight	Prolonged exposure will cause yellowing due to oxidisation	Prolonged exposure weakens fibres
Effect of heat	Becomes harsh at 100°C in dry conditions	Will decompose at 150°C	Withstands high temperatures well	Scorches at high temperatures
Dyeability	Excellent affinity for dyes – dyes well and evenly	Good affinity for dyes	Good affinity for dyes	Poor affinity for dyes
Effects of fungi and mould	Will mildew in damp conditions	Highly resistant	Highly susceptible to mildew	Highly susceptible to mildew
Effects of insects	Easily damaged by carpet beetles and clothes moths	Not damaged by insects	Starched cottons are attacked by silverfish	Not damaged by insects
Flammability	Does not burn easily	Burns slowly; usually self-extinguishing	Burns readily	Burns rapidly
Handle	Soft and warm	Smooth, soft, crisp and dry	Soft and cool to touch	Crisp and dry
Lustre	The highest lustre is in low grade wools	High lustre	Low lustre	High lustre – almost silky in appearance
Washability	Washable but needs special treatments for machine wash	Does not stretch or shrink	Fabrics may shrink during laundering	Excellent
Insulation properties	Good	Excellent	Very good	Very good

Table 1.13 Key properties of other natural fibres

Alpaca	From the Alpaca goat	Lustrous; strong in relation to its diameter; good insulation properties
Angora	From the Angora rabbit	Fine; lightweight; very warm; very expensive; often blended with wool to decrease the price and to obtain novelty effects
Asbestos	From naturally occurring silicates	Most asbestos fibres are highly toxic and no longer used in textile constructions
Banana	Fibre from the banana plant	Similar in appearance to linen; lightweight; elegant appearance; usually blended with other fibres like silk or polyester
Camel	Hair from the camel	Lustrous; strong in relation to its diameter; good insulation properties
Cashmere	Hair from the Kashmir goat	Outstanding softness; very luxurious; excellent drapeability; expensive; shorter cashmere fibres have a tendency to pill; comfortable; absorbent; good colour retention; prints well; machine-washable, dry-cleanable; good strength
Hemp	A bast fibre from the stem of a plant The highest quality hemp comes from the 'true' hemp plant called Cannabis Sativa. Sisal hemp and Manila hemp (also known as Abaca) are lower quality hemp fibres	Three times stronger than cotton; good abrasion resistance and very durable; anti-microbial; good UV resistance; naturally resistant to mould, mildew and rot; readily takes dyes; softens with each washing without fibre degradation; breathable; washable or dry cleanable; wrinkles easily/poor resiliency; poor drapeability; has a rather harsh handle which means it is usually used in blends with other fibres
Jute	Bast fibre from the Corchorus and related plants	Very rigid fibre; poor abrasion resistance; burns rapidly; scorches at high temperatures
Kapok	Fibres from the seed pods of the Kapok plant	Light, very buoyant; resilient; resistant to water. Difficult to spin, it used to be used for filling in life jackets, mattresses, pillows and soft toys. Now, however, such fillings are more often made from man-made fibres
Llama	Hair from the llama, a member of the camel family	Lustrous; strong in relation to its diameter; good insulation quality
Mohair	Hair from the Angora goat	Long, lustrous, strong fibre; luxurious; soft handle; most resilient natural textile fibre; lightweight; good insulator; dyes well; non-crush, non-matting and non-pill qualities; resists fading
Pineapple	Fruit	Similar in appearance to linen; lightweight; elegant appearance; usually blended with other fibres like silk or polyester; washable/easy care
Ramie	Fibres from China Grass, a flowering plant in the nettle family	Very absorbent (more absorbent than linen); quick drying; very resistant to mildew and rotting; good strength; smooth lustrous appearance that improves with washing; brittle, with low twisting or bending strength; poor resiliency; wrinkles easily
Sisal	Fibres from the leaves of the sisal plant	Stiff handle; absorbs moisture well
Vicuna	Hair from the vicuna, a member of the camel family	Lustrous; strong in relation to its diameter; good insulation quality

Table 1.14 Key properties of rayon, acetate and triacetate, nylon, polyester, acrylic, olefin, spandex and saran

	Rayon	Acetate and Triacetate	Nylon	Polyester
	A manufactured regenerated cellulose fibre	Both made by modifying cellulose – Triacetate has more acetate groups	Refers to the group of synthetic polymers known as polyamides	Made from chemical substances found mainly in petroleum PET (polyethylene terephthalate) is the most common polyester Frequently blended with cotton and with wool
Fibre length	Filament and cut staple as required	Filament and cut staple as required	Filament and cut staples as required	Filament and cut staples as required
Fineness	As required	As required	As required	As required
Strength	Moderate	Moderate	Excellent	
Resilience	Low – creases easily	Acetate poor, triacetate good with very good wrinkle recovery	Very good – excellent wrinkle resistant properties	Excellent to very good wrinkle recovery
Abrasion resistance	Low	Low to moderate; triacetate better than acetate	Excellent	Exceptionally good
Dimensional stability	Regular to poor	Resistant to stretch and shrinkage – cannot be heat set	Can be heat set to maintain shape	Can be heat set to maintain shape
Moisture absorbency	Very good	Poor to moderate Triacetate is less absorbent	Very low – prone to static	Negligible – very prone to static
Effects of sunlight	Deteriorates when exposed to ultraviolet light	Prolonged exposure results in splits and loss of strength	Good resistance to sunlight if behind glass – prolonged exposure cause deterioration	Good resistance to sunlight if behind glass – prolonged exposure cause deterioration
Effect of heat	Moderate resistance	Sensitive to heat Triacetate is less sensitive	Thermoplastic can be set	Thermoplastic can be set
Dyeability	Excellent	Needs to be dyed with special dyes	Very good	Good
Effects of fungi and mould	Will resist mildew if dry and clean	High resistance to mildew	Unaffected	Resists mildew
Effects of insects	Attacked by silverfish	Silverfish may attack heavily sized fabrics	Unaffected	Unaffected
Flammability	Burns rapidly	Burns moderately	Burns slowly and melts	Burns slowly and melts
Handle	Soft, rather limp, cool to touch	Soft	Synthetic, rather sleazy	Soft and crisp
Lustre	Very lustrous but can be de-lustred	Very lustrous but can be de-lustred	Very lustrous but can be de-lustred	Very lustrous but can be de-lustred
Washability	Low wet strength	Very good	Excellent – quick drying	Very good – quick drying
Insulation properties	Excellent	Good	Excellent	Excellent

Acrylic (polyacrylonitrile) Acrylics are used where bulky hairy yarn is required Frequently blended with wool and with nylon	**Olefin** (polypropylene and polyolefin) Long-chain polymer synthetic fibres Very lightweight	**Elastane** Used with other fibres to improve elasticity	**Saran** Originally developed as a packaging film – now used extensively in products that must meet flammability standards as the fibres do not support combustion
Mostly used as cut staple	Filament and cut staple as required	Filament and cut staple as required	Filament and cut staple as required
As required	As required	As required	As required
Good	Excellent	Poor	Poor
Good	Good to excellent	Very good – highly flexible	Poor
Fairly good	Excellent	Very good	Excellent
Excellent	Will not shrink unless exposed to temperatures above 150 °C	Good	Excellent
Low	Low	Moderate	Low
Excellent	Loss of strength and degradation after prolonged exposure	Resistant to light	No appreciable strength loss but fibres darken after prolonged exposure
Yellowing may occur at high temperatures	Relatively heat sensitive	High temperatures reduces elasticity	Very heat sensitive
Very good	Poor	Reasonable	Poor
Unaffected	Unaffected	Unaffected	Unaffected
Unaffected	Unaffected	Unaffected	Unaffected
Burns rapidly leaving a hot residue	Slow-burning, melts	Burns slowly – leaves sticky residue	Self-extinguishing
Soft and warm	Waxy	Rather hard	Stiff
Very lustrous but can be de-lustred	Very lustrous	Dull	Very lustrous
Very good	Needs to be washed at low temperatures	With care to avoid over stretching	
Good	Good	Poor	Poor

Table 1.15 Key properties of man-made fibres

Aramid	A manufactured fibre in which the fibre-forming substance is a long chain of synthetic polyamide in which at least 85% of the amide linkages are attached directly to two aromatic rings Kevlar® is an aramid fibre produced by DuPont	Very strong and resistant to high temperatures and extreme external forces – it has no melting point, low flammability, and good fabric integrity at elevated temperatures; used in high performance protective apparel and where flame resistance is important
Azlon	Synthetic textile fibre composed of protein material derived from natural sources such as peanut, milk, soy and corn	Soft; lustrous; good handle; dyes well; weak when wet and susceptible to microbiological growths
Carbon	Carbon graphite or CF, is a material consisting of extremely thin fibres composed mostly of carbon atoms	High strength-to-weight ratio; high tensile strength, low weight, and low thermal expansion; very strong when stretched or bent, but brittle when extended or compressed
Glass	An inorganic fibre	Very strong, but poor flexibility and poor abrasion resistance; glass fibre will not burn and will not conduct electricity; not affected by insects, mildew, and sunlight
Lyocell	A manufactured fibre composed of regenerated cellulose.	Excellent overall strength; excellent wet strength; washable; shrink-resistant; wrinkle-resistant; soft handle; excellent drape; good absorbency; dyes and prints well; subtle lustre
Metallic	Inorganic fibres made from minerals and metals, blended and extruded to form fibres	Light in weight; not affected by salt water, chlorinated water in swimming pools or climatic conditions
Modacrylic	A synthetic co-polymer (modified acrylic)	Soft; strong; resilient; dimensionally stable; can be easily dyed; good press and shape retention; quick to dry; outstanding resistance to chemicals and solvents; not attacked by moths or mildew; non-allergenic
PLA fibre	A synthetic fibre derived entirely from maize – plant starches (such as corn) are broken down into natural plant sugars. The carbon and other elements in these natural sugars are then used to make a polymer	Similar to cotton in appearance; handles like a natural fibre; low moisture absorption, good wickability/ breathability; good performance qualities; low melting point; low specific gravity (lighter); high resistance to ultraviolet light; excellent drapeability; from a renewable resource; biodegradable
Rubber	Made as either an extruded round fibre or rectangular fibres that are cut into strips from extruded film	Low dye acceptance; rubbery feel and appearance; low tenacity; lacks resistance to oxidising agents; damaged by ageing, sunlight, oil, and perspiration Usually covered by yarn of another fibre or directly woven with other yarns into fabric

1.4.3 Yarn properties

These are dependent on the manufacturing process, fibre properties, and the yarn fineness, twist, cross section, count and profile.

Effects of manufacturing processes

Spun yarns and filament yarns are quite different in terms of aesthetics, structure and performance. Spun yarns are hairy while filament yarns are smooth. Spun yarns are less lustrous and generally softer in terms of handle than filament yarns. They tend not to slip as much as filament yarns and do not tend to snag as much. Spun yarns do, however, tend to pill more than filament yarns. (Pills are small accumulations of fibre which can form on the surface of a fabric during use.) Due to the differences in performance, spun yarns are usually preferred for apparel; however, exceptions include lingerie, hosiery and fabrics that are required to be windproof.

- Yarns made with longer fibres tend to be smoother, more lustrous and stronger than those made with shorter fibres as do yarns made with fibres that are more aligned.
- Continuous filament yarns are more regular in terms of thickness than spun yarns. Irregular yarns tend to be weaker than filament yarns.
- Open-end spun yarns are more regular and have a greater degree of uniformity than ring-spun yarns,
- Combed yarns are stronger, more regular and more lustrous than carded yarns.
- Worsted-spun yarns are smoother and more lustrous than woollen-spun yarns. They are made from longer fibres than woollen yarns and the fibres are more aligned than in woollen yarns. The worsted process involves combing the fibres to give this better alignment.
- Folded yarns are generally stronger than single yarns as any weak places in the single yarns will be less of a problem in the combined yarn. Sewing threads are folded as they are required to be uniform in diameter and to have no weak places.

Effects of fibres

Fibre properties have been fully covered in Section 1.4.2

Effects of twist

Yarn twist is the number of turns per a unit length (inches, metres or cms) and the direction that yarns (or fibres) are turned during the manufacturing process. The direction and amount of yarn twist helps determine appearance, performance, durability of both yarns and the subsequent fabric or textile product. Yarns may be twisted to the left (S twist) or to the right (Z twist). Generally, woollen and worsted yarns are S-twist, while cotton and flax yarns are typically Z-twist.

Twist compacts the yarns (or fibres) bringing them closer together and increasing yarn strength. If the level of twist in a yarn is too low, the yarn may break under tension as the fibres may slip away from each other. If too high, the yarn may become too 'lively' and untwist and snarl in such a way that the yarn twists back on itself.

While the level of twist (the number of twists per unit length of yarn) is important, the factor that has more impact on yarn property is the angle of twist. This is normally quantified by calculating the twist factor from the twist level and the tex count of the yarn. A cotton yarn for weaving will normally require a higher twist factor that a cotton yarn for knitting.

For weaving, the yarns used in the warp require to be stronger than the weft yarns due to the stresses they are placed under during the weaving process. Weft yarns can be much weaker and, for fabrics that are going to be raised or brushed after weaving, the twist factor would normally be lower so the fibres can be more easily teased apart. Significantly increasing twist factor will result in a crinkly crepe yarn.

Cross section

Cotton yarns and fabrics can be given a lustrous sheen by altering the cross-sectional shape of the cotton fibres. This is done by soaking the yarns (or fabrics) in caustic soda and then neutralising them in acid. The fibres become swollen making them much more cylindrical which gives them their characteristic lustre. Mercerised cotton as it is known is also stronger and has an increased affinity for dyes. Lustrous, smooth-surfaced fabrics such as satins show wrinkles more easily than fabrics with rougher surfaces such as flannels.

Filament yarns are frequently textured to improve properties. Texturing processes can introduce crimps, coils, snarls and crinkles into the filaments. Most processes use heat to set the yarn into the required profile. A process which does not require heat is air-jet texturing where loops are formed by over-feeding the filament into a turbulent air stream.

1.4.4 Fabric properties

A fabric is made up of many elements and the properties the fabric displays are influenced by all these including component fibres and yarns and their inherent properties, the fabric construction, the density of yarns or fibres and any subsequent processes such as printing or finishes applied. All these elements will affect the final fabric – its appearance, handle, drape and behaviour in use. Subtle differences in yarn structures can lead to marked differences in yarn and fabric performance. As there are so many variables which affect the properties and characteristics of fabrics what follows can act only as a general guide.

Component fibres and yarns

The key properties of fibres and yarns have been covered previously in Sections 1.4.2 and 1.4.3.

Worsted fabrics tend to have a better crease resistance than woollen fabrics but woollen fabrics tend to be more resilient. Fabric lustre increases with fibre length and alignment. Fabrics made with man-made filament yearns are generally more lustrous than other fabrics.

Fabric construction

Woven fabrics are generally firmer and more rigid than many other fabric constructions due to the way the yarns are interlaced at right angles. They do not drape as well as knits and are not very extensible. Knit fabrics are easily stretched as they are made up of interlinked loops of yarns; however, this does mean they can distort much more. The smoother and more resilient the yarn is, the better the knit fabric recovers. Because of their extensibility, knits are very comfortable to wear. Knits provide good thermal insulation they also generally have a better handle than woven fabrics.

As the abrasion resistance of knits is generally better than woven fabrics, due to the fabrics being more easily able to absorb strains and stresses, the yarns used in knits do not need to be as strong as in woven fabrics. Knit fabrics are, however, much more prone to snagging and pilling. Lower-twist staple-fibre yarns are frequently used in knits, this and the looser structures allow fibres to easily work themselves to the surface to form pills. The looser structures are also why yarns catch and snag readily in many knitted fabrics.

Woven fabrics

- Plain weave is the simplest and most frequently used weave of all. Because it has the maximum number of interlacing or binding points possible, it is firmer and stronger than most other weave structures. Lightweight woven fabrics are usually made in plain weave to ensure that the ends and picks do not slip over each other and cause the fabric to distort. Chiffon and voile are two lightweight fabrics made using plain weave. Voiles are normally produced from cotton or linen, while chiffons are traditionally made from silk.
- Hopsack weaves are more wrinkle resistant that plain weave as the lower number of interlacings allows the yarns to move more within the structure and more easily absorb the stresses and strains of crushing and bending. The lower number of interlacings also means that hopsacks allow moisture to more easily be dispersed than plain weaves; however, it also means that hopsacks are less durable.
- Twills are among the most durable woven fabric constructions. They are very compact structures which result in low permeability and in turn high wind resistance. They are more pliable than plain weave structures due to the nature of the interlacings and as such are more resistant to wrinkling. They also have a greater resistance to soiling and are more durable. Woollen twills are frequently used for upholstery fabrics dues to these properties and the durable nature of wool.
- Denim is a 3/1 warp faced twill with a steep diagonal which is very hard wearing. This is in part due to the fact that the stronger warp yarns are more on the face of the fabric. The weaker weft yarns floats are shorter because of the steepness of the twill and so abrasion resistance is improved.
- Satins produce fabrics that are firm and drape very well. They are often made with filament yarns and are very lustrous.
- Weave crimp is the ratio of the actual length of yarn in a piece of fabric to the length of fabric produced by that length of yarn. Crimp influences fabric volume, thickness and the mechanical properties.

Knits

- Single-jersey weft-knits are the simplest weft-knit fabrics. The face of the fabric curls to the back at the sides and to the front at the top and bottom.
- The simplest purl knit is wider but shorter than an equivalent single jersey knit. Purl knits generally have excellent lengthwise extensibility.
- Warp knits are generally firmer and have better dimension stability than weft knits.

Nonwovens

- Felts are noted for their resiliency, sound absorbency and they can be moulded into a variety of shapes. They do not fray or ravel. They do, however, tear readily and are subject to pilling.
- Needle-punched structures made from olefins are used extensively outdoors and for backing for carpets. Stitch bonded fabrics tend to have high tearing strength and relatively high bulk, which means they have good insulating properties. Nonwovens are frequently engineered for consumer and industrial applications including geotextiles and protective clothing.

Fabric density

A woven fabric with more ends and picks per centimetre will be heavier than a fabric that is otherwise equivalent (that is, has the same yarn and structure) with a lower density of ends and picks; equally a knit fabric with a smaller loop size (and therefore more wales and courses per centimetre) than an otherwise equivalent fabric will be heavier. The density of a fabric influences strength, thickness, stability and abrasion resistance.

1.4.5 Finishes

As well as the fibres, yarns and fabrics, what is done to fabrics after manufacture impacts on their properties and performance. Finishes can be applied to enhance performance and appearance. Chemical finishes include anti-static treatments, flame retardants, water repellents, anti-miscrobials and softeners. The chemicals may cause a reaction in the fabric or adhere to the fabric surface. Physical finishes include raising, brushing, flattening and embossing.

1.5 Future trends

Ongoing research into fibres, yarns and fabrics means that new materials and processes are continually being developed. Environmental issues are driving the development of more efficient processing technologies and new sustainable fibres such as PLA (poly lactic acid), a renewable fibre made from maize. Microfibres have allowed the development of fabrics with improved performance and new treatments developed for wool have allowed the design and manufacture of wool suits that are fully machine-washable.

Smart textiles with novel functionality incorporate wearable electronics. MP3 players, mobile phones and headphones have been woven into jackets and coats, and curtains have been developed that light up in the dark. Originally these products transferred the energy required through wires woven into the fabric; now the conductivity is being built into the actual fibres and yarns making products that are more comfortable to wear and easier to launder. Socks have been developed with small batteries powering a heating system in the toes and personalised wearable monitoring systems are being developed that allow the monitoring of vital health signs such as ECG, heart rate, respiration and skin temperature.

High performance textiles are being engineered for highly specific requirements. One example is the specially designed fabric with a structure similar to shark skin being developed for competitive swimwear to reduce drag. Heat-modifying textiles are being developed which keep the wearer warm when cold and cool when hot.

Microencapsulation involves using thin polymer coatings to hold tiny containers of solids or liquids which release their contents over a period of time. Using microencapsulation techniques with textiles has allowed the development of fabrics with anti-odour and antibacterial properties. Socks can be made to stop smelling and airline seats can be made to be super stain-resistant; dressings for wounds can now incorporate substances to help the healing process and smart fabric patches are being developed to deliver drugs through the skin. Aloe vera, vitamins and insect repellents are all being added to textiles through microencapsulation techniques. Bamboo and algae are being added to promote cell regeneration and stimulate blood circulation.

Silver is being used in textiles to combat bacteria. When bacteria come into contact with silver ions they are damaged and so prevented from multiplying. Such anti-microbial textiles are being used in a range of medical applications.

Thermochromic and photochromic dyes have been used to make garments which change colour when they are exposed to temperature changes or sunlight and duvets which come with 3D glasses allow their designs to be seen in 3D.

Conductive fibres, microencapsulation and engineered high-performance textiles offer a wide range of possibilities for more creative and innovative textiles in the future while environmental issues will drive the development of more sustainable fibres and processes.

1.6 Conclusion

This chapter has considered fibres, yarns and textile fabrics. It has looked at how fibres and yarns are produced and processed and how fabrics are constructed and finished. It has categorised fibres, yarns and fabrics and outlined their major properties. It has also looked briefly at how textile products are currently being developed for the future.

1.7 Sources of further information and advice

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2
Woven textile design

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Abstract: This chapter considers woven fabrics, their formation, properties and applications. It explains the principles of weaving, details the basic constructions, and common weaving terminology in use. Design approaches to woven fabric design are detailed, along with the role that technology plays to create and communicate ideas. Advances in woven fabric construction, design and weave's relationship to other processes are other key topics covered.

Key words: weave design and manufacture, sustainability and weave as a traditional craft, computer aided design and the global textile market, fabric performance and advances in woven technology.

2.1 Introduction

Designers of woven fabrics are challenged with bringing together creative flair and technological know-how to create fabrics that not only excite, but perform for a given market and end-use. This chapter outlines the basic weave structures, categories, design considerations, and opportunities available in this long-established sector of the textile industry. The marriage of technology with weaving and the push to achieve cutting edge design and performance, whether in isolation or through combination with other disciplines are also covered.

2.1.1 The origins of weaving

For centuries weaving was carried out by hand in the home on a cottage industry basis, where the two processes of spinning and weaving were carried out side by side in the home. Evidence of cloth being woven can be traced as far back as 7000 to 8000 BC in Mesopotamia and Turkey, but the exact date is difficult to pinpoint due to the perishable nature of textile goods. As civilisation developed, figures in royalty and the church began to indicate their stature through the use of intricately woven ornate fabrics.

In the cottage weaving industry, men and women took on the different roles of weaving and spinning, to produce a final cloth on hand-operated looms, which was then sold on to a cloth merchant. Evidence of this cottage industry can still be seen in the weavers' cottages of West Yorkshire, where mullioned windows span the full width of the house allowing sufficient light into what was the loom chamber on the upper floor.

2.1.2 Industrial Revolution

By the 1700s imports of cheaper textiles from the Far East and India started to replace those produced in the UK, which drove the domestic weaving production of cloth to find a way to increase its productivity. The move from the domestic and cottage industry-based route in the 18th century was made possible by a number of key inventions that mechanised some of the processes involved in producing cloth. The invention of the flying shuttle in 1733 by John Kay, required faster spinning methods to be developed, resulting in the creation of the Spinning Jenny (James Hargreaves in 1766) and Arkwright's Water Frame and Spinning Mule in 1779. Steam power to drive looms was harnessed in the 1780s, and production moved to the mills that grew up near the coalfields of Lancashire and Yorkshire, a period which marked the end of the cottage industry and the start of the Industrial Revolution. These northern mills were some of the first factories in the world, and they saw a movement of people away from agricultural work into the factory system, driven by the rise in the cotton and wool trades.

The mechanisation of spinning and weaving improved the quality of the thread available and enabled 100% cotton fabrics to be produced. The Spinning Mule led to even finer stronger yarns and hence a lighter weight, finer cloth suitable for printing. Production speeds were increased through the use of steam power, which formed the basis for the cotton mills of the 1800s.

2.1.3 Mass production

The 19th and 20th centuries were a period that saw the creation of many new synthetic fibres and a whole new range of cloth types. Combining cotton with man-made fibres was found to increase productivity in weaving by 30–40% due to the strength of these yarns, which resulted in fewer breakages, and enabled looms to run at faster speeds. The development of mixed blend and synthetic fabrics satisfied the growing consumer desire for garments that were easy to wash and care for. New dyestuffs and processes to manufacture these fibre types more effectively were developed for woven fabrics types such as polyester and nylon.

Weaving today is almost entirely automated, with the exception of specialist companies, or craft weavers. Production rates, efficiency and quick turn-around times are the key drivers of an industry that has to meet the demands of the 'fast-fashion' environment of the 21st century. Manufacturing is a global business for most companies, with factories moving further east to countries such as China and India, to seek lower labour and production costs, thus enabling them to remain competitive in the cost-driven apparel and furnishings markets.

Development of new woven fabric types is intrinsically linked to developments in new fibre and fabric finishes, especially in the field of performance fabrics. Traditional techniques for fabric production are being built upon gradually with advances being made in the areas such as that of three-dimensional weaving. Long-established weaving processes like those found in the carpet industry are refreshed with the addition of new solutions of adding colour and pattern through the use of digital printing.

2.2 Weave processes

Weave covers a broad spectrum of fabrics in use within the apparel, furnishings, transportation and performance textiles sectors. Woven fabrics can be split into two categories, flat-woven and pile woven; which have a surface effect created by loops or tufts of yarn that stand proud of the body of the cloth.

Woven fabrics are made by interlacing two sets of threads at right angles to one another. The vertical threads are known as the warp (or ends) and the threads inserted horizontally are called the weft (or picks). By lifting the warp threads in different combinations, the threads are interlaced to form a vast range of cloth types suitable for many end uses.

The loom is a weaving device that typically holds a set of vertical threads (warp) parallel to one another and through the use of a harness or shafts groups of warp yarns can be lifted in different combinations before the insertion of the weft yarn. Initially the weft insertion was done by hand, and later by shuttle allowing a bobbin of yarn to be inserted across the width of the cloth at a higher speed.

2.2.1 Loom types

Weaving looms can be characterised according to the type of mechanism used to insert the weft, and the type of mechanism used to lift the warp ends in order to produce different patterns.

Weft insertion can be carried out using a shuttle, (the flying shuttle, was invented in 1773 by John Kay) where the weft yarn is wound onto a bobbin, inserted into a shuttle and then inserted back and forth across the loom. The number of shuttle boxes limits the number and combinations of weft colours inserted and these looms have been superseded by faster looms and more efficient shuttle-less loom types. These looms can run at much faster speeds, so maximising production of man-made fibre types.

- A rapier loom passes the yarn from one side of the loom to the other through the use of a rigid rod or flexible ribbon and may have one or two arms that meet and exchange the yarn in the middle.
- Air-jet looms use a jet of air to pass the weft across the width of the loom, and are usually used in the production of griege (un-finished) fabric. They have a high production rate, making them suitable in the production of finely sett fabrics.
- Water-jet looms can operate at high speeds but are only suitable with filament yarns in the production of synthetic fabrics.

2.2.2 Flat woven

The two types of mechanism that control the lifting pattern of the warp threads and therefore the complexity of the weave pattern produced are, dobby and jacquard.

Dobby fabrics are woven on a loom with a dobby patterning mechanism. Designs produced on this type of loom, have small pattern repeats created by the warp yarns being lifted in regular sequences by a series of shafts through which the warp ends are threaded. Fabrics produced in this way include: worsted suiting fabrics, and shirting fabrics such as, poplin, flannelette and oxford.

Jacquard looms are used in the production of fabrics that are more highly patterned and these looms are capable of designs with large repeats. The jacquard loom was first invented in the 1801 by Joseph Marie Jacquard, and were fully mechanised by the 1830s. A jacquard mechanism or harness is positioned above the loom and each individual thread in the fabric is drawn through the hooks. The harness may be strung using a differing numbers of hooks and varying widths and configurations, to give pattern repeat widths from few centimetres up to the full width of the loom. Fabric types produced on these looms include: furnishing fabrics, some outerwear fabrics, and cloth for transportation such as: damask, tapestry, coating fabric and aircraft seating.

Treadle looms are also still in use, but these are used primarily by the hand weaver, who operates a series of pedals connected to each shaft to form a pattern in a similar fashion to a dobby mechanism.

2.2.3 Pile woven

Pile woven fabrics are produced in a number of ways, and they are commonly seen in end uses that include both carpets and towels. Loops formed in the cloth may be cut as in the case of velvets, or uncut as in terry towelling. Patterning in pile cloths can also be controlled by a simple dobby mechanism to create plain or semi-plain effects, or more complex patterns can be formed through the use of a jacquard mechanism, for example moquette used on public transportation.

2.3 Overview of end uses

The staple cloth for thousands of years, woven fabrics are used for a broad spectrum of end uses, from the decorative to the functional. Fabrics may be produced to meet an aesthetic need, as in the case of apparel fabrics, and interior fabrics, or they may be at the other extreme and perform a specific function or have an industrial use.

Woven fabrics are used in apparel for lingerie, ladieswear, outerwear, suiting, shirting and sportswear. Interiors, curtains, soft furnishings, upholstery, carpets and bedding all use woven fabrics. Other more specialist end uses include: geo-textiles, composites, architectural solutions, airbags, transportation, and medical textiles.

2.4 Key issues affecting the designer

Weavers have a rich and varied past to draw from and they continually strive to innovate and create new surface qualities and fabric blends, creating new combinations of fibres and weaves in the realm of woven fabrics. The success of the weave designer requires an ability to be able to translate ideas not only visually, but in a textural three-dimensional form whilst working to the confines of the intended loom type.

The creative process for the design of woven fabrics can take on many forms, and is often dependent on the context of the designer and the end use of their fabrics. The inspiration for weave designs can start in the same way as that for any other fabric type, but the translation of an idea may not always be so literal due to the specific nature of a woven fabric. Colour, texture, and handle are more likely to be interpreted into the final cloth, except in jacquard fabrics where the image of a design can be represented in the fabric.

Weave design is traditionally carried out using point-paper (a series of marks on a grid) that correspond to the ends to be lifted in the loom. Historically, the designers' experience and yarn knowledge enabled them to visualise the intended appearance of their designs, designs that they were then able to check on the loom on site. Jacquard designs were painted by hand, weave structures assigned to each colour and then pattern cards were cut. We may view these processes as rather long and laborious, but the thinking time available, their knowledge base and the ease with which they could check the designs ensured a high rate of success.

2.4.1 Blurring of technologies

The boundaries between the long-established fabric categories are being blurred, as technologies are no longer restricted by their perennial function as the co-existence of craft and technology move forward. Fabrics developed for performance sportswear can be seen in streetwear, and couture borrows ideas from technical and protective clothing.

New developments in yarns and finishes, print and coatings are frequently drivers in the progression of woven fabric design, and cutting edge designers will consider these in combination rather than in isolation. The work of Nuno Corporation in Japan is a good example of this approach to design; an approach that has resulted in ground-breaking textiles. Recent work from Nuno has included pleated weaves using Kibiso silk (the silk from the outside of the cocoon) whose crunchy and stiff properties are the antithesis of most silks.

2.4.2 Niche versus mass market

As large-scale textile manufacture in the West has contracted and moved overseas, the detailed knowledge of structures and traditional skills base has slowly been lost with it. There is a growing prevalence of niche and specialised textile producers left in the UK, with a focus on high end, selected markets or on value added, high performance products. The High Street retailers are still an important employer of textile design graduates and many of their suppliers retain a design and development team in the UK supported by overseas manufacturing. Weave as a craft skill continues in its importance, especially in the current climate, where sustainability, and hand-made products are both valued and desirable.

The apparel industry is one where it is a benefit to have a good solid background in textiles. Universities and colleges are continually refreshing the content of their textile courses, in order to provide their graduates with the design and technology skills to succeed in these fast-paced and demanding textile and retail industries.

2.4.3 Craft weaving and the designer-maker

Craft weaving has the luxury to evolve organically, through experimentation on loom with different types of yarns and structures. The intuitive response to the handle and properties of a yarn are the starting point for many textile artists, and practice leads to a thorough understanding of structure and fabric properties. Craft practitioners are more often than not, engaged in the pursuit of their own practice, and their design output is less restricted by the demands of mass production. Traditional craftspeople have some involvement with all aspects of the design and making of a textile, whereas a designer-maker may subcontract aspects of their production to mills or finishers, after the creation of an original piece.

Textiles is now more complex than the original craft disciplines that it originally grew from, but these skills are still an essential foundation for the hybrid fabrics created to meet the desires of a more demanding customer.

Case study: Margo Selby

Margo Selby was educated at Chelsea College of Art, and the Royal College of Art and launched her first collection in 2003 with the help of the crafts council. Margo's double cloth fabrics are richly coloured and have a wonderful three-dimensional surface quality formed by the lustrous un-stitched areas of her weaves (Fig. 2.1). Her branded goods for interiors and fashion are sold through galleries and museums as well as through her own shop in central London. An important development between her craft and manufacturing was formed when she took part in the 'Eureka project' through Design Nation in 2008. This project to make design more accessible, resulted in a collaboration with habitat to produce an exclusive range of products that are now sold in store and online.

Margo has reached the point where her work crosses the boundary between craft and mass-production with a fabric collection aimed at fashion accessories and more recently interiors.

There are other craftspeople that use the capabilities of the manufacturing environment to develop their work in new ways; such as Ismini Samanidou.

2.1 Double cloth woven fabric, Margo Selby.

Case study: Ismini Samandiou

Ismini Samandiou is a textile artist and designer who works with the medium of woven cloth. She is not only fascinated by the construction methods of woven fabrics but also by the way textiles can exist within an architectural space. Her most recent work has been woven on a computerised jacquard loom at Oriole Mill, in North Carolina, USA, a machine capable of full width pattern repeats. The resulting site specific architectural installations have a clear narrative, as could be seen in her work 'Time line' for the Jerwood Contemporary Makers, 2009 exhibition. This piece measuring 3 metres high × 16 metres long, took inspiration from the history of the Jerwood Space site and used the current capabilities of state-of-the-art jacquard patterning technology.

2.4.4 Commercial textile designer

Weave designers in industry require a different approach to design creation and development, even though their education may have been identical to that of the craft weaver. Tight deadlines, cost and productivity demands, coupled with performance requirements all have to be taken into account, and this necessitates a more considered approach to the design process. Re-invention of classic fabrics, a trawl through the archives, or interpretations of trend predictions are the most likely routes to a design collection for an industry-based designer; requiring a decisive focused approach.

Case study: Ulf Mortiz

'A true industrial textile designer able to cope with the limitations of commerce and production, encountering there his challenge and source of limitless energy.' Lidewij Edelkoort comments about Ulf Mortiz.

At the leading edge of the market, each year Ulf Moritz creates a visionary range of textiles for Sahco Hesslein (Fig. 2.2), creators of high quality furnishing fabrics. He is able to bring together handcrafted with technology and leads the way in using new materials and fibres at the same time re-inventing traditional techniques. Ulf pushes the boundaries of weaving through his technological knowledge of textile processes.

Case study: Kathy Schicker

A graduate of the MA Textiles Futures course at Central Saint Martins, Kathy Schicker fuses craft skills with new technology to produce smart textiles for interior environments. Part of a collective of textile designers called Puff & Flock, 'risk-taking to expand new boundaries' is their mantra. Kathy's textiles explore the integration of smart fibres into high-end woven jacquard fabrics and she is also interested in designing for educational and medical end uses. Her light emitting textiles use sunlight to activate the fibres, charging them up so that they glow in the dark, revealing previously unseen patterns within her weaves. Kathy is a member of the TFRC (Textiles Futures Research and Consultation) at the University of the Arts in London.

2.2 Ulf Moritz fabric for Sahco Hesslein.

2.5 Synopsis of different weave processes

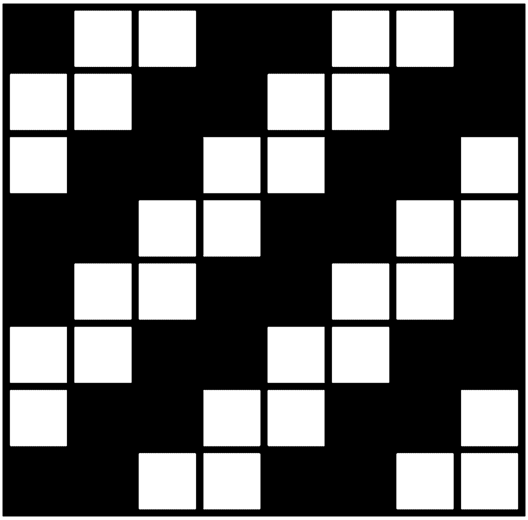
This next section will explain the basic principles and terminology used in weaving. The most commonly used weave structures and their applications will be detailed, giving an introduction to woven fabric types and their uses.

2.5.1 The principles of weaving

Woven fabrics are formed by the interlacing of two sets of threads, arranged at right angles to one another and interwoven to form the cloth. The threads running parallel to one another running down the length of the loom are called the warp or individually each thread is known as an end. The warp is kept under a constant tension and therefore must be strong enough to withstand the pressures exerted by the loom and the abrasion of weaving. Warp yarns are generally finer and have a higher twist than the yarns that form the weft, as the warp yarns need to be stronger to cope with the stresses and tension they are put under during weaving. Weft yarns or picks interlace with the warp across the width of the fabric, or horizontally in a pattern determined by the lifting of the warp ends.

Lifting plan or peg-plan

A lifting plan or peg-plan is the instruction to either lift or lower the shafts on a loom (Fig. 2.3). Lifting plans are represented by a pattern of dark squares or marks on a graph paper; this point paper and the number of shafts that they represent in a loom are usually repeats of 4. The instructions to lift or lower shafts are controlled by different mechanisms on power-looms, but were traditionally controlled by pegs



2.3 Peg plan for 2/2 twill.

in wooden boards called lags, that controlled the dobby mechanism. The word peg-plan originates from this method of controlling the shafts and is still used now, even on looms that are electronically controlled.

The patterning on jacquard looms was originally controlled by the punching of jacquard cards, a method which has now been superseded by CAD/CAM systems to lift ends in the harness.

Draft

The sequence that these ends are drawn through the shafts determines whether the pattern is simple (all-over effect) or more complex, using a series of different weave structures in combination with one another. The order in which these ends are passed through the heddles in the shafts in a loom is termed the draft. A straight draft represents threads that have been inserted in sequential shafts (there are usually up to 16 shafts used, but there may be as many as 24) working from the front to the back. A straight draft will weave a lifting plan exactly as it is represented on the point paper.

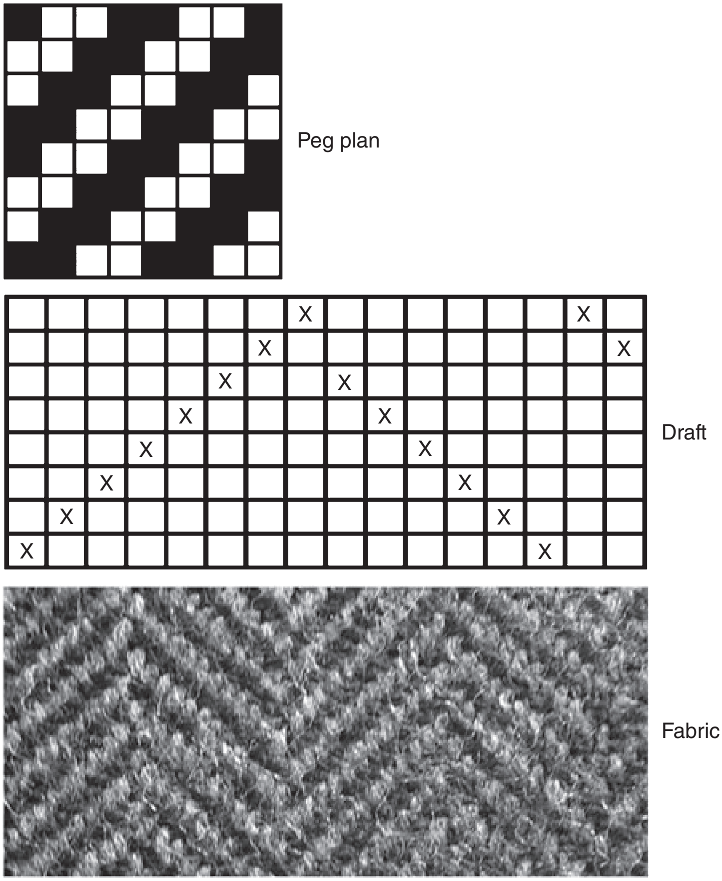
A pointed draft, as the name suggests, is formed by threading the ends in sequence through sequential shafts, then mirroring this pattern; working in reverse, back to the front of the loom.

Herringbone drafts when combined with a 2/2 twill will form what is termed 'a clean cut' in the warp lifts at the point in which the draft reverses back down the shaft order (Fig. 2.4). This type of draft and resulting weave structure is common in jacketing and suiting fabrics.

Other common draft types include: skipped draft, satin draft, and curved drafts.

Sett

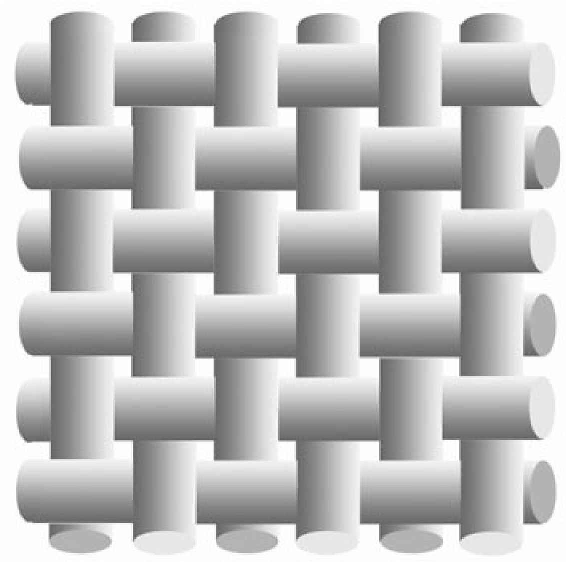
The sett of a fabric (the number of threads per cm or inch) is determined by the combination of the yarn count (diameter) and the weave structure to be woven.



2.4 Herringbone draft on a 2/2 twill.

Ashenhurst's 'setting theory', which uses factors related to the dimension of different fibre types, is one method that is used to determine the sett of a proposed fabric based on the weight of a measured length of the chosen yarn. Square sett fabrics have the same number of threads per cm in both the warp and the weft direction. The density of a weave is a critical factor in the end appearance, drape and handle of the final fabric; looser fabrics can be woven with the intention that they have room collapse or shrink in subsequent finishing processes.

Once the sett of the warp has been determined and the warp made to the length required, the ends are drawn through the shafts in the order already determined in the draft, before finally being 'sleyed' (threaded through) the reed. The reed is a metal comb that is the same width as the fabric to be produced that keeping the ends aligned and evenly spaced during weaving. Each space within the reed is called a dent, and ends are drawn through these in groups, of two or more, and this number combined with the dents per centimetre determines the sett or ends per cm in the loom-state fabric. Generally speaking there are more warp threads per centimetre than weft threads; but although this does increase the loom set up time, it most importantly increases the rate of production.



2.5 Plain weave.

2.5.2 Weave structures

There are generally understood to be four basic weave constructions: plain weave, twill, satin and sateen (as described below). Countless other variations of these structures are in everyday use and further documentation on these can be found in the work of William Watson (Watson, 1947) and Doris Goerner (*Woven Structure and Design. Single Cloth Constructions* 1989).

Plain weave

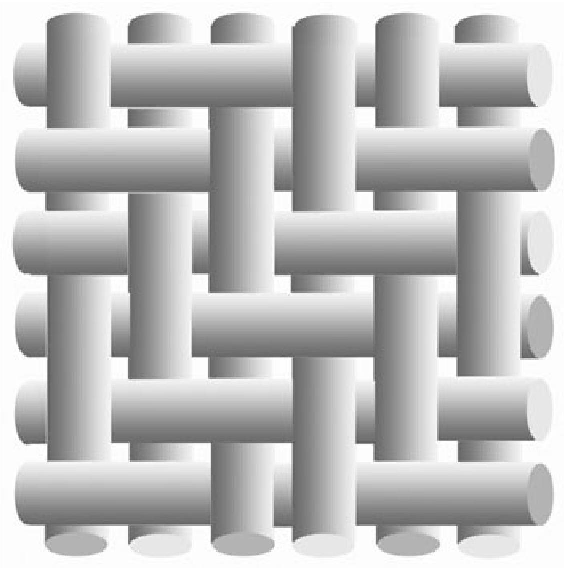
This is one of the elementary weave constructions, and although simple is used more frequently than any other. In plain weave the warp threads lift alternately allowing the weft yarn to interlace with every other end and form a tight cloth, with a firm structure, suitable for a range of end uses (Fig. 2.5). The resulting cloth can be very flat, making this type of weave suitable for printing, pleating and smocking.

Fabric types that usually use plain weave structures include: voiles, chiffon, canvas, and calico.

- Voile – semi-sheer, lightweight fabric made with fine, fairly highly twisted yarns and originally made from cotton, but other fibres are used.
- Canvas – strong, firm, relatively heavy and rigid, generally plain-woven cloth traditionally made from cotton, linen, hemp or jute.
- Calico – cotton fabrics that are heavier than muslin. These are usually left unbleached and still contain starch giving them a stiffer handle, and are made in a variety of weights, often used for making toiles.

Twill weave

Characterised by diagonal lines on the face of the cloth, the weft yarns in twill fabrics float over at least two warp threads before they go back under. Twills can be regular;



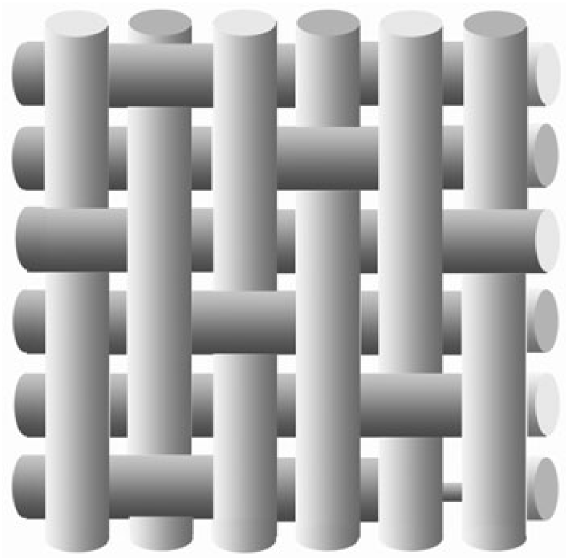
2.6 Twill weave.

where the twill runs at 45° or irregular/steep where the angle of the twill is greater than 45°. Twill lines usually run from the bottom left to top right; a right-handed twill, or less often from right to left, a left-handed twill. Twill fabrics are strong and durable, and have a natural stretch in the bias, making them suitable for both furnishings and fashion (Fig. 2.6). Twill fabric types include; denim, drill, chino, tweed and twill derivatives such as herringbone.

- Denim – a warp-faced twill, usually made from yarn dyed cotton warp and ecru weft. Strong, stiff and durable this fabric started life as workwear, before becoming the fashion staple that it is today.
- Tweed – traditionally made from wool and usually of a medium to heavy weight. They were originally handmade on the banks of the River Tweed, but most are now produced on power looms with the exception of Harris Tweed. Tweeds may also feature other structures such as hopsacks and herringbone twills.
- Herringbone twill – an even-sided twill that when reversed produces a characteristic vertical break or cut in the fabric. Suiting fabric is an area that uses this construction.

Satin weave

The appearance of this fabric type is smooth, non-directional, and characteristically lustrous due to the tightly packed warp floats on the face (Fig. 2.7). Interlacing points are set out in a regular, yet all-over manner in order to avoid any twill lines or stripes being visible with the back of the fabric looking significantly different to the face. Traditionally satin fabrics were made of silk, but now they are produced in a variety of fibres, for linings, sheets, dress fabrics and upholstery. High lustre filament yarns sett at a high-end count, are common and make best use of



2.7 Satin weave.

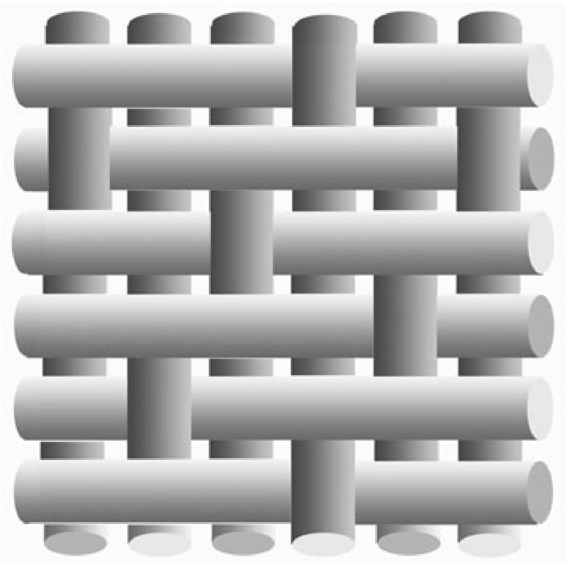
the longer warp floats in this structure, resulting in strong durable and smooth fabrics. Some satin varieties include: double-faced satin, bridal satin, ciré satin and antique satin.

- Double-faced satin – is woven with two faces of the fabric created using two warps and one weft layer. The additional weight of the fabric makes this more expensive, but both sides are equally lustrous and two different colours may also be used.
- Bridal satin – a heavy weight satin used for wedding gowns, with a smooth lustrous surface effect.
- Ciré satin – this satin is finished to produce a cire effect; an effect that is stiff and a very high lustre particularly suited to give the fabric a metallic appearance.
- Antique satin – has a smooth but dull appearance on the face and surface slubs on the technical back of the fabric. The technical back is often used as the decorative side, for curtains and furnishing fabrics.

Sateen

This weave structure is weft faced, so the floats in the weft direction are much longer than those in the weft direction (Fig. 2.8). Binding points in sateens are infrequent and arranged in a all-over manner to create fabrics that do not show diagonal lines. The smallest number of ends that a sateen can be designed over is five. These fabrics tend to have a higher number of picks than ends, which, combined with a thicker cotton yarn, produces a soft, lustrous fabric.

Satin and sateen weaves are used in combination in many jacquard fabrics, such as Damask fabrics for curtains, upholstery and napkins.



2.8 Sateen weave.

Double cloth

The elementary weave structures described above are all classed as single cloth structures, which relates to the way in which the warp and weft threads are interchanged, and the resulting cloth appearance. There are many other structures in use that are used to form a cloth that reveals multiple warp or weft colours, or which are used to have double faced patterns, appearance or contrasting textures on one face.

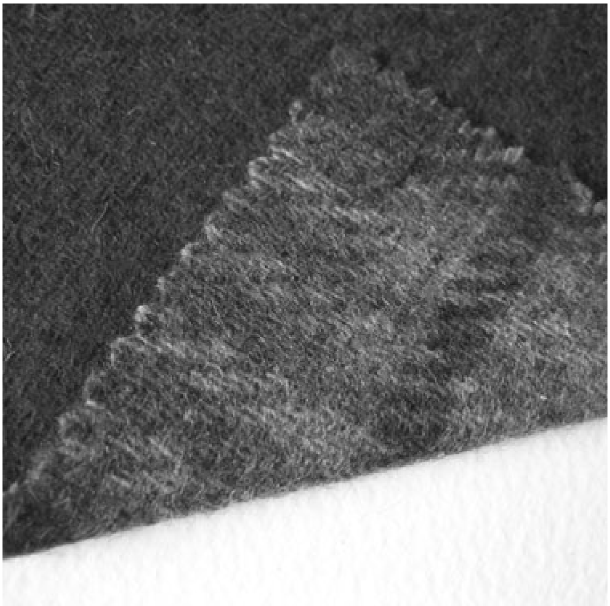
The most common of the multiple layer weave structures is double cloth (Fig. 2.9) and, as the name suggests, this weave forms two distinct faces in the finished fabric, that are interlinked through the use of stitching points between the warp and weft. The requirement of more than one set of yarn in the warp and weft makes these fabrics more expensive to produce, as they are heavier and slower to weave, due to double or treble the number of picks being inserted to produce one pick on the face.

Double cloth fabrics include Matelassé (a figured fabric with three or four sets of yarns), Cloque (with four sets of yarns that simulates quilting stiches), blankets and other interior fabrics.

Jacquard weaving

Jacquard designs are usually a combination of smaller-scale weaves applied onto a larger scale repeating design that has been produced on a CAD/CAM system such as; Scotweave, Pointcarré, EAT or Ned Graphics.

Jacquard looms are fitted with a jacquard patterning device or harness that enables individual ends to be lifted in complex patterns to form larger and usually colourful designs. Fabrics produced by this method can be of any fibre type, and are generally in greater use in the interiors sector where their higher price can be afforded. The usually high sett fabrics with multiple colours and many layers make



2.9 Double cloth fabric.

them too costly for most areas of the apparel industry. Jacquard designs can be geometric, organic, large scale, or form a all-over repeat, and the design is made up of a combination of dobby weaves applied to chosen areas of the fabric (Fig. 2.10).

Other fabric types

Pile fabrics fall into two main categories: cut pile and loop pile.

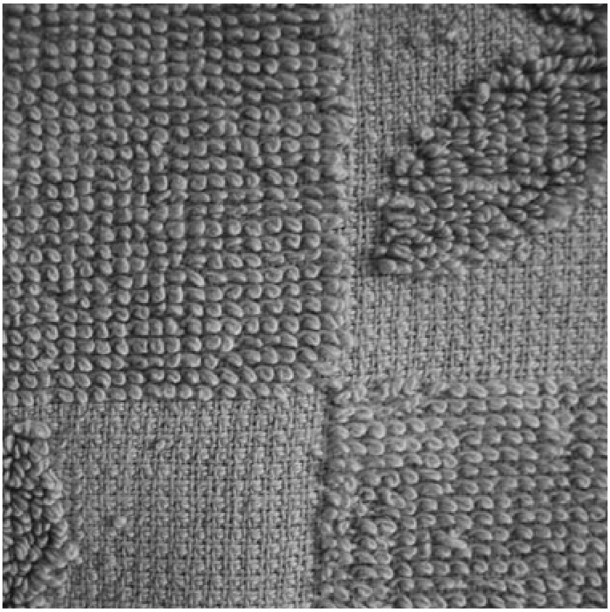
- Cut pile – where the threads created in between the cloth layers or on the face of the fabric, are cut (usually on the loom). These fabrics will be cropped to the desired height during finishing.
- Loop 'pile' fabrics – can be produced in the same manner as cut pile but the loops are left in place. The loops can help durability or absorbency in the case of towels.
- *Velvets* can be produced through the use of an additional set of warp yarns that produce loops over a wire inserted at regular intervals; these wires include a cutting blade that shears the loop as the blade is withdrawn. The ground warp forms a tight, plain weave to hold the pile threads in place. The other common method of velvet production is to use a double cloth (two layer) construction, where the two cloths are woven face-to-face. In these looms the pile yarn weaves up and down between the two layers of ground fabric, and this interlinked construction is then cut whilst still on the loom, in the same method as some carpet production.
- *Velveteen* is similar to velvet, but an additional weft yarn forms the pile rather than warp yarn. The fabric needs to be cut in finishing to produce the pile that is, generally speaking, shorter than that of velvet.

2.10 Jacquard fabric.

- *Moquette* fabrics are still used as seating fabrics in the bus, train and tram sectors, where its weight and durability are needed. These fabrics are produced in a similar way to velvet, and may be composed of cut pile, uncut pile or a combination of both; usually produced in worsted, mohair or nylon.
- *Terry towelling* is an example of an uncut pile fabric, whose softer, looser sett loops provide maximum absorbency. This is usually woven in cotton, for towels (Fig. 2.11).
- *Woven carpets* are split into two categories named after the towns of Axminster and Wilton, and these types are both more hardwearing constructions than other tufted or nonwoven carpet types. Three warps make up the structure of Wilton, which is again produced using wires to form loops in the ground, which may be cut or left uncut. 'Gripper' Axminster woven carpets are produced using a different method, where the coloured cut tufts of yarn are pre-arranged in a sequence to form a finished pattern, inserted by the grippers.

2.6 Computer technologies

CAD packages are an essential part of the design process for weave designers, acting not only as a tool to create ideas, but also as an essential link to the loom (especially in the case of Jacquard weaving). The creative process no longer demands that the designer sit in front of a loom and work through various weave connotations in isolation. An industry-based designer will work alongside specialists from a background of science and quality control, whilst considering parameters set by the sales and marketing team. The current range of weave software packages, allow the designer to visualise a design without ever having to weave one pick. Yarns can be



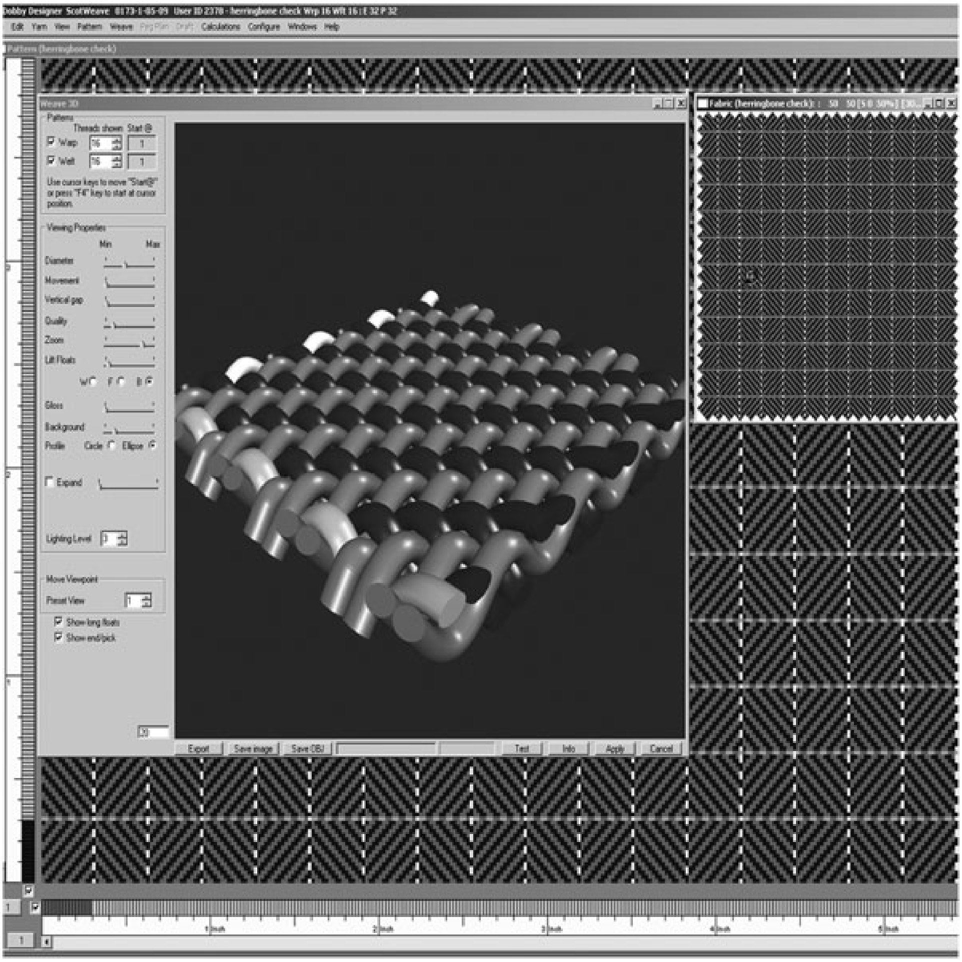
2.11 Terry towelling.

simulated; construction details entered, and weaves edited for long floats or bad joins. Not only can this reduce costly mistakes, by enabling the designer to visualise the design before committing to an actual fabric, it can also replace some of the early stages of sample trials. Printouts can be generated to show to a customer at the early stage of design development; in colours matched to their standards.

This ability to view a weave design, both in a 2D and 3D format and to immediately see the impact of a change to a draft or peg plan on the cloth, has made it possible for the less skilled weaver to work with confidence in the textile industry. CAD systems are an excellent tool in the teaching of weave students, at all levels of higher education, giving the them chance to experiment and make mistakes, before setting up a loom.

CAD software from companies such as Scotweave, Pointcarre, Ned Graphics and EAT are all capable of generating realistic simulations of both dobby and jacquard fabrics; which can be then transferred to a chosen loom for immediate weaving. This ability to create and control a loom through CAD has helped facilitate the development of overseas manufacturing, whilst at the same time keeping the design development control in the UK. Designs are easily sent electronically to the weaving facility, enabling quick turnaround and ease of editing a design as necessary. Fabrics can be simulated and mapped onto realistically generated garments, bodies or other three dimensional forms giving a good indication of how a given fabric will look *in situ* (Fig. 2.12).

Simulation of woven fabrics may not, however, always be executed by a specialist weave designer. High Street retailers frequently use less technical forms of weave simulation software to mock up designs as ideas of direction for their suppliers. Lectra Product Lifestyle Management systems include dobby weave design based



2.12 Fabric simulation.

on a library of weaves and yarns, which can be used in combination to mock-up fabric designs. This type of software does not rely on specialist knowledge of weave structures or how they are formed, but does give the designer a visual tool with which to communicate their ideas.

Current CAD packages cannot entirely replace the physical weaving of a cloth, as they are cannot easily simulate the physics of weaving; the effect of yarn twist, for example, or the dimensional changes between one weave structure and another. Spider weaves, whose distorted threads are a result of using a combination of long warp threads surrounded by tight plain weave, are one example of this.

Scotweave have recently developed new software to meet the needs of the more technical weaving industries such as the automotive, aerospace and medical industries. Real-world yarn information, including fibre types and cross-sections of the weave architecture can show multi-layer fabrics, interlacing of yarn, and calculations of tensions expected when woven.

2.7 Practical design applications

The design and production of woven fabrics and the design of a garment or interior furnishing are not as closely linked as they are in knitting, where you are more likely to design the garment alongside the initial sample. Woven fabrics are designed as a length and then the garment is produced from it. Fabric producers for both apparel and furnishing, design ranges each season, from which their customers select fabrics for the next season's collection. These fabric ranges are sold by the supplier's, at fabric fairs such as Première Vision (fashion) and Heimtextil (interiors). Some modifications to the colour or design may be requested by brands at the high end of the market, as they aim to stamp their own identity on their ready-to-wear collections. Haute couture garments use some of the highest quality unique fabrics available. Performance fabrics for end uses, including those for Automotive and Aircraft, are developed exclusively for each client, but designs often start life as part of collection based on trend predictions.

2.7.1 Apparel

The apparel market can be divided into five main sectors: supermarket, high street, independent designers, ready-to-wear and haute couture. Most woven fabric types are used in all market levels, with some minor differences in weight, colour fastness, or yarn content. The type of garment that the fabric is designed for, and its perceived value may sometimes be the only point of difference between how a given cloth is differentiated.

Cheaper fabrics are used by the supermarkets, whose bulk buying power also enables them buy some better quality fabrics at a lower price. The high street retailers vary in that some will demand high wearing easy to launder fabrics, and others are looking for a lower quality fabric for fast fashion purposes. Ready-to-wear, as already mentioned, looks to use more unusual fabrics with some point of difference. This may be in the use of fancy yarns, more expensive constructions or exclusive fibres.

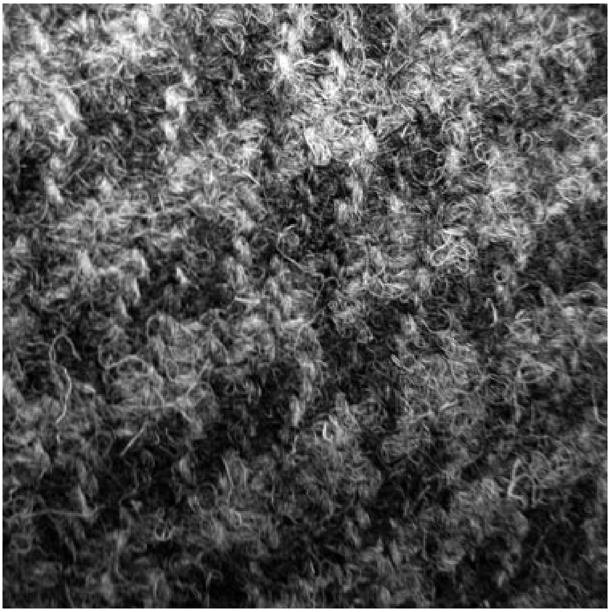
The main categories for apparel woven fabrics are:

- outerwear – coating fabrics, including tweeds, cavalry twills, in polyester, wool, worsted, and microfibres
  - shirting, linens and cotton viscose and polyester
  - dress weights, chiffons, silks,
  - support fabrics and trimmings.

Case study: Harris Tweed

Independent designers may source woven fabrics with some heritage cachet, such as Harris Tweed a cloth that has been handwoven by the islanders of Lewis, Harris, Uist and Barra in their homes, using pure virgin wool that has been dyed and spun in the Outer Hebrides (Fig. 2.13).

A plan in 2008 by Yorkshireman, Brian Haggas, to revive and rationalise the Harris Tweed industry, by reducing the complexity and number of colour-ways and patterns woven backfired. The true appeal of this traditional fabric lies in the won-



2.13 Harris Tweed.

derful and varied colours produced using the locally dyed yarns, whose colours are influenced by the landscape of the Outer Hebrides. Scottish designer Deryck Walker featured Harris Tweed fabrics in his 2009 collection and Italian powerhouse Gucci has recently placed an order for the fabric.

The profile of this struggling industry was recently boosted by the wearing of jackets made from their cloth on television (Doctor Who) helping to raise the profile of this traditional cloth, and hopefully attracting a younger customer at the same time.

2.7.2 Interiors

The interior textile market can be segmented into two main categories. These are the areas of contract furnishings: for hotels, offices, and other public buildings or home furnishings, for interiors in the home. Woven textiles in this area are used for the bedroom, bathroom, dining room, window treatments, upholstery and flooring.

Interior woven fabrics are required to perform to a level suitable to last the lifetime of the product, be suitable for its end use, and include any requirements for aftercare in order to maintain appearance. The performance requirements of the proposed fabric are dictated by standards set out by the customer, and are usually more stringent for contract furnishings than those for say a cushion in the domestic home furnishings market. Designers in this field need to consider weave construction and float length (the number of ends/picks that a given yarn floats over in the peg plan) in order to meet abrasion requirements. They also need to consider colourfastness of the yarns so that they do not fade or transfer dye, flammability and the suitability of the fabric for laundering or dry cleaning.

High end manufacturers are represented in locations such as the Design Centre at Chelsea Harbour in London; an invaluable resource for the independent interior designer where all the top companies are represented. These interior fabric producers are long established, and yet many are at the cutting edge of the latest trends and innovations in this market. Companies like Sahco Hesslein, Osborne and Little, Zimmer + Rohde, Romo and Colefax and Fowler are all represented; and sell primarily through interior design companies. These fabric companies cater for both the high-end domestic market and the more demanding contract furnishings sector, where innovation needs to be underpinned by high performance standards.

Trend forecasts drive the direction for colour, pattern, texture and finish in interior woven textiles, as they do in the apparel market. Historically a slower moving industry than that of apparel, the introduction of lower pricing, more demanding consumers and fashion retailers branching out into interiors have created a more 'throw-away, quick change' approach to buying in this market. Mid-level manufacturers, although not well known to the buying public, work closely to supply fabrics to the high street retailers with targeted ranges of bedding, towelling and curtain qualities. Concepts and ideas are presented to these customers and then further developed to fit the brief for colour, design and fabric performance.

Main fabric categories are:

- bedding – sheets, duvets, pillows in cotton, polyester and some silk
- curtains – using dobby structures including hopsacks and satin
- jacquard weaves – such as damask and tapestry.
- furnishings – upholstery, soft-furnishings and cushions.

Case study: Herbert Parkinson

Herbert Parkinson design and weave John Lewis 'own brand' furnishing fabrics and manufacture ready-made and custom-made curtains, and other soft furnishings. They also produce a wide range of fabrics for other customers outside the John Lewis Partnership, but this company is the one remaining fabric production unit owned by the partnership.

Herbert Parkinson designs range from heavy tapestries to fine cottons and from dobby woven plains to fine figured jacquard designs. The yarn types used for these fabrics are typical of those used extensively in the home furnishings market and include: cottons, cotton/linen mixes, cotton/viscose mixes, linens, acrylics/modacrylics, chenille and polyester.

2.7.3 Performance fabrics

Woven fabrics are used in many of the industries where high performance, quality and durability are essential qualities. Some of the products within this category may also have an aesthetic importance attached to them, which includes transportation seating fabrics for the automotive and aircraft and the outdoor/sports apparel sectors. The final look or appearance is however a secondary consideration in the fields of medical textiles, geo-textiles, narrow-fabrics and those used in canopies and supporting structures.

Fibre type in combination with the weave construction, high specification colouration and finishing treatments are all key factors in the performance of products in this sector. In sportswear higher value, smart textiles using the latest developments in new fibres, and finishes are replacing the traditional cotton fabrics, as consumers demand a better product. Rigorous and frequent testing is required in both the development and manufacturing stages of technical and performance fabrics, to ensure fit-for-purpose, and consumer confidence.

Case study: Airbags International

Air Bags International is a company that have developed a patented weaving process to produce a one-piece woven air bag, reducing the need for cut-and-sew processes. Their latest development has been to create a 'smart' airbag, which inflates relative to the size of the occupant at the point of impact. The force of the occupant during impact triggers specially engineered (sacrificial) seams within the weave design, break and increase the volume of the bag to be inflated.

2.8 Future trends

The ability to innovate, re-invent and add value, are as important now as they ever have been in the long-established weaving industry. As mentioned previously, the weaving industry in the UK has become increasingly focused in niche areas of the business where fabric production is for a high end product and the more discerning customer. Performance textile weavers invest a lot of capital in the research and development of new products that keep them at the cutting edge and open up potential new areas of business. The key themes of smart textiles, nanotechnology, and sustainability and three-dimensional weaving are at the forefront of technical innovation in weave.

2.8.1 Sustainable choice

The future strategy for many high-end European mills is to pursue a sustainable or eco route in the development of their products and the production of their cloth. The high-quality textile producers are aware that their customer base has socio-environmental concerns about the provenance of the garments they buy. Valuing craftsmanship and tradition are as important as the eco credentials of the yarns and processes involved in the make up of these luxury items. The weaver and the tailor are master craftsmen, valued by brands such as Holland & Sherry, who promote the use of cloth from Yorkshire and Scotland, fabrics that are produced to a high quality in a time-honoured way.

Wool is a sustainable and natural product, which produces far lower carbon emissions during production than man-made fibres. The benefits of wool and cloth made from it are currently the focus of a new promotional campaign to boost the use this fibre in the middle and value retail markets. This Wool Project aims to raise awareness of the natural benefits of the fibre, and this is echoed in the resurgence of woollen cloth being used by cutting edge fashion labels.

Case study: Dashing Tweeds

This trend towards responsible lifestyle choices and the desire to keep traditional crafts alive can be seen in the Dashing Tweeds brand, co-founded by Guy Hills and RCA trained weaver Kirsty McDougal. They develop their own range of woven designs that are then produced using worsted yarns sourced in North Yorkshire and woven by Lochcarron of Scotland. Their innovative and often humorous approach to design, has seen the creation of some traditional tweeds with a twist. Reflective yarns woven into a ground of tweed check inspired by the wet pavements and yellow lines of London's roads are used in coats for cyclists and bike riders; a welcome alternative to a reflective yellow jacket.

Case study: Cradle-to-Cradle and Lantal

'Ultimately, we want ecologically intelligent design to become so integral to product development and economic systems, that it becomes known simply as good design', William McDonough quotes of the Cradle-to-Cradle thinking that he has developed in conjunction with German chemist Michael Braungart. The C2C 'cradle-to-cradle design is an ecologically intelligent approach to architecture and industry that creates materials, buildings and patterns of settlement that are wholly healthful and restorative . . . Materials designed as biological nutrients provide nourishment for nature after use; technical nutrients circulate through industrial systems in closed-loop cycles of production', William McDonough and Michael Braungart 2003.

Lantal, a world leader in transportation textiles with its Climatex® LifeguardFR™ fabrics, was nominated as a finalist of the Crystal Cabin Award 2010 in the category Greener Cabin. Lantal achieved the Cradle-to-Cradle Gold certificate with these woven fabrics, which are fully biodegradable. The fibres and finishing components used in the production of, Climatex® LifeguardFR™ have no toxicological or eco-toxicological effects, so after a long service life, the seat covers can be returned to biological cycles.

Lantal have also made great strides to reduce the weight of its fabrics used in the aviation industry, through innovation in yarn and fabric construction and more recently with its pneumatic comfort system. This system uses inflatable chambers placed in layers between the seat fabric and seat frame to increase passenger comfort, whilst at the same time reducing the weight of the seat and importantly adding to a reduction in fuel consumption.

This sustainable approach to design is the key to the survival of fabric producers from all areas of the industry, be it for apparel, interior or technical end uses. Key players in the transportation sectors, such as the car manufacturers, and the airlines, are now tasked with taking ownership of the disposal or re-cycling of their products, a responsibility which therefore also falls to the Tier 1s and their suppliers.

2.8.2 Three dimensional weaving

The very nature of woven fabrics is three dimensional despite the two dimensions of the traditional warp and weft. The interlacing of the ends and picks, combined with differing float length, yarn types and specialist looms can combine to create cloths with a third dimension; a dimension that is still being explored.

Current examples of 3D weaving technology can be seen in the field of medical science for woven vascular vents, prosthetic applications and artificial arteries. Air-frame and self supporting structures also use circular (polar weaves) and demonstrate amazing strength; whilst carbon fibre and tri-axial structures are important components in the aerospace industry.

2.9 Conclusion

This chapter has detailed the main types of woven structures, and their construction. It has considered their characteristics, formation, and application and how the textile designer applies these to different markets. It has also considered the challenges and future opportunities for the design and development of woven textiles.

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3
Knitted textile design

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Abstract: This chapter explains the principles, advances and applications of knitwear and knitted fabric design and manufacture. It includes a short history of the processes involved, how basic stitches and structures work and the advances and influences of modern technology. It describes the various roles of a knitwear or knitted fabric designer, how they in turn interface with other textile designers, and processes in relation to contemporary fashion and lifestyles. The chapter concludes with future trends, global business, ethics and sustainability in relation to the subject.

Key words: Weft knit design and manufacture, advances and influences of knitting technology, knitting in the context of contemporary fashion, digital technology and its impact on knit design.

3.1 Introduction

A knitted fabric designer needs to understand the creative potential of knitting technology and work in partnership with available technology and technical expertise. The following chapter is an introduction to the fundamental principles relating to the design and manufacture of weft knitted fabric and fashion knitwear. There are few texts on this subject and most have been written by knitting technologists. This chapter has been approached from a design perspective but includes information from a variety of technological sources. The aim has been to provide a useful overview of the subject that explains its diversity and complexities in an accessible form.

3.2 Context for knitted fabric design

3.2.1 A brief history of knitted textiles

Knitted fabric can be produced by either hand or machine processes. When and where hand knitting began is unknown, although areas associated with the early domestication of sheep, and therefore woollen yarn, such as Persia (now Iraq, Iran and Afghanistan) or the Holy Land (Israel, Jordan, Syria and Lebanon) or the Atlas Mountains in North Africa are most likely. Woollen fabrics from such early times would not have survived the climatic conditions of these mountainous areas, and this would explain the lack of any examples from four or five thousand years ago.

Hand knitting was a peasant activity and as such would not have been documented. First written references appear in the inventories of religious houses in western Europe in the 12th century. They refer to very basic domestic items such as knitted leggings and gloves, so it is reasonable to deduce that such simple garments had long been in general use before the monks felt the need to record the practice. The convenience and practicality of hand knitted garments such as socks, caps, leggings and gloves eventually resulted in hand knitting becoming an important industry in medieval Europe. The manufacture of these common products had many advantages to maker and wearer, the chief one being that the stretch qualities of knitted fabric allowed both ease of fit and a single size approach. Also production involved simple and highly portable equipment and no complex finishing techniques. Contemporary evidence of knitted textiles other than practical garments are 'knitted carpets' which were more probably bed coverings and 'decorated knitted cushions' which were ecclesiastical.

By the late 1500s the craft of hand knitting had developed into a sophisticated industry, carried out by men and controlled by national guilds. The most important product was fine silk hose for the nobility. These hose were knitted in bright colours, in the round, on extremely fine wire needles and were usually richly embroidered with gold and/or silver threads. These items were expensive, highly regarded and the most important part of a gentleman's wardrobe.

The first knitting machine (or frame) was invented by the Reverend William Lee in 1589 in Calverton, Nottinghamshire and was designed to speed up the process of manufacture, producing a cheaper and more available product. However, the inventor initially failed to acquire the necessary patents to manufacture his invention in England but his brother James developed the idea after William's death and set up a small manufacturing plant in London early in the 17th century. After a slow start, this cottage industry rapidly developed so that by 1750 there were 14,000 frames in the UK, with 10,000 of these being in the East Midlands.

This significant stage in the development of machine knitting has been captured and preserved in the *Ruddington Framework Knitters' Museum*, which provides an insight into the historic working practices of the Framework Knitting Industry. It is a small independent working museum under the control of a Charitable Trust and provides knowledge, education and research opportunities for interested participants ranging from schoolchildren to postgraduate scholars.

Further developments over the following two hundred years involved enhancing the facility and efficiency of the knitting machine allowing a variety of patterned and textured fabrics such as intarsia, jacquard, stitch transfer and pointelle. This, in turn, led to the development of a wider range of knitted structures and products such as knitted lace, underwear, sportswear and eventually to knitted outer garments or knitwear as we now know it.

Hand knitting obviously did not cease when the process became mechanised, but continued as a rural, domestic craft practised mainly by women for their own families initially using yarns that they had spun themselves, but by the 18th century using commercially manufactured yarns and patterns.

3.2.2 Relevance of fibres and yarn structures

The quality, handle and behaviour of any knitted textile depend largely on the fibre and yarn structure selected for its manufacture. Therefore it is important to understand and appreciate the source material (the fibre), and the different ways that it might be processed or manufactured into yarn. Fibre and yarn selection will also depend upon the market and end use of the product as well as availability of production, colouration and required finishing processes. Within this chapter it is not appropriate to cover the wide range of fibres, yarns and yarn production systems that are available.

However, one specific example of how modern fibre development has influenced the design and manufacture of knitted products is the invention of man-made fibres in the 1930s. These synthetics became commercially viable in the early 1950s, starting with Polyester, followed by Nylon and then various forms of Acrylic (the fibre most used in knitted garment production). Used independently or blended with natural or other synthetics, they revolutionised product design, manufacture and wearing and caring properties. As these man-made fibres were considerably cheaper and more versatile than natural fibres, they facilitated the application of knitted product to broader markets. Ultimately this has resulted in the saturation of Western retail. The current trend for '*fast fashion*' and disposable knitwear poses ethical dilemmas for the industry and fibre producers are now exploring the potential of sustainable resources and recycling on a commercial scale.

3.2.3 Weft knit manufacture processes in context

Globally, knitted fabric is used extensively for garment manufacture. Knitted jersey fabrics form the staple for underwear, T-shirts, sportswear and men's and women's fashion. Knitted fabric is also used for soft furnishing, interiors for the automotive industry and, increasingly in the manufacture of technical textiles for such purposes as filtration or surgery. The knitted garment is now a standard, generic part of the Western wardrobe and is manufactured globally in every weight and fibre. Developments in knitting machine technology have speeded up production and have revolutionised knitwear and knitted fabric design potential. Knitted design solutions that were previously made using handcraft techniques are achievable and therefore cost effective to manufacture in volume. It is also important to note that most of these changes have also been relatively recent, (effectively over the last 25 years), and that this has coincided with the rapid economic and industrial growth of the developing world (in this context, Asia and Eastern Europe).

Whilst knitwear and knitted fabric are now less expensive to produce, with the designer having more options to choose from, global manufacturing processes are still complex. The processes used in knitted fabric production are well documented by authors such as Brackenbury (1992), Spencer (2001), and Power (2008). Essentially, the four main processes used in knitted fabric manufacture are: circular knitting, fully fashioned, flatbed and complete garment.

Circular knitting

This process produces a continuous tube of weft knitted fabric that can be used as a tube if the diameter is appropriate or as fabric for T-shirts, underwear, sweatshirts or fleece. It provides the fastest and most cost-effective production method for knitted fabrics and essentially simple structures can be achieved, e.g. double jersey, rib structures, tuck and miss stitches.

Garment assembly using circular knitted fabric is called '*full cut and sew*'. This process is similar to the type of production route used for woven garments. Knitted fabric is produced, the garment pieces are cut out of the fabric and assembled, usually by over-lock stitch as this binds the cut edges and joins the fabric together at the same time. Knitted trims are applied during this process.

Fully fashioned knitting

This manufacturing process is mainly associated with high quality knitwear made with luxury raw materials (such as cashmere, silk, merino wool or Sea Island cotton). The technology involves the manufacture of shaped body panels of single bed fabric that are then assembled into finished garments (minimising waste). The panels also have finished (uncut and therefore secure) selvedges, which make them easier to construct into garments. This finishing process also results in flatter seams.

Flatbed knitting

The early forms of this weft knitted fabric technology offered the designer the most versatility and choice in terms of colour, texture and patterning. It also had a unique place in knitted fabric manufacture as it did not compete with the faster, circular production or the single bed fully fashioned process because it facilitated the production of patterned and textured fabrics. In the early days of this technology, knitted fabric blanks were produced and body shapes were cut out and joined together but later technological developments have resulted in intricate shaping whilst simultaneously using complex patterning sequences through combinations of colour and texture. (Power 2008).

Complete garment manufacture.

Historically this manufacturing concept was a standard hand-knitting process achieved using 4 double-ended needles; however, the first seamless garment production machine was not introduced until 1995 by Shima Seiki (Prince and Sivakumar 2010). The initial programming and manufacturing difficulties have been largely overcome and this technology now offers the designer versatility and innovative potential as advanced three dimensional garment shaping can be combined with texture and colour use. Shima Seiki based in Wakayama, Japan offer this under the *Wholegarment* label and Stoll, Reutlingen, Germany produce *Knit and Wear* machines.

All four of these knitted fabric manufacturing solutions are currently in use. Machines purchased in the last twenty years will be digitally operated, but depending on the local economy of the location of the plant, older, mechanical or even hand operated machines could be in use. It is possible that all types of manufacture could exist in one factory.

The influence of manufacturing requirements on the designer will depend on where he or she sits within the industry. For example, if the designer is independent or based in retail, and is therefore essentially a 'buyer', they will be able to source the product from whichever manufacturing base is most appropriate (considering availability, cost, lead times, location, etc.). However, if the manufacturer employs the designer, their design scope will be limited by the production plant available (see Section 3.2.4).

Computerisation of the manufacturing technology in the later part of the twentieth century liberated the design process. Machines were no longer dependent on mechanical, and therefore expensive patterning systems (such as steels or tapes), which were only viable for long manufacturing runs. This one significant difference facilitated the commercial possibility of larger design ranges and shorter design 'seasons', giving both the designer and the consumer more choice.

This technology is now in its second or third generation, far more user-friendly and inspirational for those designers who want to work with its potential.

3.2.4 Key issues affecting design and the designer

The knit design discipline is demanding in that designers have to be creative within a variety of constraints. In the majority of cases they are responsible for creating both fabric and finished form, which require that the designer possesses multidimensional skills. At any one time they need to consider that the yarn selection is suitable for fabric and product design, as well as being appropriate and available for the knitting and manufacturing technology to be used. This process requires a flexible and open-minded approach to design, particularly in the context of the economic industrial terrain that has precipitated the rapid growth of diverse supply structures.

In addition, it is important to recognise that there are many areas relating to knit production requiring the designer to have a different function; some may work in one area whilst others across several boundaries.

The main areas of definition are: Jersey fabric for the garment industry which includes underwear, T-shirts, sweats and fleece; knitted fabric for domestic upholstery; knitted fabric for domestic interiors, nets and soft furnishings; knitted fabric for the automotive industry; knitted sportswear, which includes footwear; women's knitwear; men's knitwear; children's knitwear; knitted accessories; hosiery; hand knitting; knitted technical textiles. Each area listed is almost a unique industry in itself and some manufacturers are very specific.

Designers can also work in the following different ways.

Designer label

Cost may not be a consideration. Products are concept driven so suppliers need to be sympathetic to this. Designers may opt to work directly with the designers attached to the manufacturer, as they will understand the nuances of the production.

For a manufacturer

The designer will represent a manufacturing plant and the primary concern will be to ensure that the factory is fully operational. The manufacturer will supply different labels/designers/retailers and will need to work around the limitations of production and customer requirements in relation to cost and supply chain. In this context the designer will have access to knitted fabric design systems and so will become conversant with knitted fabric and product manufacturing technology.

For a high street retailer

The main concerns for this designer are cost, lead times and reliable supply. Performance and value of the product are also important considerations. The designer will usually have their own department and will need to co-ordinate with other lines. The role is dependent upon market placement in the high street.

For a private label

The designer is essentially a middleman using the expertise of manufacturing and design, selling design ranges to global brands and retailers and then overseeing the production and final delivery.

Designer maker

The designer is also the manufacturer and probably sales person too. Issues will involve resources, appropriateness of product to market, manufacturing costs, sales and cash flow. Their work is usually handcraft based and skill orientated.

Freelance

The designer could supply specialist skills to brands, retailers or manufacturers who do not have their own design departments. They can work on a daily or hourly basis as appropriate. They are usually employed seasonally or to develop concept ranges.

Design studios

These supply inspirational design services for the industry as a whole. They are usually staffed by small teams of designers who produce seasonal collections of dynamic fabric and/or garment ideas in the latest fibres and yarns.

Design consultant

This would be an experienced designer who would be knowledgeable about the broader aspects of design, markets, materials, manufacturing processes, production and suppliers and who would be employed in a strategic and advisory capacity.

Issues that will affect the designer depend on the specific product area and the way he or she is employed. All design depends on the desired market level and selected available production. Different parameters determine the appropriate approach. Design interest can be added to knit at varying stages of the manufacturing process so knitwear designers need to understand the whole procedure, from fibre and yarn selection to optional finishing processes such as dyeing, washing, destressing or felting, and embellishment.

3.2.5 Case study

Sophie Steller owns a '*knitwear design & fabric inspiration*' studio (see Design Studio above) based in London. It was originally established in 1996 when Sophie returned to the UK after working in New York for *Joseph Abboud* and *American Eagle Outfitters*.

Sophie recognised that there was a gap in the market for original and inspirational design ideas, produced as knitted swatches that could form the basis for single garment or capsule collections. These swatches, or '*mini garments*' (which can be individual or in sets of three or more) are approximately 35 × 45 cm and include garment design finishing details such as neck or collar trims, fastenings and edgings. Sophie established her broad client base of retailers and manufacturers, ranging from high street to high-end brands, through showing at international fabric fairs in Paris (*Indigo, Premier Vision*), Florence (*Pitti Filati*), Shanghi and New York (*Spin Expo*). As her business developed she enhanced her range of knitting machinery and expanded her design team. Currently she employs six experienced designers who cover machine knit, hand knit, embroidery and crochet.

The business provides exclusive collections for clients. Sophie is also a consultant for *Novetex Spinners, Hong Kong* providing colour advice and design inspiration. In addition to this, Sophie offers live design projects with textile students at various universities and regularly employs placement students at her studio.

3.2.6 Relationship to other design disciplines

Knitwear designers sit between the disciplines of textile and fashion design. The textile designer is responsible for the exploratory processes in terms of creating fabrics, working on design and experimental developmental processes relating to fabric manufacture and production. They will be fully conversant with technology relating to their specialism and will work in partnership with the fashion designer, who is responsible for the concept and production of collections of 3D garments. The worlds of textiles and fashion have become closer over the last two decades (Braddock Clarke and O'Mahoney 2007). Increasingly, technical developments in terms of cloth manufacturing have led to more innovative fabrics, the properties of which have an impact upon the end garment performance, requiring the textile and fashion designer to work collaboratively. The same can be said of the knitted fabric designer, if they are involved solely with creation of knitted fabric. However, if the knit designer is involved with 'product', at whatever level, they need to be concerned with both the two and three-dimensional elements of the design process and therefore require knowledge of both. They should also be aware of all the embellishment possibilities that are available for knitted fabrics such as printing, embroidery and beading and the resultant design potential that they provide.

3.2.7 Design education and training

Because the knitted textile process is so technically based, and because the technology has evolved so rapidly since the 1950s, it has been challenging for educational institutions (be they colleges or universities) to maintain a cutting edge position in the field. The cost of capital investment in state of the art technology, which requires specialist air-conditioned space, and the constant updating of staff expertise have resulted in very few centres dedicated to the education of knitted fabric and product.

Another significant influence on knitted textile education is that, historically, knitted fabric design has been situated in Textile Departments (or sometimes in Textile Technology Departments) and has been taught as a two-dimensional subject. As knitted garments are designed as three-dimensional products, then it is fitting that the design theory and practice should be centred in fashion design education. Therefore the complete subject can only be effectively covered in its entirety in educational centres that include both fashion and textile areas.

Also, at the point when a school leaver would usually select their preferred higher education subject, their previous design experience would not normally have exposed them to any professional knitting or knitwear practice. It is therefore understandable that few applicants select knitted textiles or knitwear design as a primary option.

The best educational opportunities in this subject exist in internationally positioned design institutions that possess the breadth of subject, modern technology, practical staff expertise, industrial links, and global networking. These centres of learning should also place an emphasis on creativity and innovation within an aesthetic context and allow students to experience the different parameters of the subject and specialise as they develop.

During the last half of the 20th century, when the knitting industry in the UK was sizable, there were technical training opportunities accessible through 'day release' programmes within regional technical colleges. The decline of the industry has meant that these are no longer available. However, knitting machine builders such as Shima Seiki (Japan) and Stoll (Germany) have training schools that support the purchase and use of their equipment. These technical courses are not design programmes and assume that the participants are already design educated.

3.3 The principles of weft knitted textiles

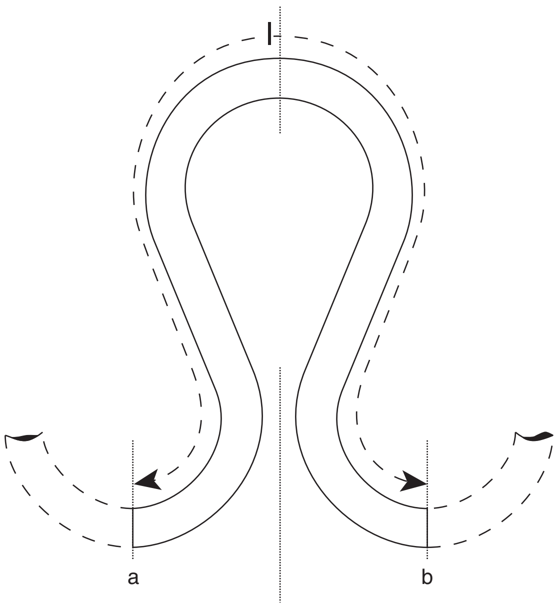
3.3.1 Knitting fundamentals

Weft knitted fabric is made from a series of intermeshing loops. Each knitted loop (Fig. 3.1) is an 'upright noose' which has a head, two side legs and two feet. Where the lower part of the loop joins its neighbour, the 'sinker' loop is formed.

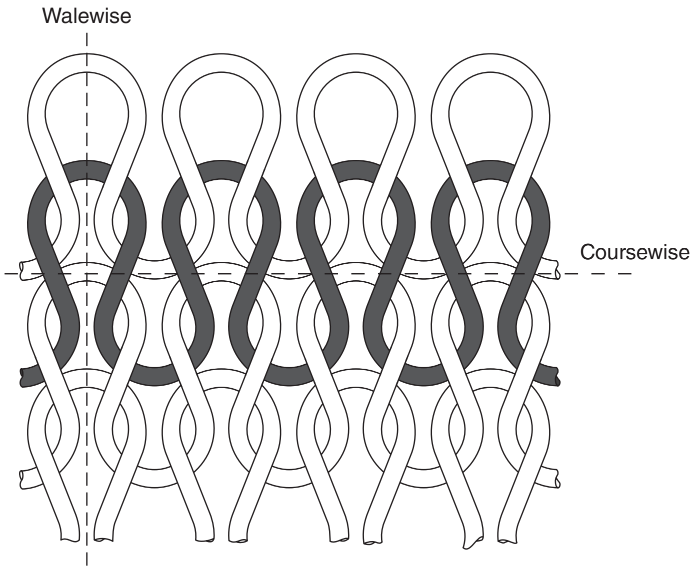
A knitted structure is formed by yarn being carried across the needle bed and being received by the needles creating a row of knitted loops. The needles retain these loops until they receive newly fed yarn. When the new yarn enters into the needles, the originally held loops are knocked off. The old loops then hang suspended from the legs of the new loop. Loops that travel horizontally across the fabric are called courses (or rows) and the loops that travel vertically are called wales (or stitches) (Fig. 3.2).

The advantages and limitations of knitted fabric

The intermeshing loops give knitted fabric specific performance properties that can be enhanced by yarn choice. The loops provide an open area in which air can circulate freely and so provide thermal insulation. As knitted fabrics will extend in all



3.1 The knitted loop (*courtesy Brackenbury 1992)*.



3.2 Courses and wales (*courtesy Brackenbury 1992)*.

directions, when stress is applied the surface area of the fabric is increased making the fabrics able to fit any form. After extension, the loops will attempt to retain their original position, allowing yarn to move and slip; this prevents the formation of sharp folds in knitted fabric. This ability to stretch and recover is a fundamental characteristic of knitting, a positive attribute being the production of fabrics that are comfortable and easy to wear. As the knitted loops move freely within fabric, it is often the case that it will not often be stressed to the extent of breakage. (This is unlike woven fabric that is made from warp and weft yarns that are interlaced at right angles.) However, as the yarns/fibres are only bound into a loop that is essentially a loose construction, pilling (bobbling) and snagging can occur, resulting in an unsightly fabric surface.

The extensibility of knitted fabrics can prove to be a challenge in terms of manufacture. Knitted fabrics require an amount of tension to be placed upon the loops during the fabric construction process, after knitting relaxation shrinkage occurs, making it sometimes difficult to obtain dimensional stability.

Knitted fabrics come in a variety of weights; this is determined by the both yarn diameter (yarn count) and the machine gauge. Machine gauge is calculated by measuring the distance between two needles within the needle bed. The various machine gauge measuring systems use numbers to indicate size; for example, the English gauge system is based upon counting the number of needles within one inch of the needle bed; 5 gauge = 5 needles per inch, 10 gauge = 10 needles per inch. Course gauge machines have thick needles with large hooks, fine gauge have fine needles and small hooks. Regardless of gauge measuring system, the higher the number, the finer the gauge and, the finer and lighter the weight of knitted fabric.

3.3.2 Basic stitches and structures

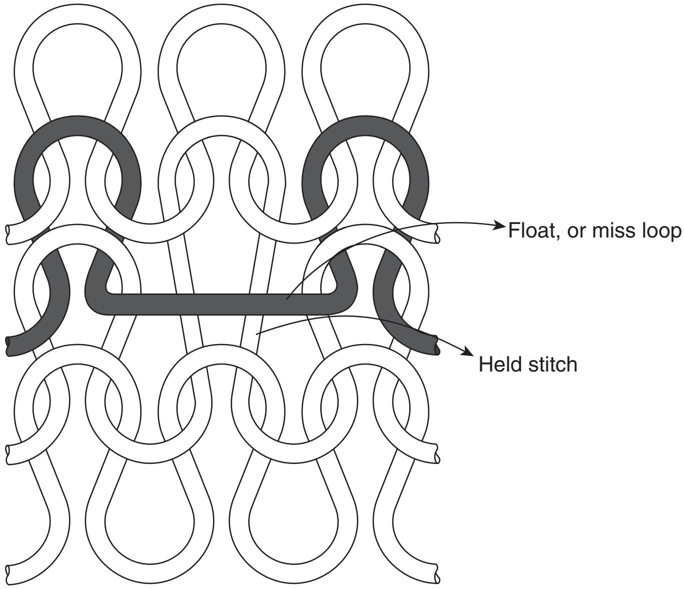
Irrespective of the mechanics used to operate them, knitting machines have the ability to knit, hold and tuck a stitch. Machines can be constructed with one or two needle beds, producing single or double bed structures. These base stitches and structures provide the designer with fundamental elements of the process that have their own specific properties, regardless of yarn choice.

The held stitch is formed when a knitted loop remains on the needle whilst others in the same course are knitted. Combining a held loop with a knitted loop produces a float or miss stitch (Fig. 3.3). Fabrics containing float/miss stitches can have reduced elasticity in width, but as a consequence of this, improved dimensional stability (Figs 3.4, 3.5).

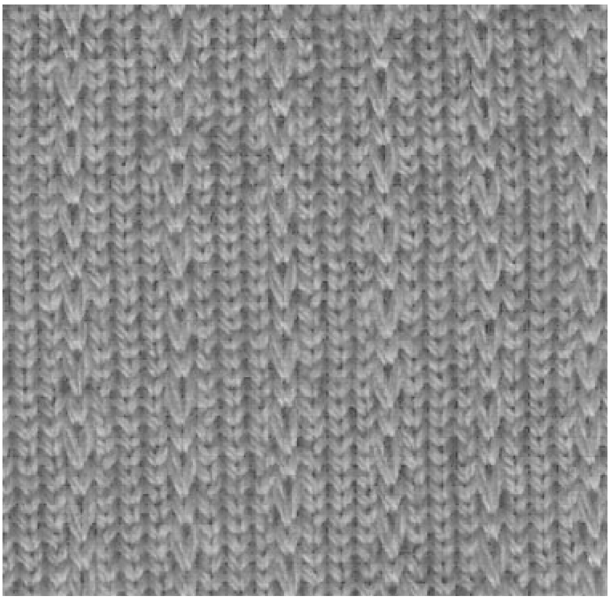
A tuck stitch is formed when a needle already holding a loop, receives a further loop (Fig. 3.6). This second loop is tucked in behind the held stitch. Fabrics with tuck loops have reduced length elasticity but increased width as the tuck loops pull down the held loops and cause them to spread (Fig. 3.7).

It is possible to transfer knitted loops from one needle to an adjacent one or to a needle on the opposite bed. Loop transfer can be achieved manually with the aid of transfer tools on hand operated machines, or mechanically on automated machines. It can be used for either aesthetic purposes to create visual interest or to create shape, or both.

Single bed structures, knitted on one needle bed, are the base fabric for hosiery, underwear, T-shirts and knitwear. They can be manufactured in various weights and are also called plain or single jersey. The fabrics are smooth with even stitches and limited stretch. In appearance, the front and back are different, the front is smooth with visible columns of ‘V’s (Fig. 3.8), the back has ridges of interlocking reverse loops (Fig. 3.9). This ‘imbalance’ results in the fabric having a tendency to curl at the edges and dropped stitches will ladder easily.

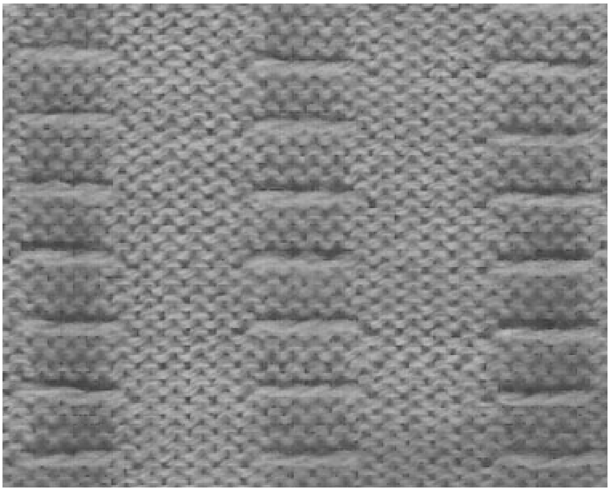


3.3 Held and float stitch (*courtesy Brackenbury 1992)*.

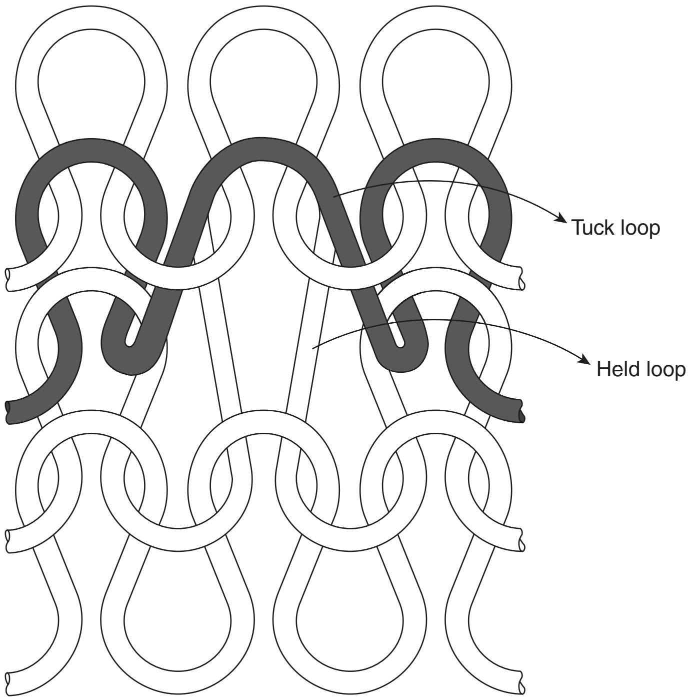


3.4 Held stitch fabric.

Rib structures are knitted on two needle beds (can be termed 'double bed'). They are produced by the yarn passing equally from one needle on one bed to another on the opposite bed. Because of this they require more yarn for the process so are heavier and more balanced than single bed structures. The characteristics of the structure are different: they are more extensible, do not curl at the edges or ladder as easily. When relaxed, this structure appears the same on the front and the back



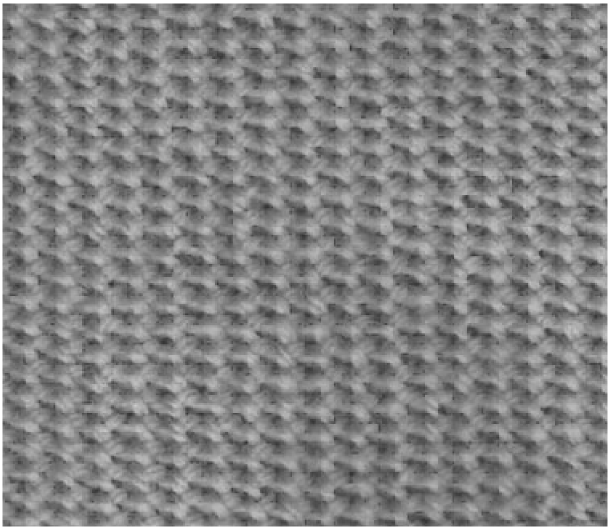
3.5 Float stitch fabric.



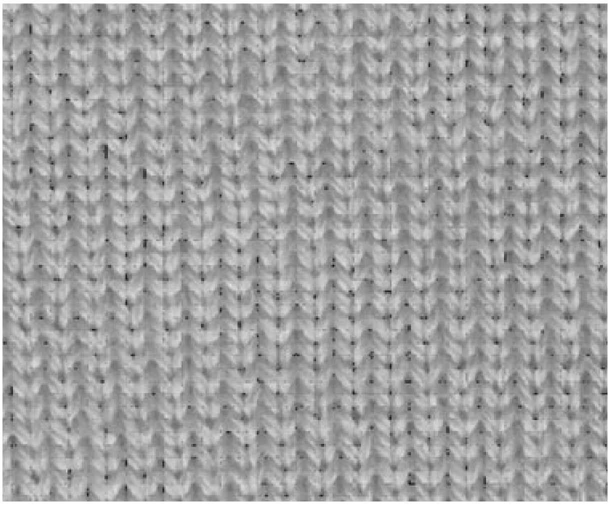
3.6 Tuck stitch (*courtesy Brackenbury 1992*).

(Fig. 3.10), but when stretched horizontally the reverse loops are more visible (Fig. 3.11). Varying needle set outs can be used to form differing rib layouts.

Purl fabrics (Fig. 3.12) are also referred to as links-links fabric and require two needle beds as the transfer of stitches from one needle on one bed to its opposite needle on the other bed forms them. To achieve this, the needles must be positioned directly opposite each other. Specific flat bed machines were developed with double-



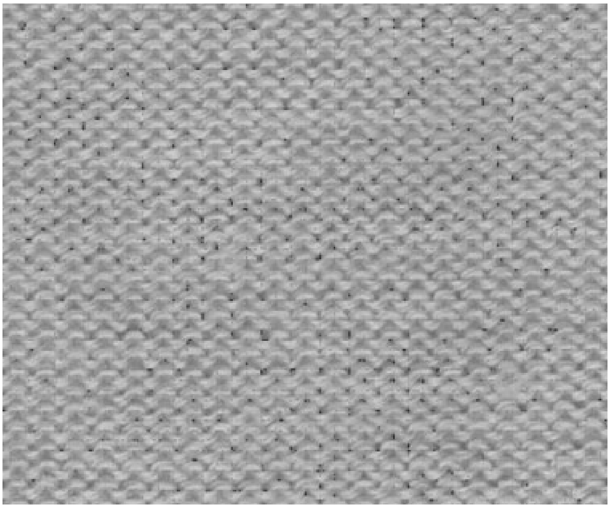
3.7 Tuck fabric.



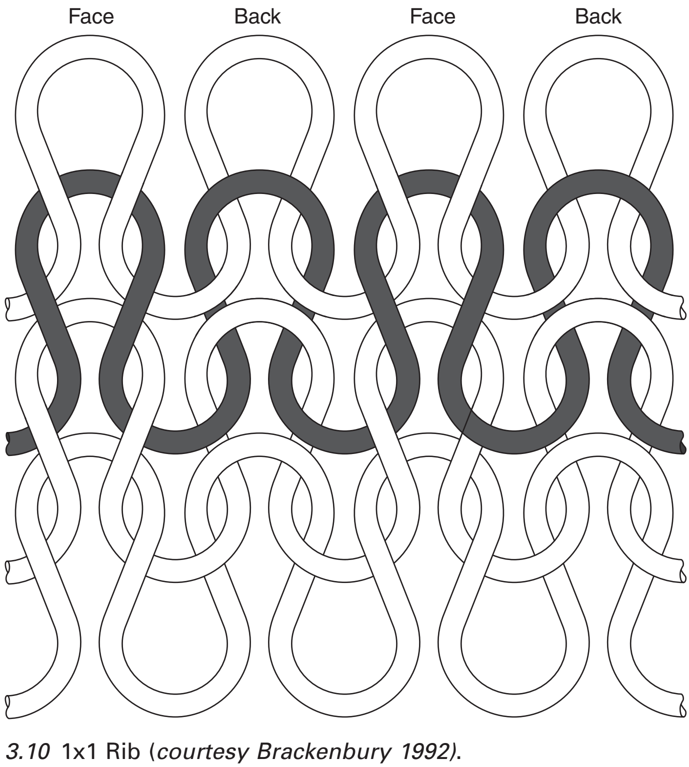
3.8 Single bed fabric – front.

ended needles to create purl fabrics. However, it is possible to create purl structures easily on standard V-bed machines. In these fabrics the front and back appear the same with semi-circular reverse loops being predominant but when stretched lengthways V loops are apparent (Fig. 3.13). These structures have excellent lengthways stretch but when manufactured on V-beds the transfer process extends knitting time.

In addition to plain, rib and purl structures, the now less commonly used interlock structure produces a smooth, balanced and stable fabric without any tendency to curl. These qualities made it appropriate for underwear manufacture in the late 19th and early 20th centuries. However, in comparison to other double bed structures it is heavy and thick, using twice the amount of yarn (one visible course takes two

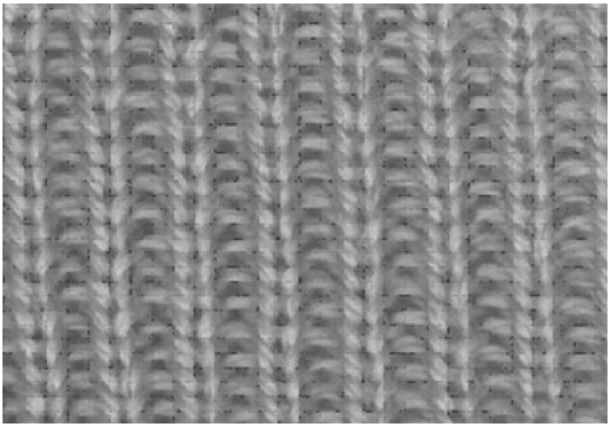


3.9 Single bed fabric – back.

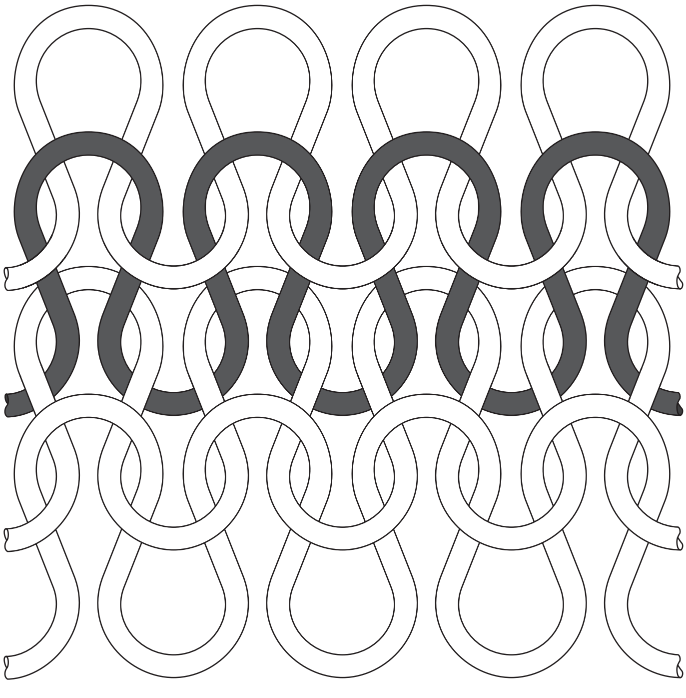


3.10 1x1 Rib (*courtesy Brackenbury 1992).*

traverses of the knitting carriage). It is due to this that interlock has traditionally been made on fine gauge circular knitting machines. However, the further development of yarn and knitting technology has meant that it is now rarely used. Over time other simple, double bed structures have been developed utilising the holding and tucking mechanisms of basic knitting machines.

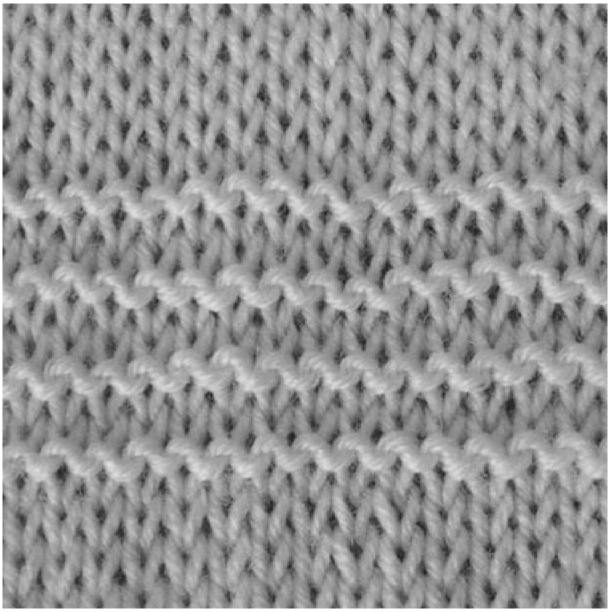


3.11 1x1 Rib fabric – stretched.



3.12 Purl (courtesy *Brackenbury 1992).*

Milano fabrics provide a more stable double bed structure with similar qualities to interlock fabric but are quicker and therefore less costly to knit. Half Milano involves knitting one course on both needle beds and one course on the back bed whilst holding front bed stitches, presenting fabric with smooth, extended front loops and crammed back bed stitches. Full Milano has one course knitted on both beds, a course knitted only on the front bed, followed by a course knitted on the back bed making a more stable and balanced structure than half Milano.



3.13 Purl fabric – stretched.

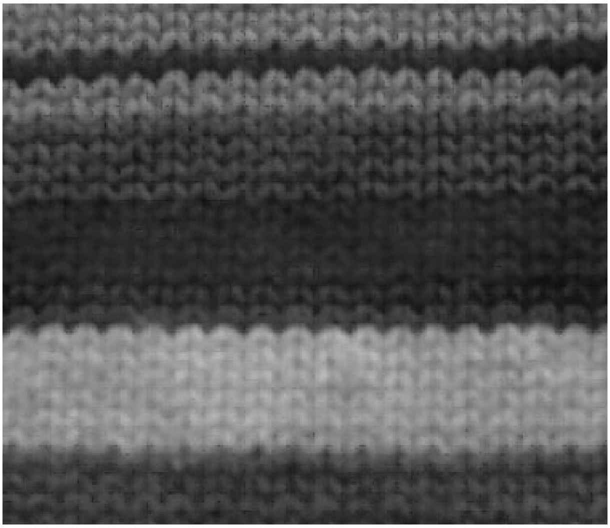
Cardigan stitch fabrics use knit and tuck stitches and as the tuck stitches spread, cardigan fabrics have greater width than basic rib fabrics. Used in conjunction with basic ribs, the technique will provide knitted 'frills'.

Half cardigan is produced when one course is knitted on both beds, followed by a second course knitting on the front bed whilst tucking on the back bed. The back bed tuck emphasises the rib appearance on the front bed. Full cardigan is produced by knitting one course with plain loops on the front bed and tucks on the back bed, followed by a second course knitting tuck loops on the front bed and plain loops on the back. As a result of double tuck loops, full cardigan fabric spreads more than half cardigan.

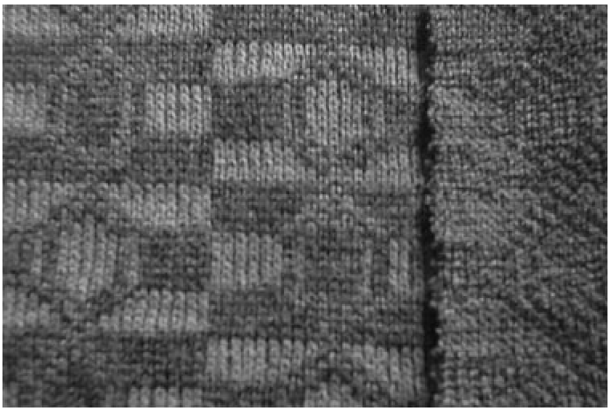
3.3.3 Using colour in knitted fabric

Exploiting colour in knitted fabric is not difficult as it can be applied at various stages of the manufacturing process. Using dyed yarn offers a range of creative opportunities to the designer, and as yarn is fed into the knitting machine course by course, it is possible to create knitted fabrics in various colours. The simplest process is stripes, achieved by using selected different colours of yarn for each knitted course or multiples of courses (Fig. 3.14).

Not every knitting machine will be able to produce patterned fabrics, as it is dependent upon the patterning ability inherent in the design of the knitting machine. The three different knitting processes that are used for two-dimensional colour patterning are: double-bed jacquard, single-bed or float-stitch jacquard (Fairisle) and Intarsia.



3.14 Striped single bed fabric.

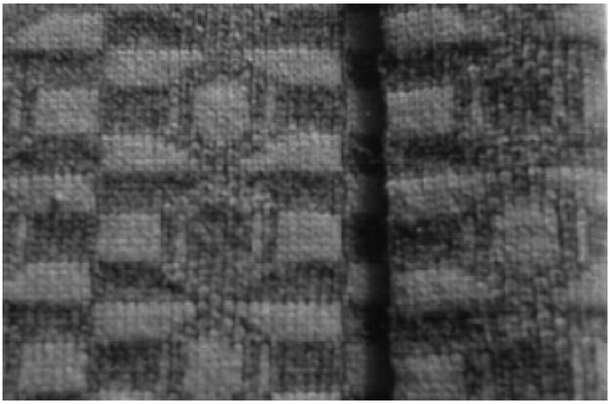


3.15 Striped back double-bed Jacquard fabric.

Double-bed jacquard

Usually jacquard is a double-bed structure for two or three colours. When all needles are used for a two-colour pattern; colour 1 will knit on all needles on the back bed and on selected needles on the front bed, colour 2 will also knit on all needles on the back bed and the remaining pattern needles on the front bed (Fig. 3.15). Therefore, for every one-pattern course there are two courses of knitting on the reverse side of the fabric and for a three colour Jacquard structure, there would be three courses of knitting on the reverse side.

As these structures have twice as many courses on the reverse compared to the front, the fabric is unbalanced and can curl towards the front. Also, the front stitches are stretched and so colours from the back may 'grin' through and show on the face side, distorting the design. These characteristic and technological developments



3.16 Tubular Jacquard fabric.

have meant that various adaptations have been made to the reverse structure, so there now exist jacquard structures with 'birds-eye back' and 'ladder-back'. One particularly effective development has been tubular or reversible jacquard. This structure has the same pattern on both fabric sides, but the colours are reversed. Colour 1 knits selected pattern needles on the front bed, leaving the opposite back bed needles empty. On the returning course, colour 1 knits the selected needles on the back bed, leaving the opposite front bed needles empty. Colour 2 then knits on all the needles that colour 1 did not knit. The fabric is knitted in a tubular/circular construction and two circuits make one pattern course (Fig. 3.16).

Single-bed or float-stitch jacquard (or Fairisle)

This is a single-bed structure that features two (or sometimes three) colours in one knitted course. The design is visible on the face of the fabric (Fig. 3.17) with unknitted floating threads on the reverse (Fig. 3.18).

This structure is formed by colour 1 knitting on selected pattern needles with colour 2 floating across the back of these needles. Colour 2 knits on the remaining pattern needles and floats across the back of those previously knitted in colour 1.

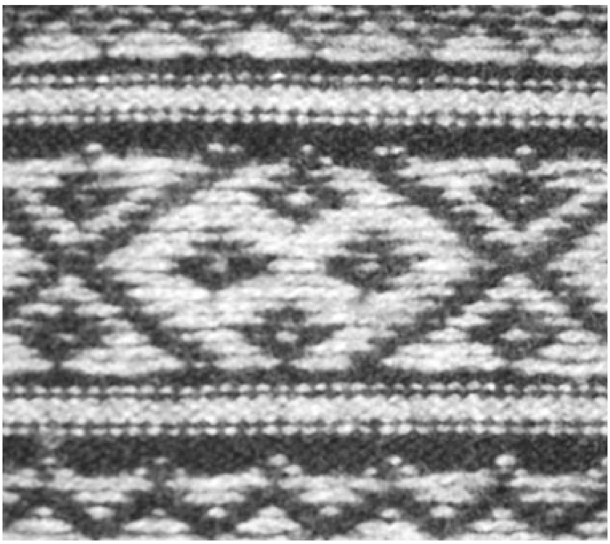
This process is only appropriate for small repeating patterns as floats of more than an inch (or 2.5 cm) restrict stretch and hinder manufacturing.

Intarsia

This knitted fabric has solid areas of single-bed knitting with loops of one colour, without any other yarns interfering in the base construction. In handcraft production the number of colours used in any one course is unlimited. The different colours are joined together by yarn overlaps (Figs 3.19, 3.20).

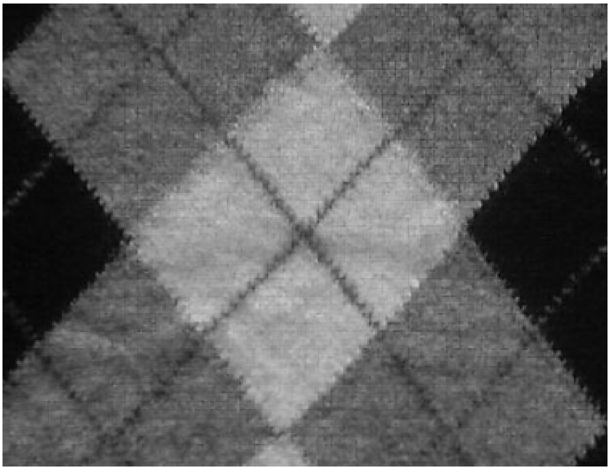
When knitted on industrial knitting machines there are limitations in relation to the number of colours that can be used within one course. Generally designs tend to be geometric to maximise mechanical limitations. Hand intarsia knitting allows a greater flexibility of patterning but is time consuming and consequently, costly.

3.17 Float-stitch Jacquard fabric – front.

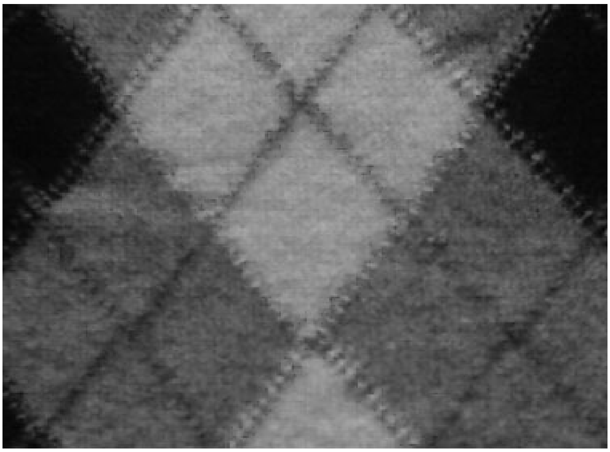


3.18 Float-stitch Jacquard fabric – back.

Colour can also be applied after the knitting process by 'piece dyeing'. This is cost effective as early commitment to colour palettes and the cost of storing dyed yarn ranges are eliminated. It also means that colour decisions can be made much closer to the selling period. However, it does limit the knitted products to a single colour. Knitted fabric or garment pieces in the undyed state are called *'greige'*.



3.19 Intarsia fabric – front.



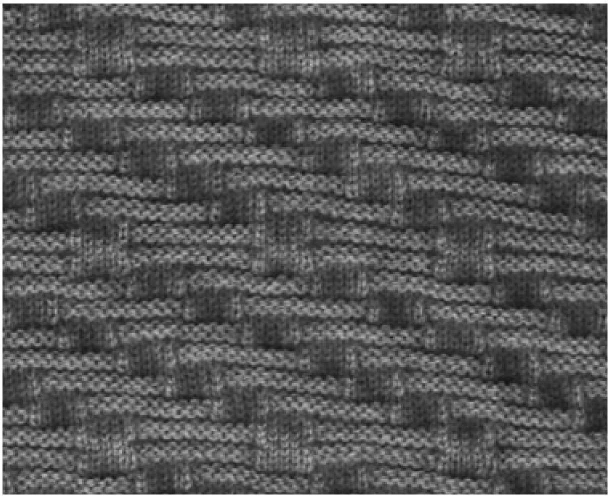
3.20 Intarsia fabric – back.

3.3.4 Stitch interest fabrics

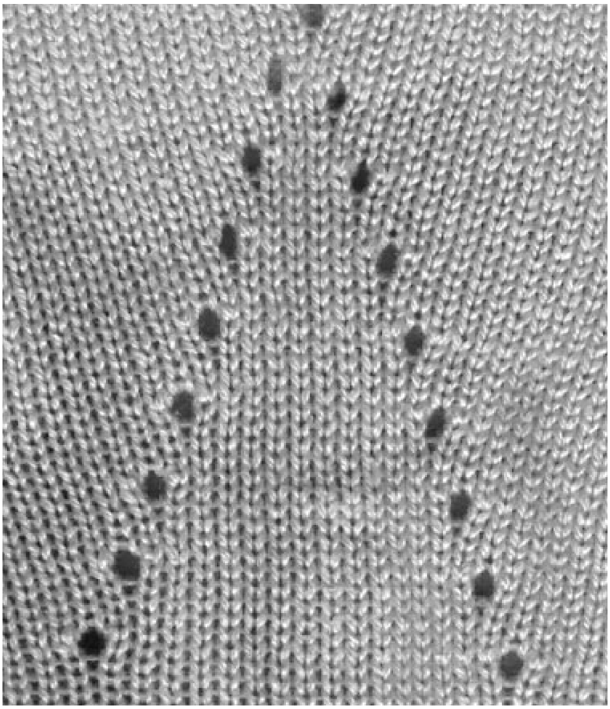
Simple stitch interest can be achieved by alternating plain and purl stitches in one course producing seed, basket and chevron variations (Fig. 3.21).

It is also possible to create visual interest in fabrics using stitch transfer, a method that also allows for the creation of shaped fabric (see Section 3.3.5). The ability to transfer a stitch or a section of stitches has allowed a variety of interesting textured knitted fabrics to be produced. As with every other knitted structure, the ease of this process is dependent upon the knitting machine available and even with electronic knitting technology can be a time-consuming (and therefore costly) process (Fig. 3.22).

Textured structures include eyelets, the transfer of one loop to an adjacent needle, therefore making a hole or eyelet and the basis of lace structures and cables, where



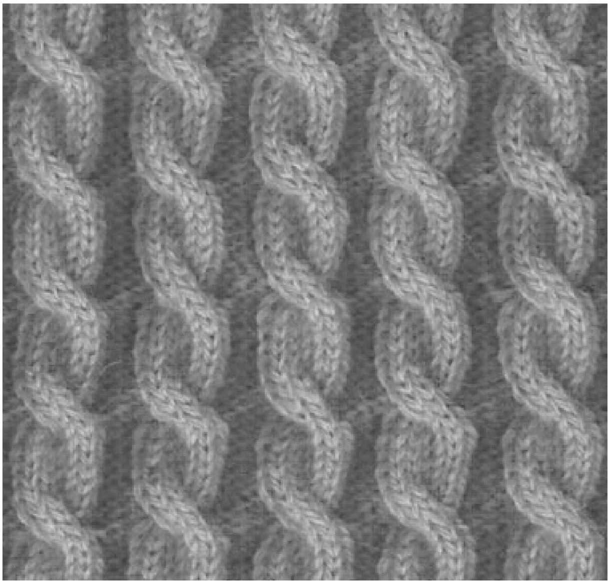
3.21 Purl and plain stitch fabric.



3.22 Stitch transferred eyelets.

sets of loops (2, 3 or 4) are removed from the needles and 'exchanged' with an adjacent and equal in number set of loops (Fig. 3.23).

In hand knitting even more three-dimensional or raised textures are possible, such as blackberry stitches, bobbles (Fig. 3.24), overlapping cables (Fig. 3.25) and raised diamonds (as seen in traditional fishermen's and Aran sweaters).



3.23 Machine knitted cable.

3.3.5 Shaped knitted fabric

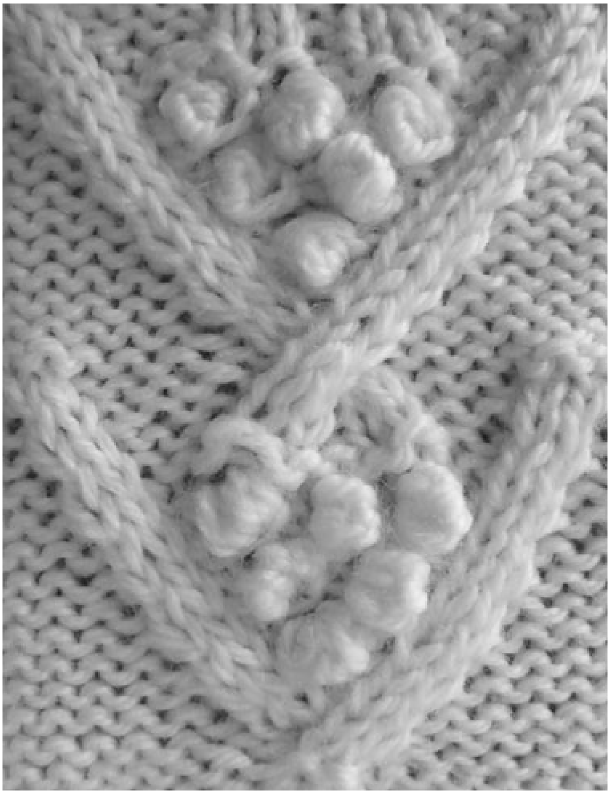
This process is used in fully fashioned knitwear manufacture (see Section 3.2.3) and involves the transfer of one or more stitches (at the fabric edge) to adjacent needles either towards or away from the centre of the fabric piece, and placing the redundant needle(s) out of action. This will result in the narrowing or widening of the knitted piece. Integral shaping is the same process, but not on the fabric edge, and necessitates the repositioning of all remaining stitches across the needle bed. This technique has become more viable with the development of electronically controlled machinery where the process can be programmed to occur automatically. It is used for generating innovative three-dimensional pieces when '*complete garment*' technology is not available.

A beautiful example of experimental use of this principle can be seen in the work of Sunny Sang, 2008 MA Graduate from The Nottingham Trent University (Plate I between pages 166 and 167). Sunny exploited three-dimensional shaping using electronic knitting technologies, stretching the limitations of the Shima SES120RT. The resulting miniature garments were exhibited at '*New Designers*', London 2008 and Li Edelkoort's '*Designhuis Talent*', Eindhoven 2008.

3.4 Practical design applications of knitted textiles

3.4.1 Fashion

As explained at the beginning of this chapter, the process of knitting was originally used for hosiery, gloves and hats. The mechanisation of knitting and its associated technological developments resulted in it becoming an industry in its own right, with extensive apparel applications becoming possible.



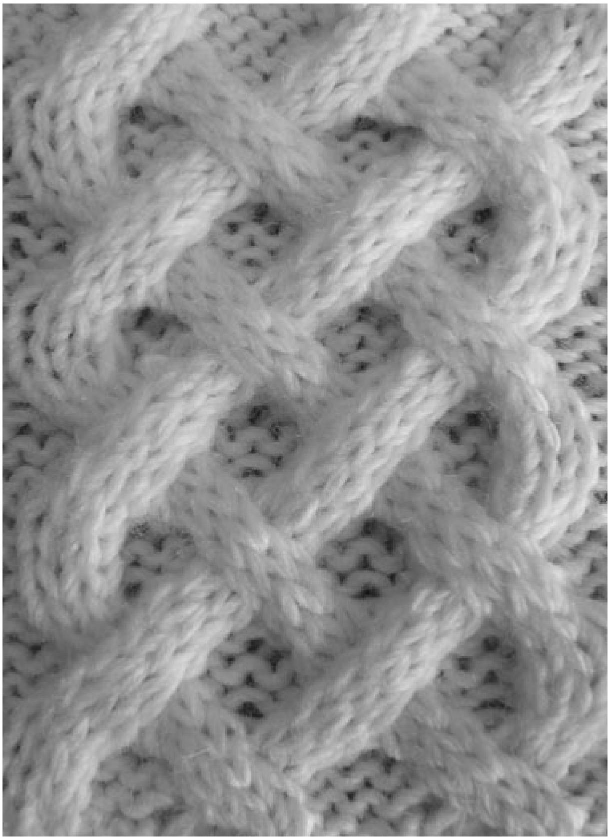
3.24 Hand knitted stitch transfer with bobbles.

Over the last six hundred years in clothing terms, the use of knitting diversified from hosiery to underwear and then to outerwear, and now forms approximately 30% of the apparel industry.

However, knitwear did not become a really fashionable (or particularly desirable) outerwear item until after the First World War. The leisurewear boom was pioneered in the 1920s by Coco Chanel who was the first designer to create comfortable and practical clothing made from fabrics that had previously been confined to knitted underwear (Black 2002). She designed expensive and beautifully made fully fashioned knitwear such as casual walking jackets and golfing sweaters for both men and women. From this time on the classic ladies' fine gauge, knitted twin set became a standard in every woman's wardrobe.

The rise of the movie industry during this period, shortly followed by the invention of television also made everyone more aware of and hungry for stylish and affordable clothing. Fashion became relevant to all, not just the rich. The general public looked to the movie stars for inspiration, (Black 2002) and classic knitwear styles became the vogue as celebrities adopted them themselves.

Since the 1950s knitwear has become a key item of clothing in the fashion market. This has happened because new manufacturing processes have enabled specific knitted fabric characteristics to be mass-produced allowing clothing to become less formal. Examples of these are the skinny rib sweater of the 1970s, which replaced



3.25 Hand knitted plaited cable.

the shirt under the jacket; the 'picture' sweater of the 1980s, which in turn influenced the 'spectator sport' market relating to golf, which was popularised by Sir Nick Faldo and Pringle.

There are few brands or designers who started exclusively in knitwear, but those who have include: Pringle, Jaeger, Missoni, Sonia Rykiel, Joseph, Marion Foale, Artwork and Alexander McQueen. However, many designer-labels or designer-brands include knitwear as an integral and important part of their collections: Marc Jacobs, Jil Sander, Donna Karan, Prada, Max Mara, Paul Smith, Azzedine Alaia, Comme des Garcons, Yohji Yamamoto, and Jean-Paul Gaultier to name but a few.

3.4.2 Lifestyle products

Alongside the development of knitwear in the fashion, sportswear, clothing, hosiery and accessory market, the last thirty years have witnessed an increasing application of knitted products into the life-style market. This has been fuelled by the never-ending quest for the invention of new products and new markets, the commercial need to keep all available industrial plant in constant use combined with the stable, easy fit and simple to manufacture characteristics of knitted fabric and product production.

Interior lifestyle products such as knitted cushions, blankets, throws, sheets and hot water-bottle covers started to appear in the 1970s. Design ranges can now include even more indispensable pieces such as i-Pod and mobile phone covers. Other items such as knitted accessories and toys for babies have also become available and popular products in global markets over the last twenty years.

3.4.3 Industrial solutions

Due to the flexibility of manufacture, weft knitted fabrics have many industrial applications and the technical textiles field is a growing area for research and development within the Western world.

Technical developments in fibres and yarns have facilitated a greater flexibility within the raw material selection and therefore determine yet more desirable base characteristics that can be manipulated. For example, they can be flexible or stable, thick or thin, permeable or impermeable. Weft knitted fabrics can be manufactured in two dimensions or in the round, as tubes, the diameter of which can be controlled. New knitting technology has enabled how these two- or three-dimensional fabrics can be shaped as they are made, resulting in cones or funnels, fan shapes or circles of fabric.

As a result of these variables, the industrial applications are almost endless but currently the main ones are as follows:

- Medical: used in surgery as dissolvable templates or supports to facilitate the repair of joints.
  circular bandages constructed with elastomeric properties for injury support or to pressurise the limb in the case of DVT.
- Hydrological: used in water and effluent filtration.
- Automotive: used in car interior lining and seat covers.
- Aerospace: used in interior and exterior fabrication.

3.4.4 Technological influences on knitwear design

Innovation in knitted fabric technology has always led design in that when new technologies or processes become available, designers will inevitably use and exploit them. This process invariably leads to yet more technological developments. According to Power (2008), the first motor driven, jacquard flatbed weft knitting machine, introduced in 1926, revolutionised knitted fabric design. 'It provided knitwear designers with patterning capabilities that had not previously been possible and thus established for itself a unique place in fashion' (Power, 2008).

Over the next fifty years further modifications gradually occurred so that by the mid 1970s the mechanical machine was transformed to a sophisticated, computer-controlled facility that eventually could both create pattern and shape simultaneously. This is evidenced in the bold, graphic design exploited in commercial knitwear between 1975 and 1985. This would have been impossible to achieve without electronic technology.

Integral shaping (or wale deflection) was a technologically facilitated feature previously difficult to achieve in knitwear manufacture before the introduction of electronic production. This technical development was then exploited as a design element for the less expensive sections of the market as structured knitwear became more fitted and more tailored and more commercially available. This was also made possible using manually operated machines in regions where labour was low cost, making time consuming stitch transferring more feasible.

3.4.5 How technology and the creative process affect each other

As mentioned previously, knitted fabric (or knitwear) design and technology are intrinsically linked and developments in one area will automatically affect and influence the other. It is difficult to be a successful and relevant designer in the current global market without being aware of the technological capability of the industry. Similarly, the technology can only usefully develop if it is both utilised by designers and/or cost effective within commercial markets.

For example, *complete garment* technology was very expensive when it was first commercially developed in the 1990s. The timing of this coincided with the increased costs of traditionally manufactured knitwear in the West and a strategic shift to production in developing countries where labour costs were low. The new technology was also revolutionary, so it is possible that Western retailers were not prepared to introduce their consumers to seamless knitwear at this time. It was therefore deemed commercially viable to continue traditional manufacturing techniques offshore rather than invest in the new technologies, restricting the expansion of this manufacturing (and design) innovation for another ten years.

When the knitting production process was first mechanised and subsequently, computerised, designers worked alongside technologists or programmers to achieve the end product. This was sometimes challenging but always time consuming and expensive. Machine builders recognised this with the introduction of second-generation electronic knitting machines eliminating the need for the designer to be as dependent upon a programming technician. However, despite such advances there still exists the need for designers to work in partnership with knitting technologists.

3.5 Future trends

3.5.1 Knitwear and knitted textiles as big business

It is difficult to obtain current statistics but knitted fabric and knitted garments appear to account for approximately one third of the global apparel market. Knitted fabrics and knitted products satisfy the consumer demand for more relaxed dressing which has become a 'standard' at every market level. Within fashion and textiles, knit plays a significant role as knitted fabrics also allow for greater ease of wear and care. The extended versatility of knitted fabrics has been facilitated by technical developments in fibre and yarn production as producers have responded to economic, environmental and consumer demands. Characteristics that previously restricted popularity and end use of certain fibres have been overcome. Wool, for example, a fibre that once needed careful handling during laundering to avoid felting and shrinkage, can now be machine washed and dried. Similarly, the man-made fibre industry has responded to difficult environmental issues by researching possible alternatives to oil derivatives, manufacturing yarns made from regenerated and easily renewable resources, such as maize. Black cites the arrival of Lycra and elastomeric yarns as being a key development of commercial knitting as they provided already flexible knitted structures with enhanced body contouring properties allowing them to diversify into new markets. (Black 2006)

3.5.2 Digital technology and its impact on design and manufacture

Electronic communication is an essential tool in this global industry. Fabric and garment designs, prototype specifications, amendments and other associated information are sent via email, satisfying the requirements for a speedy response. Software from Microsoft and Adobe provides a 'common' platform of communication between designers, buyers, manufacturers and technologists.

As with the other textile disciplines, specialised digital CAD systems have been developed to reduce costly prototyping and accelerate the design and decision-making process. CAD systems with this function have been available since the end of the last century and the principle of these is to facilitate the design of 'virtual' fabrics that mimic yarns, structures and gauges and replicate actual knitted sampling. Designs that are developed on screen use computer-generated stitch structures to build fabrics that are then printed on paper to communicate ideas to both buyers and manufacturers, either in fabric or garment form. *Lectra* and *Colour Matters* are just two of the companies that have developed computer-aided design systems for the commercial market.

When designers utilise this type of tool it is important that they remain conversant with the knitting machine's technical capabilities and restrictions taking care not to become 'over-enthusiastic' with the creative, on-screen, visual possibilities. With these systems colour/printer calibration problems can also occur. Another drawback when used to represent knitted structures is that buyers can be reluctant to make business decisions without seeing and feeling 'real' products in 'real' colours and yarns. It is for these reasons that this type of technology has gained a more important role in design studio presentation rather than replacing knitted fabric samples.

Within knit manufacturing, the recent developments in machine programming are such that the knitting capabilities are extreme. Digital and mechanical developments are so sophisticated that an infinite range of knitted fabrics and products can be developed. The integration of design and manufacturing systems has helped facilitate ease of manufacture, reduce development time and provide an accessible technological interface. This is particularly important in terms of complex 3D products where development can be time-consuming. Through the 'knitting simulation' and 'fabric simulation' processes it is possible to foresee problems before committing to the knitting stage.

For example, the Shimatronic SDS-one system for working alongside the Shima SWG-mini makes it possible to create gloves (Plate II between pages 166 and 167), hats and socks from standard menus. It has removed the need to 'start from scratch' and is far more time efficient and effective by allowing a high level of choice from basic templates and menus. Pattern can be added with stripes, float stitch jacquard or intarsia and textures can be achieved using stitch transfer. It is therefore possible for a 'novice' to work through the various stages and produce a series of prototypes in a few days. However, this 'simplistic' approach can have drawbacks as any problems that occur during the processing and simulation stages require a high level of understanding of knitted structures and programming.

3.5.3 Relationship between machine and handcrafted techniques

Weft knitting has evolved from hand pin knitting to hand machine knitting and into digitally/electronically mechanised knitting. The current global manufacturing field means that all of these routes are available to knitted fabric production and there is a place for each within a variety of markets. On a knitting machine the action of the needles can be hidden, preventing observation of stitch and fabric development. This is not the case in hand knitting, which uses different processes to create similar structures. (Tellier-Loumage 2005) It does need to be recognised that each route does have particular constraints and it is important to note that a machine cannot necessarily reproduce a fabric that can be knitted by hand. Hand knitting has a mass accessibility and this aligned with its design flexibility creates opportunities for original 'one-off' concepts. However, this method is slow and is dependent upon individual craft knitting skills, which have to be learnt.

Recent research has documented the health benefits associated with hand knitting, hailing it as 'cheap therapy' (Lucy Broadbent, *Times* 2005) and this century has seen a resurgence of the craft of hand knitting, influenced by exhibitions such as Knit 2 Together, (Crafts Council 2005). This has resulted in the craft of knitting finding a new place within popular culture. Its virtues are extolled as a creative outlet, a stress reliever and allowing the individual to resist capitalism and consumerism by reacting against them and being recognized as an individual (Charlotte Higgins, *Guardian* 2005/Jan/31). Rachel John's concept of *Extreme Textiles* (www.racheljohn.co.uk) has pushed hand knitted textiles into a new forum. Her work is not limited by conventional yarn thicknesses and knitting pin sizes. She has experimented and exhibited massive textile pieces that challenge the 'norm' of hand knitting.

There is an intermediary solution between hand pin and electronically controlled machine knitting. The hand-knitting (or domestic) machine allows the individual to manipulate stitches that are created by manually passing yarn through latch needles, which are arranged on either one, or two needle beds. Stitches can be physically picked up using transfer tools and moved to create knitted textures. Some, but not all of this type of machine have the ability to knit patterned fabrics. This is a much quicker process than hand pin knitting but does depend upon the availability of hand-operated machinery. These can be 'domestic' or 'industrial' and are commercially available in a range of gauges. This also means that there is a limitation relating to the resulting fabric weight. Knit design studios (see Section 3.2.4) that develop collections of conceptually driven knitted fabric swatches utilise this type of hand-operated machinery and they will have a range of machines in different gauges that can produce fabric in a variety of weights.

Ria Thomas, 2008 Nottingham Trent graduate and winner of the *Pringle Visionary Knitwear Award*, *River Island Graduate Fashion Week*, used this technology extensively in her collection exploiting versatility of the domestic machine to its limits (Plate III between pages 166 and 167).

Electronically mechanised knitting machines, including circular knitting machines, are also available in a variety of gauges. As these machines facilitate the mass production of knitted fabric and products, this method takes time to develop new fabrics and products and renders it too expensive to produce individual or 'one-off' pieces. Historically, one of the disadvantages of mechanised machine knitting was that it forced a level of compromise within knitted fabric design that was dependent upon the knitting machine. Nevertheless, they are effective in allowing the production of finer gauge fabrics and are more expedient for creating complicated stitch structures and other processes that are time consuming by hand. The 'older' generations of these machines (essentially pre 1990) often have limitations in terms of patterning memory and so have reduced flexibility in comparison with the newer generations of 3D machines that have been developed to encompass the attributes of all three methods discussed above.

3.5.4 Sustainable knitwear

The environmental disadvantages associated with the fashion and textiles industry have led to the emergence of designers who responsibly address ethical issues surrounding '*fast fashion*'. In 1997 Orsola de Castro developed a capsule collection where she customised second hand knitwear and has since created a label that '*consistently addresses the issue of waste within the Fashion Industry*'. (www.fromsomewhere.co.uk). De Castro's garments utilise discarded and unwanted pre consumer waste produced by the industry. She is a co-founder of '*ESTETHICA*' the sustainable fashion section that was introduced to London Fashion Week in September 2006.

Two examples of companies who design sustainable knitwear are: *Keep and Share* and *Makepiece.*

- Under the *Keep and Share* label, which is based in Hereford, Amy Twigger Holroyd produces luxury handmade knitwear pieces that '*transcend short lived trends and age gracefully*' (www.keepandshare.com). Her company donates 1% of profit to an African charity which is dedicated to reducing poverty through developing small enterprises and self-sufficiency.
- *Makepiece*, based in Todmorden was founded in 2004 by Nicola Sherlock and Beate Kubitz. The company designs and produces knitted garments that are manufactured locally, using sustainable yarns made from natural fibres through environmentally friendly processes. This is a small but vertical company that organically rears their own mixed flock of sheep to produce various woollen fibres for their unique design range. The company sets out to create knitwear that respects and works with the local community producing clothes with longevity that '*when they've finally been worn to shreds, they can be composted*' (www.makepiece.com).

Another example of a textile designer who focuses her work around ethics and sustainability is Annie Sherburne who *'has been incorporating environmentally friendly materials into her design work for ten years'* (www.anniesherburne.co.uk).

Sherburne specialises in felted textiles and has contributed to the collections of Hussein Chalayan and Jean Muir. Her work is exhibited in galleries such as the Victoria and Albert Museum, London and the Musée Des Modes in the Louvre, Paris.

3.5.5 How design can be influenced by global production

The geographic shift of knitted fabric and product manufacturing over the past twenty years has been swift (see Section 3.2.3). The current international knitwear arena is characterised by divergent production facilities: low technology facilities with low cost labour-intensive production mainly located in Asia; continuously evolving expensive, technological knitwear machinery located in higher labour cost countries such as UK, Italy, Japan and Korea. Both have a commitment and a responsibility to protect their employees and investments, hence the ever-continuous search for innovative fabrics, products and new applications which have been embraced by both designers and technologists.

It is difficult to specify particular brands or designers, as most companies now take advantage of global production opportunities in order to balance the cost and diversity of manufacturing, research and development. Designer brands such as Donna Karan or Dolce and Gabbana would use high-end technology for their '*first line'/catwalk* collections, as these are relatively experimental and small, and are consequently more expensive and exclusive. For their '*second lines*', DKNY and D&G will use more widely available and perhaps less sophisticated technology allowing their products to be more commercially accessible to a wider end market.

3.6 Sources of further information and advice

This chapter has utilised some of the more recent sources of information relating to design, knitting manufacture and garment technology.

The relatively few publications on knitting have been written by knitting technologists. However, this century has seen authors such as Sandy Black and Francoise Tellier-Loumagne celebrating the existence, and creative potential of knit. In addition to the books listed in the bibliography, there are a number of much older publications, sadly no longer in circulation, by authors such as Chamberlain J (1951) *Principles of Machine Knitting*, Mills R.W. (1965) *Fully Fashioned Garment Manufacture,* and Dubied E (1967) *Dubied Knitting Manual* that continue to provide a wealth of reference material and technical inspiration and are worth hunting for.

Knitting machine manufacturers strive to promote their developments and products and these are constantly updated through their web sites:
www.shimaseiki.com
www.stoll.com
www.santoni.com

3.7 Acknowledgements

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3.8.1 Articles

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3.8.2 Websites

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www.fromsomewhere.co.uk
www.keepandshare.co.uk
www.makepiece.com
www.anniesherburne.co.uk

3.8.3 Exhibitions

Crafts Council (2005). 'Knit 2 Together', an exhibition at the Crafts Council Gallery, London, from the 24th Feb to the 15th May 2005. This exhibition subsequently toured the UK through 2005 to 2006 showing in Leicester, Harrogate, Dublin and Newton, Powys.

Plate I MA collection produced by Sunny Sang 2008.

Plate II made@ntu gloves produced on Shima SWG mini (2009).

Plate III Photograph of Ria Thomas's work (courtesy Chris Moore).

Plate IV Amanda Briggs-Goode has worked with photographic imagery and digital manipulation in her textile work.

4
Surface design of textiles

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Abstract: The chapter opens with an explanation of why surface design appears in a textile book explaining that the future of textiles is in treatments and finishes such as coating, embedding, cutting or even growing.

Surface design covers everything that we come into contact with interior, exterior, land, fashion, accessories – the list is endless. It is not possible to include all these in one small chapter, so we have concentrated on developments in interiors with reference to walls and floors. The chapter covers developments in design imagery, three-dimensional surface, treatments, and finishes.

Key words: interior, walls, floors, design imagery, three dimensions, surface treatments, finishes, coating, embedding.

4.1 Introduction

The words 'surface design' in a textile book seem almost out of place. Whilst some surfaces are constructed out of fabric or a combination of fabric and a treatment, such as coating, embedding in resin or Perspex or even covered in tile or ceramic, the majority are not.

We are at the dawn of a new era**,** where everything is evaluated and re-considered. Therefore, much more is possible because of the development of new machinery and computers. Links between science, design and new technology are also having an enormous effect, challenging the way we think and what we do. Even between design and art, barriers are beginning to be removed and preconceptions about how we do things and who designs what are changing. This concept is not revolutionary but is a new way of thinking which is becoming the norm rather than the exception. One example of this changing world is graphic designers who are now working in fashion and/or textiles and who are, in some cases, being regarded as fine artists. Barriers are being broken down because communication is so much quicker and faster. For example, the world can now see a catwalk show in Paris live (Alexander McQueen October 2009). Seventy years ago cameras were not allowed into a Paris fashion show and the press were only able to sketch. This shows a less precious attitude to design ideas and is having an enormous effect on the way we can respond to design and the market.

This chapter aims to show a diversity of approaches to surface design. Surface design is almost the renaming and a new description and definition of textile design and textile designers. Art colleges around the world are developing textile designers who have broader capabilities.

Surface affects everything we see and touch: interior, exterior, floors, land, gardens, ceilings, lighting, furniture, fashion, accessories; and everything we use: decorative objects, cutlery, crockery; the list is endless.

This chapter attempts to explain what we consider surface design to be and, while this is difficult to define, our solution may not satisfy all views. We have kept this mainly to interiors, as it would not be possible to cover every aspect in a chapter of this size. Geographically, most of the developments and key trends have been referenced within Europe, although there are some to other parts of the world. We have outlined both the decorative aspect of surface design and the more technical developments that are taking place.

The chapter continues by looking at the influence of technology, key future trends and some educational developments. This chapter offers a glimpse of some of the developments that are breaking boundaries within surface design both aesthetically and technically. Every day reveals new additions and it would be impossible to cover everything but it is hoped it will give the reader an appetite for further research.

4.2 What is surface design?

In the Compact Oxford English Dictionary, surface is defined as: **Noun 1:** the outside part of the uppermost layer of something **2**. The upper limit of a body of liquid **3**. The outward appearance as distinct from less obvious aspects. . . . Origin French from sur – above + face 'form, appearance, face'.

In America the Surface Design Association has a definition, which says: 'Surface design encompasses the colouring, patterning, and structuring of fibre and fabric. This involves creative exploration of process such as dying, painting, printing, stitching, embellishing, quilting, weaving, knitting, felting and papermaking'.

Surface design is also referred to by scientists, for instance. The *Journal of Physical Chemistry B* has an article by Riccardi *et al.* (2008) from the department of Chemical and Biological Engineering, Missouri University of Science and Technology on 'Rational Surface Design for Molecular Dynamics Simulations of Porous Polymer Absorbent Media'. Similar papers with reference to science appear from Hungary, India, Germany, Japan and many others.

Science also plays a great part in our future from growing surfaces or skins to enabling surfaces to be covered in living plants, for example 'Wonderwall' a system by Copijn. This growing exterior that changes with the seasons is by Venhoeven Architects on the Sportplaza Mercator, Amsterdam.

In Great Britain we have established a 'Surface Design Show' this event is described as: 'The only UK event bringing together thousands of architects, interior designers and building specifiers to interact with hundreds of the most innovative and creative surface products on the market.'

The exhibition, 100% Design London, says it is 'the leading architectural and design event showcasing everything for the modern building and interior'. The event started in 1995 and has now been followed by 100% Design Tokyo and similar fairs in Shanghai, Beijing and Rotterdam. 100% has become the 'world's most influential contemporary interiors event, attracting the attention of the press, encouraging product innovation, hot housing new design stars and educating the taste of the consumer'.

Milan week 'Salon Satellite' is yet another very influential exhibition that is growing in stature and showcases the work of new and established designers. There are endless exhibition opportunities around the world that offer opportunities to designers and manufacturers and are pushing the boundaries of design.

All this leads to our trying to respond to the question: 'What is surface design?'. It becomes clear we are designing for, as the dictionary says, above/face/surface. The product equally affects surface, wall surface, chair, kitchen ceiling or floor, for instance, but ultimately it is about appearance and performance. Whilst it is impossible to outline all aspects of development in the past few years, we have selected and outlined those which we believe are significant and hope this will whet the appetite for further research. The design and manufacturing world is moving very quickly. New developments are taking place all the time and we are currently moving in a world where there is an explosion of interest in 'the new' and what is currently perceived as contemporary. Communication, travel and lifestyle are putting pressure on new ways of thinking about living. Sustainability is a new consideration and we are at the beginning of a very exciting period. We are being pressed to think about a more sustainable planet; waste less and, where possible, we need to make things less hazardous to people and the world. The computer is opening up many possibilities and opportunities but in itself it is a new development that is progressing all the time with tremendous opportunities for the future.

4.3 Applications of surface design

Developments in surface design have been rapid over the past five years mainly due to new technology, world competition and the emergence of a new talented range of designers and innovators coming from all fields, i.e. science, technology, art and design.

Barriers have been broken down and artists such as painters are equally as capable of designing a wallpaper range as a textile designer. Skills such as computer graphics are being used across a range of applications, wallpaper, and interiors products such as tea towels, ceramics, glassware and bed linen, for instance. Manufacturing is also becoming easier and it is no longer necessary to produce huge numbers to make a product successful.

Product is becoming more flexible and the dividing line between contract and domestic is also easier. Whilst price differs between domestic and contract (it is still higher prices and larger quantities for contract), there is a change beginning to appear, with companies being able to supply to the domestic market. Barriers are being broken and it is now possible for the domestic consumer to purchase contract products at a price. There is every evidence that this gap will narrow and even disappear over the next few years.

It is now much easier for a designer or an ambitious person to set up a business because of new production methods such as computer production and the new levels of what is acceptable in design.

4.3.1 Wallpaper: design and pattern

Substantial changes are taking place in the wallpaper/wall covering market. The range of designs available is increasing dramatically. The longer established companies such as Zoffany, Colefax and Fowler, Laura Ashley, Jane Churchill and

Designers Guild remain and business is progressing slowly, building on ranges and past performance. We are seeing a wide range of newcomers all with signature design collections of their own and all looking forward with a more modern and risky approach. Design is evolving. What is acceptable as design image is changing, providing a huge range of ideas and excitement in the modern market. Designs that were once unacceptable as decoration are suddenly becoming very desirable and sought after. Maxalot, a Dutch company, is just one firm that has invested in designers and is producing a wide range of wallpaper panels, through its wallpaper company Exposif, to suit any taste. In his piece entitled ‘Flow’ for Exposif Kam Tang uses wild graphic lines and shapes in very large scale and these overlap and swirl in rich reds, oranges and pinks. A rich feast for wallpapers an explosion of pattern and scale.

In contrast, again for Exposif, Kenzo Minami’s uses circular and angular forms in large-scale printed black and white panels entitled ‘Chambre Avec Vue’. This is a very strong, bold, exciting design dramatic in its use of scale and black and white. Alternatively, readers might be excited by the octopus tendrils depicted in Mari Inukai’s panels for Exposif showing large-scale animals with wild teeth and dark eyes looking in a menacing, almost supernatural way.

The trend for making things not what they seem, for instance Timerous Beasties toile de joey, which looks like a normal toile but is, on inspection, London Bridge and other contemporary London buildings. This is echoed by MTAF whose clever pattern ‘Horror’ looks like classic Elizabethan acanthus leaves but reveals ‘creatures, skulls, snakes, birds and swords’.

Further designs for Exposif include a complicated wallpaper ‘From hell with love’, designed by a leading design group in Singapore called :phunk(studio), shows fish, men with two heads in chains and flying pigs in a large-scale piece with red lines and spots on a black background. This paper shows just how complicated and how individual design can be. It is extremely weird and almost dream-like.

Stranger than fiction is a mural type wallpaper from Pixelnouveau called ‘Untitled’ showing a surrealistic creature with a telephone dress and a TV like head standing in front of a bowl full of pink creatures. These are placed on a lawn together with two traditional looking black cats. Her fascinating designs are quite unique and strangely beautiful. This company is progressive and their varieties of possibilities are quite unique although other companies are following this trend and giving customers a wider range of choice.

Eboy, on the other hand, is called ‘The Godfather of Pixel’ and bases his work MXL_Inka on mixing popular culture and commercial icons with their wild imaginary worlds. He builds three-dimensional illustrations filled with robots, cars, guns and girls.

Satoshi Minakawa has a more realistic approach with his cityscapes wallpaper and others such as Motorway and Cityscape all showing photographic panoramas that are reminiscent of the panoramic views printed as panels in the 1950s but this time around cover the total wall and have a more modern edge.

Antistrot from Rotterdam, a collective of different artists producing a custom-made product featuring wild graphics of girls heads, animal heads, aircraft and bats, claim they ‘got fed up with boring artistic restrictions’. For instance, they say that one of the influences on their work is ‘mockery of trends like “street” and “urban” and other clueless phenomena’. This would have been unheard of in the past.

Erica Wakerly runs her own company and produces a gentler collection of strong geometrics using foil print against hard graphic lines so that you get the effect of seeing the design and not seeing it, depending on where you are standing. She also has geometrics that give the effect of quilting and a quirky drawn style showing little houses, giving a contemporary clean look.

Sam Pickard launched a range of very strong geometrics and geometrics with flowers. Her digital hawthorn/dancing leaves print shows hand-drawn leaves with lines echoing the shape of the leaves. This is complemented by large-scale geometric oblongs and squares with lines around the edge making a cleaner stronger look.

Deborah Bowness uses fun in her work with collections such as 'Salvage' showing rows of large-scale standard lamps in a photographic style tinted like 1950s post cards. She has designs using picture frames, telephones, and clothes on hangers all within the same idea. Typography shows lettering in reverse blocks, which is a new departure for her.

Tres Tintas from Barcelona has a range of 1970s revival prints in bold geometrics, florals and stripes. The collection called Revival is bold, strong yet simple. Other collections from this company are also largescale and exciting. Images of planes, traffic signs, cars and city buses are quickly represented in 003Ciutat while strong lettering is seen in Lletras I Tipos. The ranges from this company are varied exciting and young in approach. Art Gallery is their latest project and they say 'it is the latest project in wallpaper to decorate your walls or define any type of space. Murals by prestigious designers that are full of personality – it is a collaboration between artists around the world to create an online wallpaper art gallery'.

From a more conventional perspective Fromental aims to 'create the world's most beautiful wallpapers'. They offer a rich extremely smart and lush effect in wall surfaces with woven fabric, often silk, backed onto paper. Sometimes subtle silks coloured and washed over with metallic paints such as 'Strata' or a hand embroidered and painted surface to look like paper folding called 'Origami'. This company provides chinoiserie wallpaper richly painted and embroidered in a traditional way.

4.3.2 Wallpaper developments

Wallpaper is now developing beyond the expectation of a flat print. It is also becoming interactive in many ways. Taylor and Wood frames by Graham and Brown is a series of empty frames on a wallpaper background. It invites the purchaser to colour in or use your imagination 'create your own work of art in the frame. Draw, paint, add your own photographs the possibilities are endless'. Jennifer Ooi provides something similar in an outline wallpaper that can be coloured by the purchaser.

'Interactive Wallpapers' a company run by Rachel Kelly produces stickers for your walls. It involves the customer in the design process. These can be applied to any surface, doors, frames, tiles, windows, appliances and painted surfaces. The range comes in regular colour finishes, a range of transparent for glass and foil for shine, and also a range of patterns with lace cut designs. These stickers can be used indoors or out. The imagery of Rachel's work tends to use floral and pretty decorative shapes that interact well with each other.

Walls of the Wild, on the other hand, are a company that produce stickers of a more photographic and realistic variety using animals, farms, underwater and jungle images, birds and dinosaurs as inspiration. The transfers are easily removed if the customer wishes and they can be built up in different ways. This allows customer reaction and participation in design. Stickers in themselves are not new but their concept and application is changing. They are now being used in a more innovative and avant-garde style. It is the 'interactive' aspect that is being promoted. Domestic. fr is making more imaginative and exciting stickers with a range of styles to suit every taste. 'Florence Manlik whose work 'Here Comes The Rain' (an illustrator's view of a map or a landscape) was featured in the September 2009 issue of *Elle Decoration*, describes it as 'I look for the best imbalance. In the end it is all quite serious it only looks like fantasy. Or the contrary'. Alternatively, silhouettes of people on cycles or skateboarding, birds on branches by Timorous Beasties. Shadows of chairs for floor stickers or plants for wall stickers by Wieke Somers or Tania et Vincents cakes, biscuits or jewels gives exciting possibilities for any room. For something more romantic, Rob Ryan's pretty cut outs 'Ladder Kiss' or something stranger that fiction 'chat botté' by Klaus Haapanieni who has drawn a five-legged creature carrying two frogs like singing animals across a landscape of flowers. Domestic. fr. also produce wallpapers that are very exciting and challenging. Dylan Martorell, an Australian Designer/Musician, produced a soft grey geometric landscape that is visually pleasing but because of the huge scale of the design it also becomes challenging. Strong geometric shapes roll across a soft background.

'Skeleton' by Studio Job, are known for their more 'rebellious scale-less way of creating an own universe'. This design is kaleidoscopic using skeletons of animals, birds, sea horses and other creatures. The work of the studio is quite unique and they are described as 'walking a tightrope' between design and art.

In a simpler Kandinsky-like form Earth I.O by Genevieve Gauckler is a landscape of 'simple, colourful shapes' and shows a river running through a field with strange geometric characters almost childlike in its approach.

Tracy Kendall is looking at walls in a different way. She has developed the three dimensional aspect of the wallpaper surface. Her first collection, EAT, shows panels over two metres in length, of kitchen cutlery, one item per panel and these can be hung together or separately, vertical or horizontally. She stresses that the wallpapers are starting points. The customer can design how they want to hang them. From this initial collection she has developed feathers, florals, stacks of books all of which can be arranged as the customer wishes. Sequins sewn onto the wallpaper, puzzle pieces hanging on Kimble tags, paper stripes, zips, overlapping shapes hanging in layers and letters in metallic paper hanging from the surface all have opened up a new direction in what is acceptable as a wallpaper. Historian Lesley Jackson says that: 'Tracy's work is moving in a new direction entirely, treating paper more like a textile, weaving it or creating 3D effects by manipulating and involving paper'.

Claire Coles offers a different three-dimensional effect by using old wallpaper and stitch or embroidery. She plays with all kinds of effects, sometimes stitching flowers, birds and leaves onto the wallpaper, collaging some effects with sewing on three-dimensional pieces always in a very pretty and feminine way.

Catherine Hammerton also works on birds, hand-stitched lace and paper birds are delicately strewn across hand-printed papers. Flyaway birds hang away from the paper base cut out and appearing to fly out of the background, ginkos hand cut paper in layers from a 'second skin' for a wall. She is also launching a range of background prints with what she calls ‘flounces’ to finish the walls with a three-dimensional effect. Much of the work is printed, stitched and embellished by hand with the exception of the computer printed work.

Michael Angove enhances beautifully drawn wallpaper designs by gilding and hand painting his images with 24-carat gold, platinum or silver leaf. He also prints onto fabric for the wall. Fabrics such as cotton drill, cotton velvet, and double georgette silk can be used. The pasting side of the fabric is pre coated for cleaner easier installation. Rebecca Ellen Edwards embroiders hand and digitally printed wallpaper to create three-dimensional effects. Scenes and objects that appear in day-to-day landscapes inspire her work. These can be a mixture of appliqué and stitch with hand painted effect backgrounds.

There are so many new directions and ideas. ‘Tear off’ wallpapers by ZNAK are innovative modular wallpapers created with a specially designed perforation so that you can tear off shapes to create your own space. The backing is transparent to reveal whatever is on the wall in the first place. Tearing off pieces is easy, allowing the customer to create their own wallpaper. This is perforated non-woven wallpaper.

Not quite a wallpaper but produced in continuous form, Magiflex is described by Genesis PD, the company that produces it, as a ‘multi-lensed effect plastic manufactured in vinyl polycarbonate or cellulose propionate’. Magiflex gets its effects of motion and dimension from thousands of minute parabolic lenses that are moulded into the surface on both sides of the film. These lenses create a pattern of absorption and reflection of light, which results in optical characteristics that are remarkable and unique. It comes in a variety of patterns and colours, translucent and opaque. Shimmering silk, stardust sparkles, geometric repetition, and three-dimensional are some of the ways to describe this material. Magiflex can be printed by silkscreen litho or flexo. It can be bonded to many different substrates and die cutting is also a possibility. It can be used for a wide variety of things including walls, floors, stairs, blinds, and translucent Magiflex has the added possibility of being used very effectively with background lighting.

At the other end of the scale of thinking is Braille wallpaper that is printed with brightly coloured Braille on a white ground with all Braille printed in flock. Ilias Fotopoulos, who designed the wallpaper, say in their editorial magazine ID, ‘The wallpaper highlights the issue of design’s “universal accessibility” through a clever role reversal: while sighted observers can appreciate the dots’ decorative effect and feel the flocking as they pass by, the wallpaper only makes true sense to someone who is able to read the tactile language.’ The company are using this wallpaper to allow the visually impaired to publish their writing by entering into a competition for the next edition of the wallpaper.

Grass or woven effects are not new but many companies have developed exciting ranges of ideas, Phillip Jeffries Ltd one of Americas leading handcrafted wallcovering manufacturers, has a beautiful range using all kinds of Japanese paper weaves, a source for glass cloth and natural wall coverings Hemp, Zebra Grass, Woven Rattan, fine arrowroot metallic paper weaves and Japanese paper weaves, bamboo, cork, embroidery, glass beaded, granite and mika, pleated, rice paper and vinyl – the collection is endless.

Maya Romanoff from America who says they are ‘a leader of the most advanced wall coverings’ is a company well known for its interest in new surfaces and their approach to wall coverings is exciting and constantly challenging and exploring new directions. David Rockwell has designed surfaces including a durable woven wool blend wall covering with thick and thin embroidered pattern of stripes and in contrasting threads called ‘blanket yarn and stitch’. The wall coverings are treated for stain and water resistance and they are backed with polyester non-woven material. ‘Stitched Puzzle’ is a hand dyed paper that resembles lacquered leather with a curving pattern of stitching on top that swirls around the paper. Another surface from this company is made of tiny glass beads enhancing a brush stroke effect on a metallic ground.

The beading effect is seen in other ranges including Retro Butterfly from Designer Wallcoverings.com. This is a print of butterflies’ wings enhanced by a layer of glass beads. Wood Veneer is another material being used by several companies. Maya Romanoff has launched some exciting ideas using veneer. Ajiro Sunburst is a ‘sunburst’ pattern while Ajiro Basket weave is a simple interwoven idea. Maya Romanoff claim that the wood used in these surfaces is from a fast growing farm-raised Pawlonia wood IOW VOC and PVC free, the micro thin wood is laser cut then hand painted. It also has a low smoke process and inks free of cadmium and lead. Maya Romanoff uses mica in different ways. This is natural silica, mica shaved micro thin and then laminated to a sturdy and flexible paper backing it is then given a protective finish to give the paper a good fire rating.

Consideration to Acoustics is given by many people to wall surfaces Doschawol exists 100% from the technically high gravity animal fibre keratin (sheep wool) and contains no chemical binders, fire reducers or other additives. It has excellent thermal acoustic and fire security properties. It is a product of Doscha BV and is used mainly for insulation and acoustic purposes.

Aleksandra Gaca has developed a strong collection of woven effects in wool and metal or other opposing materials. Initially she developed this collection as an acoustic wallpaper or wall panel group of designs. The surfaces invite you to touch and feel them. The bubbles or intricate folds make for some exciting ideas; Selo, Floro, Ondo and Tero are all being used in various architectural projects and varied situations from walls, floors, windows, screens and furniture.

Gill Hewitt produces a series of flexible modular sound absorbing panels called ‘Strata’. Inspired by rock formation Strata has a background of predominantly black and grey tones. The substrate of the panels consists almost entirely of glass, over 70% of which is recycled from household glass and glass wool. Panel sizes can vary and Gill works with interior designers and architects.

4.3.3 Wall surfaces and panels

A huge explosion of different wall surfaces and treatments is now being experienced. A shift towards the use of all kinds of raw materials: wood, plastic, light sensitive, textured, reusing materials, new ‘smart’ technologies everything is becoming acceptable. Anne Kyyro Quinn has revived felt that could look dull and lacking in interest. She says: ‘her approach has pioneered a new genre of interior textiles based on three-dimensional structure rather than a smooth surface ornamentation’. The panels are made from felted wool folded, pleated and stitched down to form dramatic often large-scale geometric effects. These are being installed in public and private spaces around the world in such places as Bloomberg offices, China, Swissotel, Germany, Wit Boutique Hotel, America, and Zain Concept Store, Kingdom of Bahrain.

Ronan and Erwan Bouroullec have developed a modular wall/room divider system made up with fabric pieces held together with elastic bands. This system, called 'Clouds', was devised from an experiment that they did with paper folding called North Tiles. The fabric version of Clouds absorbs sound, is adaptable to be hung from a ceiling, hung on walls, or used as dividers. The shapes are cellular but distorted almost like pomegranate seeds, the scale appears large and impressive.

Wood is another material that is gaining interest being either recycled or developed in other ways. Photographer Leo Ribbens 'not' he says 'an eco warrior', 'more a man on a mission against homogeneous design' has recently been featured in *Elle Decoration* for his forward thinking in the design of his home, using wood in a new and exciting way. He has used wooden boards sprayed with stencilled letters from a packaging firm. This gives the wall a rustic but modern effect.

Studio Ditte has designed a range of wood effect wallpapers that are printed for *Designs Daily*. The paper replicates the look of wood and multicoloured scrap wood on a smooth paper surface. They have followed this with prints of ribbons that are more colourful and have a more feminine look.

Another wooden product suitable for walls and floors is Barnwood, supplied by Ebony and Co from Amsterdam. This wood is carefully recovered from old American barns and the boards are a mixture of wood types, often cut thinly and beautifully aged to show the magnificent worn and weathered effect.

Ceramic wallpaper sounds impossible but CCflex from the German manufacturer Evonik Dequssa is just that. It is a 'flexible ceramic sheet having all the handling advantages of a standard wallpaper and the resistance of a ceramic tile'. It looks like a high-quality wall covering but it behaves more like a normal wallpaper. CCflex is a flexible fleece base material such as polymeric fleece with a ceramic nano coating that gives the material outstanding properties. It is UV safe, breathable and does not contain PVC, formaldehyde or any other so-called volatile organic compounds. It is claimed that it is easier and faster than ceramic tiles to put up and has a similar effect.

Another fibre-backed product is Stoneplex Sand. The backing is cotton and the sandy finish changes according to the rock formations that the sand comes from. This makes each roll slightly different. The German company A.S Creations Tapten. Ag, who also supply a similar product called Stoneplex Slate, supplies the product. This is made of mineral fillers handcrafted to reproduce a concrete effect that is supplied on a roll. It is knock resistant, free from PVC, emollients and solvents and has soundproofing and insulating properties.

The idea of salmon leather would seem almost stranger than fiction but the company ESLTDA produces just that. This is a versatile product produced from the skin of salmon that has been treated and protected as a surface, and is used for many applications. It can be produced on continuous rolls for walls and in natural colours. Epoxy is developed and researched by Genesis who specialise in a wide range of coatings. The coatings are free of sulphates, melting point is around 200°C and the coatings are environmentally friendly. They have a wide range of products including tiles and wall decorations, liquid floor and Magiflex, for instance. Allusion manufacture stunning effects with stabilised aluminium foam. Ceramic particles have been added to the aluminium alloy and poured into a foaming box. The chemical process produces a foam structure that is predominately closed cell. The cell size is controlled by the gas flow rate. The company used Allusion together with (transparent) epoxy and LEDs and a spectacular light effect can be realized. The product is produced in sheet form. Another exciting product from Genesis is Kirei panels, a natural decorative plant material created by pressing the stalks of the Sorghum together with water-based glue. The stalks used to be burnt as a waste product but they are now bought from the farmers to be reused. The panels have been used for all kinds of applications including walls and bar tops.

One of the most exciting companies producing panels is 3form. Their product Vana is very varied and flexible. The product allows you to select the colour, pattern, texture interlayer and finish of your panel. The gauges of the material are from 1.6 mm to 25 mm. Finishes are as varied as the product. High gloss, opacity or gentle texture and you can have a different finish on each side. The company produces a whole range of different effects such as organics, metallics, graphic structure, colour and textile effects. For instance, the colour options are described as 50,000 options to play with instantly as you work with the colour palette.

Another product, Chroma, wall panelling that is described as solid surface saturated with luminous colour. 'This product is ideal for horizontal as well as vertical application for tables. It is engineered to be resurfaced and recoloured again and again presenting the product from entering the waste stream.' It is described as durable, formable – can be shaped to accommodate radius and curves, renewable, structural, thick and stable, load bearing and translucent – it has amazing light transmission. The 3form glass collection encapsulates durability, transparency, good performance and playfulness. Encapsulating organics and fabrics with a poured cast resin produces this. The liquid lamination technology allows even distribution of objects throughout the glass and it makes possible clean, exposed edges that allow for a frameless application. It has many benefits. It is made to order, is durable has a long lasting, non-combustible finish, high flex stiffness, is optically clear, easy to clean, chemically resistant and UV stable. 3form products are used for a wide variety of end products such as ceilings, walls, and reception areas, bar fronts, partitions and inside windows ornamental purposes.

Washi, an architectural parchment produced by Precious Pieces, is made from elongated fibres of a variety of plants. It is made from harvested inner white bark and instead of cutting down a tree these plants can be harvested regularly. The mulberry is the primary plant used. These fibres are stripped cleaned, pounded and stretched, mixed with the sticky mountain potato and made into a solution. The fibres are then laid across bamboo screens to dry, resulting in a durable paper. This contains no chemicals or acid dyes can be made to any size and is suitable for walls, room dividers, window blinds, wall coverings, laminated glass panels or even as an exterior application. It is said to last over a hundred years with normal use.

There are so many different approaches to surface and so many different materials and end uses.

Riverstone building systems is a new wall system using different interlocking pieces. They claim that the system is finished on all sides, the ideal 'stand alone' solution for those wishing or needing an easy and effective wall/partition system, curved elements are a new edition. The elements are staggered as in many normal brick system. The panels are hollow and glued together with clear silicone or tile adhesive. The hollow centre allows cable, pipes and corrugated tubes access; it also has a special internal lighting system. The system is plain neutral pebbles set in a translucent resin like substance that could be effective in many settings. A version using a combination of pebbles and wood is also available for use as flooring. The pebbles come in different sizes, e.g. small, medium and large, to create different effects. They also use pebbles of different natural colours with the resins in a wide range of different colours for different requirements

Annemette Beck uses a wide range of different materials for her woven projects such as rugs, room dividers, panels and wall hangings. These can be hand or factory woven using such things as rubber, metal threads, crystals, coated polyester or even recycled bicycle tubes. The philosophy behind her work is 'to remove what is unnecessary so only what is essential remains – to make a clean, clear and sharp design by way of carefully controlled fantasy'. Rubber inner tubes are woven as a flat wall piece or rugs while 'paper loops and fringes' are woven for a number of ideas as the title suggests the effect is much more inventive and textured.

4.3.4 Wall sustainability

Many companies follow sustainability issues, this is certainly a way forward with some companies investing huge amounts of money in research. Eco friendly, recycle, non-PVC and nano – structures or technology are the way forward. It is only possible to mention some developments since there are hundreds of developments in this area.

York wall coverings recently launched a range of breathable, non-woven substitutes with water-based inks. While Omnova Solutions have launched wall coverings containing 30% recyclable content and they are stain resistant, scrubbable and recyclable through the company's reclamation programme. Omnova Solutions, another company committed to environmentally responsible practices including water based inks, scrap reduction, and recycling programmes, are also reducing the energy required for production. This company is committed to help build a more sustainable future. The company has introduced 'Recore' into some of its brands. 'Recore' in America means 'recycled wall technology'. All manufacturers using the 'Recore' symbol agree that their products will contain a minimum of 20% post consumer recycled content.

Leathertile from CC. Leathers Inc. is a thick, solid vegetable tanned leather that can be used for vertical or horizontal applications. It is flexible and may be cut into any size or shape. This company also produces a leather that can be used on the exterior: 'Xtreme Outdoor' gives the touch and feel of real leather, hard wearing enough to withstand attack from dirt, chlorine, mould, alcohol, oil and ultraviolet radiation. It is impervious to wind and weather and demonstrates exceptional durability with excellent tensile and stretch characteristics. Leatherlok is woven 'basket weave' pattern of strips of leather wrapped around a wood and solid cast aluminium base to form small modules that will fit together to create a seamless grid system. This system forms panels of any size for large or small spaces.

One thing that must be mentioned here is the lighting surfaces of Stuart Haygarth's chandeliers such as his 'Tide Chandelier' made up of hundreds of tiny plastic items found washed up on the beach. He has also made lighting with hundreds of discarded party popper cases and another with old spectacles. Is this a trend that will be important in the future or is it just a whim? Recycle or sustainable? Certainly following Tracy Kendall's wall surfaces it could be new wallpapers or set in plastics or resin for walls or counter surfaces. Another interesting surface creator is Olu Amoda, a Nigerian sculptor, who creates burglar-proof doors, gates and windows out of waste from steel and iron from scrap yards and streets of Lagos. He calls these creations Doors of Paradise and Windows of Dreams. This again is an inventive and yet practical use of waste. Perhaps leading a way forward for the future.

4.3.5 Walls: paint

Paint is developing in different ways but one of the more novel aspects is to give a wall/surface another possibility. Magpaint Europe have done just this with magnetpaint. This transforms walls into magnetic surfaces, has the ability to be applied to walls in two or three coats and then a top coat of any paint can be put over the surface. It is being used in all kinds of places such as houses, educational, commercial and medical buildings.

Idea paint is a product that transforms almost any surface into a dry erasable white board and the paint can be applied to any surface. It allows the user to write, draw and scribble on it like any chalk board surface and is especially useful where children are present. It is environmentally friendly, is formaldehyde free and does not produce any gases when applied. Another company that has a paint that can be used as a white board is Dry Erasit – dry erase paint from Designer Wall coverings. It is a water-based paint that transforms a surface into a seamless high-performance writing surface better that white boards.

Umbrae Studios Inc. has developed a revolutionary and completely different tile product that is software-based on an image-generating process called Ombrae. This process allows the customer to develop their own ideas whereby images can be translated into a three-dimensional surface texture. The images are created by computer into materials such as interior and exterior concrete, glass, acrylic, stone, metal and fabric. The process has tremendous opportunities for developing a sensory surface where images can change subtly depending on the position of the viewer.

4.3.6 Tiles: wall and floor

eluna exploits the natural qualities of glass. They say 'our glass is sourced from a waste-stream. We have developed a method of sorting and sifting through glass to produce products which are 100% recycled'. They produce a wide range of tiles suitable for interior or exterior use. These come in all kinds of qualities opaque, semi translucent, with natural or anti slip finishes. They are suitable for lighting, walls, floors and paving. Polished surfaces are available and lighting can be an integral part of the tile. For a project in Reading they have made 100% recycled paviors with up lighters that are powered by fibre optics. These have been utilized as outside flooring. Lighting is also a part of the tile produced by Mosa BV. Mosa Linea LED is a ceramic wall tile with integrated LED light. The tile has an extremely long life (60,000–100,000 hours), is said to produce very little heat and incurs low electricity costs and can be installed in the normal way.

Liquid floor is made from tiles, which contain a fluid that reacts as soon as pressure is applied causing the fluid to move around at the point of pressure. The company describes these as monochromatic, bi-chromatic, silver trace PVC interactive floor tiles.

Ekobe has four main drivers: natural materials, native presentation, quality and creative enhancement. Products are made out of natural materials, and no chemicals are used. The company uses vegetable matter for an environmentally sustainable product with the trees that the products are taken from remaining alive – the AOBA series is made from coconut endocarp (hard coconut shells). This is a natural product, which has no environmental impact, has great resistance to decomposition by micro-organisms and insect attack as well as a high level of mechanical resistance. The surfaces in this range vary from very rich browns, whites, and creams depending on the part of shell that is used. The tiles are a mosaic formation, for instance 2 cm mosaic of natural coconut made from the inner shell. These form an irregular pattern as do all the tiles from this company but this is part of the charm and freshness of the collection. In contrast èhony gives a semi-polished black look with a 2 cm tile. These require no grouting. Another series, Membra, needs grouting but the shell is spaced accordingly to give a different effect.

Rubber is another surface that is most suitable for tiles and it comes in many forms. Sustainable Floors says that rubber can be used inside and outside, it is hard wearing, easy to clean, antistatic, easy to install, absorbs noise and is eco friendly. Rubber is eco friendly because it can be used without glue and it can be easily recycled.

Heavy duty flooring comes in many ways and one of the most impressive is a system of interlocking plastic tiles ideal for industrial, commercial and domestic use, even tiles with an interloking system but with a hidden joint.

4.3.7 Conclusion

Surfaces affect our lives every moment of every day. We hope this gives you an insight to the wide variety of different approaches to the design of some of them and the way that they are not just aesthetic but they are expected to perform in different ways too. The variety is endless and we are moving at a very fast pace in the design of new surfaces as you can see from this chapter. Where we go from here is difficult to say but we are looking forward to a very exciting future.

4.4 Future trends

Accountability, acoustics, collaboration, cost effective, easy care, ease of application, eco friendly, energy saving, functional, futuristic, health and safety, innovation, insulation, labour saving, recycling, sustainability, and versatility are all words that will be thought about when planning for the future.

We are at the dawn of a new age when we will be setting aside all our preconceptions about what is acceptable as a surface. A time when how the surface is designed, produced or made will depend on the team making it. For instance, at 100% Design in the autumn of 2009 one of the predictions was that perhaps we will be growing skin that will cover surface. This was as a result of a fine artist growing skin to use for her artwork. This suggests that surface design will come from sources other than textile/surface designers. Architects, scientists, engineers, and artists, for instance, are contributing currently but there is every indication that this will change from the way it is working at the moment. In the future it is possible that people who are from different disciplines will work together in teams to produce new surfaces and developing ideas. A future where we will think of new ways of educating to accommodate these changes, teaching perhaps across disciplines and doing more teamwork projects. A future where it is possible that each building, domestic or commercial, will be self-sufficient in providing its own power, heat, air conditioning, and lighting.

Recycling is one of the most influential areas of thinking for the future. In the last decade we have become even more aware of the problems of producing endless waste. We are producing too much waste for landfill sites and for using in other ways. In 2003/4 we produced 30.5 million tons of waste in the UK. In this chapter we have illustrated some of the possibilities of how we can use waste but this is reactive thinking rather than being proactive. For the future more thought will be given, right from the start, to the design of product and how we can reuse an item when it has passed its useful life. What we can make from waste will be continually important and how we can reuse it again and again to its best advantage. We already know that we can reuse at least 80% of most cars in making new product. This is an enormous step forward in our thinking. In 2005 in Japan the Aichi Expo undertook to make the exhibition as spectacular as possible while keeping changes to the natural setting to a minimum. The main venue was intended to be dismantled, the structures recycled and reused elsewhere, and the site returned to its natural state. This was a tremendous undertaking for an exhibition that welcomed more than 8 million visitors. It points to a future where we will become more and more aware of how we can recycle and reuse every bit of waste we produce.

Versatility and 'green' is key to the future of our homes and new building as the world's consumer demands are continually changing. We are rethinking space and how it is arranged as families grow up and the demands on family life change. Obra Architects have designed a home that you can pick up and take with you. Is this the start of a new way of thinking? We already have office space that is versatile, moveable walls and walls that can be taken down and quickly reassembled. There are many companies that offer partitions and systems for changing walls in a contract/commercial world such as Lindner-Group. They offer a partition system 'the right wall for every room whether you are interested in glass, wood or metal'. They also offer a Room-in-Room system that makes it possible to organize a room exactly as you wish. Commercially there are walls that link and are flexible on tracking systems or wheels so that a space can be changed in minutes. This will in the future be something that will be possible in domestic interiors, and surfaces will be changeable very quickly to accommodate the systems. Wallpaper that slides into a case rather than being glued, for instance. Kitchens that can moved and be assembled in other spaces with plumbing and electrical systems that are as versatile and as movable and as flexible as the walls. This points to the need for versatile decoration systems.

The need for designs that you can assemble for yourself. These may even be printed or produced by the consumer from computers or other means but they will allow for total flexibility and individuality. The opportunities for changeable domestic space are endless. We are at the dawn of an exciting surface design dream.

4.5 Sources of further information and advice

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5
Printed textile design

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Abstract: This chapter discusses the current status of printed textile design, providing a basic introduction to its historical, technical and manufacturing contexts. The history and methods of textile printing are introduced, before outlining the relationship between the print and design processes. Contemporary principles and applications are considered and future trends within the sector proposed, with particular reference to the impact of digital technology on both design and printing.

Key words: printed textile design, surface pattern, printed textile manufacture, printed textile techniques, digital fabric printing.

5.1 Introduction

This chapter discusses the current status of printed textile design, providing a basic introduction to its historical, technical and manufacturing contexts. The history and techniques of textile printing are introduced and a broad synopsis of main printing methods is provided. The issues surrounding the relationship between the print and design processes are examined, with reference to influence of manufacturing requirements and advances in technology. An overview of contemporary principles and applications is considered in the light of the shift from hand painting or drawing to digital design. An outline of the positions of textile designers in industry, their design training and the profile they have in relation to other design disciplines is given. Finally, a range of future trends within the sector are proposed, with particular reference to the impact of digital technology on both design and printing.

5.2 Basic history and principles of applying colour to cloth: methods and types of textile printing

5.2.1 Historical context and techniques

Storey (1974, p. 11) suggests that 'various records show that printed fabric did exist about 2500 BC'. Since this time, a wide range of techniques have been used to apply designs to fabric. These include the application of a resist or mordant to the cloth and its subsequent dying or the application of a paste containing both dyestuff and fixing agents to parts of the cloth. The latter is sometimes referred to as direct printing, but more commonly by the name of the process by which the paste is applied. The majority of printed textiles are now screen printed (Bowles and Issac, 2009, p. 170). Prior to this, roller printing, first used as a commercially viable process in the 1780s, was the dominant method (Schoeser, 2003, pp. 181–182). In turn, this superseded block (and to a lesser degree, plate) printing, which can be traced back over 2000 years ago to both China and India (Storey, 1974, p. 11/p. 27). Running parallel with early printing was the development of number of processes by which pattern was applied to fabric by other processes such as hand painting, batik and shibori or tie dye. Many of these are still in use today, particularly within the craft sector.

The rise in digital technology at the end of the last century has already had a significant effect on the design of printed textiles. Digital fabric printing accounts for a small, but ever increasing, percentage of the printing market.

5.2.2 Synopsis of main printing methods

Screen printing

Screen printing has its roots in stencilling techniques. A mesh is stretched over a frame. Areas to print are left open; the negative parts are blocked. The screen is then placed onto the fabric; when dyestuff is pulled over it with a rubber blade (squeegee), the colour passes through the open areas, transferring the colour to the cloth. Screen printing gained widespread commercial use with the development of rotary screen printing. A tube of metal (the rotary screen) has the design cut out of it (normally now by laser) as a series of tiny holes. This is then attached to a machine, with a blade and a dyestuff supply inside. Fabric is then passed under this rotary screen, the blade of which, as the screen rolls over the cloth, pushes the colour through the holes and onto the textile. Each colour in the design requires a different screen.

Rotary screen printing factories are able to print up to 120 metres of fabric a minute. Currently the fastest industrial-scale inkjet printers are only capable of printing around 20 metres a minute, which gives screen printing an advantage. However, while the print time is fast, the lead time needed for a design to get into mass production can be 8–12 weeks. This is because traditional printing plants require someone to colour separate the design, repeat management, engrave screens, colour match and print a strike off (sample) for customer approval before proceeding to production.

Costs per screen (one for each colour) affect the total costs with rotary screen printing. Costs of dyes and inks can be significantly different when using traditional methods and hence a lot of research has been completed in this area.

Digital printing

Digital printing is essentially an inkjet process. A series of print heads pass back and forth across the fabric, spraying dyestuff onto it (see Fig. 5.1). The print head is supplied by a range of colours normally based around cyan, magenta, yellow and black (in some instances with tonal variations), the optical mixing of which, when printed, gives rise to a full spectrum of colour. A printer driver, using a digital version of the design as reference, controls which colour is printed and when.

5.1 A digital printer Mimake 3 which prints with four reactive dyes on a broad range of fabrics from silk to furnishing velvet.

Unlike previous print processes, where in most cases all the necessary ingredients to colour the fabric are mixed together, thickened and then printed, digital printing normally involves pre-treating the fabric with the fixing agent. The digital printer then prints only the dye or pigment colour.

Block printing

This is a relief printing technique where dyestuff is applied to the surface of a carved block of wood (see Fig. 5.2). Fine detail may be achieved with inlaid strips of metal. The block is then pressed onto the surface of the fabric, transferring the design. Tiny pins in each corner are used to register (align) the print to its neighbour. The blocks could range from a simple small motif which used only one colour to complex and large-scale blocks which required stamina and skill on behalf of the printer. This was the main printing method during the 19th century in Europe. It is interesting to note that recent concerns for sustainable and ethical issues within the fashion and textile industry have seen an upturn in interest in block printing, albeit on a small scale.

5.2 A wood block which is engraved with a relief pattern. Prints can be either one- or multi-print blocks.

Copper roller printing

Developed from engraved copper plate printing, copper roller printing is an intaglio technique. The design is cut into the surface of a copper roller, which is then covered in dyestuff and scraped with a blade so the colour only remains in the incisions. Fabric is then run over the roller, transferring the pattern. In contrast to block printing, roller printing enabled unmatched detail, seamless repeats and a vastly superior productivity. Within a few years of its invention (1785), over 10 km of fabric per day could be printed on a single machine. Rubber roller printing, a relief rather than intaglio process, is still in fairly common use for printing wallpaper.

Other techniques in current use

- Transfer printing – the design is printed onto paper and transferred from this onto cloth (see Fig. 5.3). There are a number of methods; the most common uses sublimation paper and disperse dyes. The sublimation process describes a process of taking a solid to a gas and turning it into a solid again. Uniquely for a textile method, the standard four colour separation process employed by the (paper) printing industry is used. After the paper is printed with the design, it is then pressed onto the fabric with heated rollers which transfer the dyestuff onto the fabric. Transfer printing was first introduced in the early 1950s and has retained a small, yet growing, presence ever since. The process was originally developed for application onto synthetic fabrics and this limited its use until fairly recently

5.3 Transfer printing process, larger machines are used in industry. The dye is transferred from paper to fabric via heat from the printing press.

where advances in man-made fibres and fabrics have impacted upon markets and applications.

- Pad printing – the design is etched into a surface which is filled with ink. A flexible pad picks up the ink and presses it onto a surface. Generally only used in the fashion and textiles sector for care labels.

Other techniques no longer in widespread use

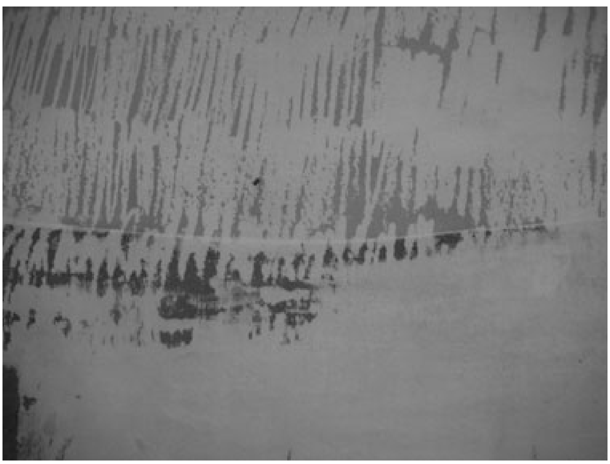
- Perrotine printing – a mechanised version of block printing.
- Lithographic printing – parts of the printing surface are coated with oil, for example, to repel the dyestuff; other parts with gum, for example, to attract the colour. Although this process is one of the mainstays of paper printing, problems with registration meant it never became widely used on textiles.
- Duplex printing – both sides of the fabric are printed at once.
- Polychromatic dyeing – jets of dyestuff are run directly onto the fabric which is then compressed between rollers to give a range of effects similar to marbling. In some ways, a mechanical precursor to digital printing.

5.2.3 Synopsis of main printing dyestuffs and inks

Colour can be applied to cloth either chemically or physically. With the chemical process, the colour becomes part of the fabric, normally via the action of a fixing agent when steamed or dry heated. In most cases, the process is essentially localised dyeing. After printing and fixing, the fabric is then washed to remove all the print ingredients leaving the colour itself and the original handle of the fabric. The main dyestuffs used in screen and digital printing include acid dyes, reactive dyes and disperse dyes. Colour can also be applied physically to the cloth; this involves binding pigment to the fabric, which is then fixed or cured by dry heat or certain types of light, such as infra-red. Pigments can be printed using both traditional and digital techniques.

Additional processes are also possible when screen printing, sometimes in combination with another specialist technique. These include:

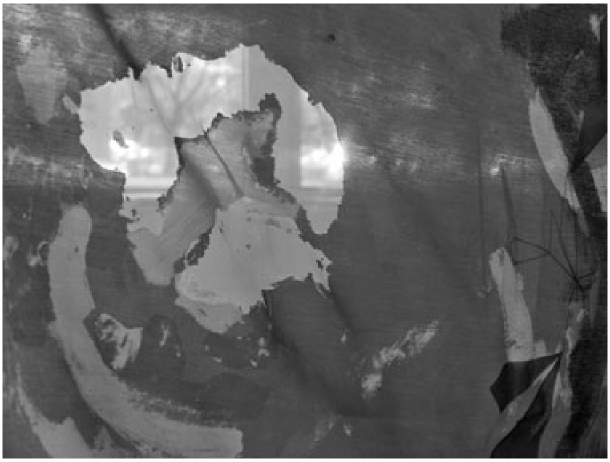
- Discharge printing – the print paste bleaches a pattern out of a fabric pre-dyed with discharghable colour (see Fig. 5.4). Dyestuff that is resistant to the discharge can be added to the print paste for the addition of a new, illuminating colour.
- Devoré printing – a strongly acidic print paste is printed onto a specially constructed fabric, burning out cotton, linen or viscose and leaving silk or polyester. The fabric is (generally) woven so that when one fibre is burnt out, the other's structure can support the textile, often with a transparent effect (see Fig. 5.5).
- Flocking – a glue is applied, normally via screen printing, to areas of the fabric. Tiny pre-treated fibres are then electrostatically applied (so they all lie perpendicular to the cloth surface), resulting in a velvet-like finish (see Fig. 5.6). This technique can be applied to almost any surface, but is not particularly resistant to abrasion.
- Foiling – following the printing of a glue, a metallic foil is heat pressed onto the textile. It remains on the glued areas only (see Fig. 5.7). The process works best on non-stretchable fabrics as the foil is liable to cracking if the surface is sheared.



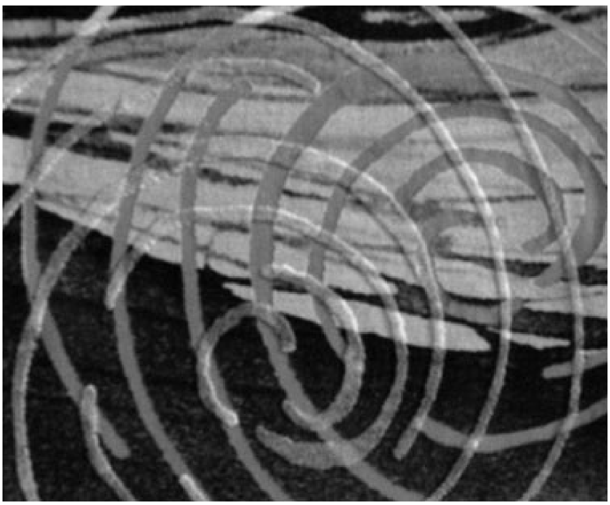
5.4 Dawn Dupree has used discharge printing in this example whereby previously dyed or printed fabric is returned to its natural colour by screen printing with a discharge dye. This results in a 'bleached' area in the fabric.

5.2.4 Key issues affecting design for print

The printing techniques used within the fashion and textiles sector to apply designs to fabric have had a significant effect on the methods designers use to create with. The notion of repeat (the duplication of pattern over the surface of cloth) is one example of this; a professional designer will be very aware of each element of a design recurring at a set distance horizontally and vertically. Screen, roller and block printing onto fabric all require each colour to be printed separately. As this means



5.5 Kezia Regan's digital print to which she has printed a devore paste on top which has 'burnt out' one of the fibres in the textiles and thus creating semi-transparency.



5.6 Katy Aston has worked with both devore and flock in this sample which therefore creates three different surfaces – the fabric itself, a burnt away layer and a layer which sits on top of the surface.

5.7 Kezia Regan has changed the surface quality of the fabric by printing puff binder, mixed with grey, on top of a digitally printed fabric.

that for each additional colour there is an attendant increase in cost, designers usually work with palettes that feature a fixed number of colours. As photographic effects or smooth transitions from one colour to another may be expensive or impossible to achieve with these printing methods, designers may be encouraged to avoid them.

Two points are worth noting here. Firstly, designers often become skilled in concealing the limitations of the manufacturing techniques. For example, within the industry, if the term 'a good repeat' is used, it generally means one where the duplication of the design is difficult to spot. The skill of the designer is evident in balancing the elements within the design so that no one part of it stands out.

The second point of note is the potential impact of digital fabric printing on design. Previous printing constraints, that a pattern should repeat and comprise a limited range of colours, are potentially no longer necessary. The impact of the latter is already being seen, particularly within the fashion sector.

5.3 The relationship between textile printing and design

5.3.1 The influence of manufacturing requirements and technology on design processes

Commercial printed textile design exists in a framework defined by the technical requirements of manufacturing and the perceived requirements of its consumers. This structure affects both the form and the content of each design to a very large degree. The successful textile designer must balance the technical skills required to create a design suitable for printing with the aesthetic judgement necessary to satisfy the style requirements of the client base. In practice, almost all designers (even freelance ones) receive input and, in some cases, a team or succession of them are involved in the direction, design and conversion process. This normally involves working to a brief of some kind; even if they are not, what they produce will be influenced by an awareness of trends and market.

Although the arrival of digital fabric printing has the potential to change them, the principal criteria defined by the print processes used in manufacture that govern how designers currently work are composition – either repeat or placement – and colour – a fixed, limited range. It should be noted here that designers do sell work that may not fit inside these boundaries. This will either be as inspiration – for example, as source material for new designs that are printable – or for conversion to a design that is printable. For example, sometimes freelance designers sell work to the fashion industry that is not in repeat, but suggests an all-over arrangement of pattern in its layout. Prior to print, however, the design will, if appropriate, be reworked in repeat. In comparison, this is rare in the furnishing sector, where designs are almost always sold in repeat.

Repeat

If a length of fabric is to be covered with pattern when printing, designs are created so that they occur repeatedly down and (generally) across the cloth. The distance at which the pattern recurs (repeats) is in most cases governed by the technology. For example, a standard size for a rotary screen is 64 cm in width and thus designs are commonly produced to have either a 64 cm repeat or a fraction of that number (32 cm or 16 cm, for instance). In some cases the width of the repeat may be governed by the fabric itself. A standard furnishing fabric width is 140 cm; some designs use a 69 cm wide repeat, allowing two occurrences across the fabric with a 1 cm selvedge left clear on either side.

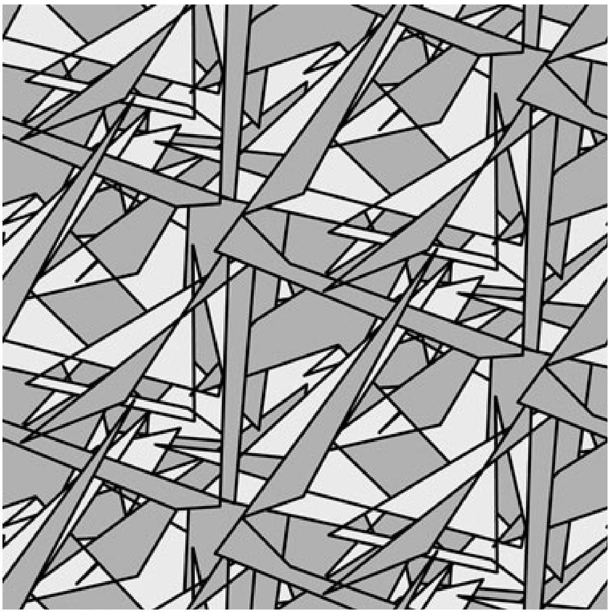
The simplest repeat structure, generally known as a block repeat, is where the design re-occurs exactly below and to the side of itself. Although there are a huge number of different repeat structures (comprehensively explored in Phillips and Bunce (1992)), the most commonly used, particularly within fashion, is the half drop (see Fig. 5.8). Here, the design repeats exactly below itself, but drops or steps down half the repeat size horizontally (it is sometimes also known as a half step repeat).

Very large designs (for example, in use in bedding) are sometimes printed width for length. In this case, the design repeats down the fabric, but not necessarily across it. An example might be to have a border running down either side of the fabric with a simple all-over pattern in the middle. The fabric is then turned through 90 degrees, so (for example) what were the selvedges become the top and bottom of a duvet cover.

Placement prints

These are designed to be engineered and be applied to a specific part of the final product, rather than all over it. An obvious example an image on a tee-shirt – indeed, sometimes placement prints are referred to as front prints or tee-shirt prints for this very reason. In some cases, they may be printed after the product has been manufactured; again, most printed tee-shirts are an example of this (see Fig. 5.9). On occasion, a print may be designed to occupy a particular position on (for example) a garment block (pattern piece) and be printed prior to garment assembly. This is

5.8 Katy Aston has used foiling to create this matt/shine surface effect.



5.9 A geometric print design in half-drop repeat.

sometimes referred to as an engineered print, particularly if the design is not a simple border or edging.

Colour

Although digital printing has already started to change this, most printed textile designers are used to working with a set number of colours. Block, roller and screen printing costs rise proportionately with the addition of each colour; a (for example) five colour screen print will normally require five screens. As a result of this, designers become used to working with fixed colour palettes where each colour is discrete. In many cases, the base colour of the fabric is used in the design. Normally, this would involve the white parts of the design, so a black and white pattern would only require its black parts printed. In some cases, designers make use of overprinting. Here, areas of the design are printed with two or more colours to obtain additional colours beyond the print dye palette. A yellow and a blue, for example, could be overprinted to give a green.

Overall, colour is absolutely central to printed textile design. Professional designers become adept at creating rich and evocative work with highly limited palettes. The ability to handle colour skilfully in this way is pivotal at present, but as the near limitless colour range offered by digital print becomes more prevalent, the colour palettes of the future may include (for example) blends from one colour to another and photographic colour effects, both very difficult to achieve with screen printing.

5.3.2 The effect on design of advances in technology

As printing technologies have developed, so the possibilities open to designers have changed. Copper roller printing offered a far higher degree of detail than block printing and also introduced the ability to print perfectly continuous stripes. The finely detailed crosshatching and shading techniques that the change afforded were quickly incorporated by designers and engravers into their technical repertoire. However, getting large areas of flat colour with either technique was difficult, a problem solved by screen printing. This process also offers a greater degree of control over the quantity of dyestuff that can be applied to the cloth. Heavyweight or pile fabrics can have a greater amount of colour applied than finer textiles, resulting in deeper colour. A wide range of textured effects are possible and the integration with photographic techniques results in the capability of easily translating most hand painted or drawn imagery to cloth, albeit a single colour at a time. Just as the introduction of copper roller printing changed the style of printed textile design, so the new aesthetic seen in textiles of the 1950s and 60s is a reflection of designers making use of the new potential of screen printing. However, it should be noted that although fabrics were printed that exploited the possibilities of the new screen printing technology; these did not necessarily become prevalent, particularly within the furnishing industry. Design history sometimes gives prominence to relatively isolated examples that illustrate change and pays less regard to those actually selling in the highest quantities. (In defence of this, this may be due to difficulties in accessing widespread information about manufacturing or sales figures.) It is also important to understand that the biggest factor in the acceptance of a new printing technology is inextricably linked to lowering manufacturing costs or increasing production speed.

While digital printing does not offer the perfectly flat colour or variable quantity application of screen printing (the latter making deep colour penetration on heavy fabric difficult), the near infinite range of colour possibilities it offers may be only the start. For example, digital technology opens up the prospect of highly customisable design or non-repeating pattern.

Recently, the impact of the textiles industry on the environment has become a major issue. Almost every part of the production process has a potentially detrimental impact, from the fertilisers and pesticides used to grow cotton, to the use of huge qualities of water required in manufacturing or the large carbon footprint of a supply chain that may span much of the planet. Digital printing requires far less dyestuff per metre than screen printing; although this is a relatively small difference, in an industry having to address its sustainability, any such changes are important.

5.3.3 Use of print and pattern on fabric

The content and style of printed textile design may be governed by a number of different factors, but the underlying impetus is the desire to sell more by adding value. For a number of reasons, not least that most trend books and design briefs start with the idea of visually communicating individual or mixes of existing styles or looks, many textile designs tend to fairly transparently reference other textile designs. By extension, this means many are deeply rooted in the past, although isolated examples are more innovative. Even the simplest of designs may have been reworked in countless different ways, changing enough to bypass copyright laws, but not so much that the influences become unclear.

The roots of this date back some considerable time. Printed textile design has been influenced by the global distribution of its resultant product for a number of centuries, unlike many other examples of design or visual culture. One of the main staples of early trade routes was fabric, particularly from India and China. Until the 18th century, this was generally of far higher quality in design terms that that which was being produced in Europe, and most Western companies attempted to compete by producing designs that essentially copied content from the East. Although European designers did eventually start to create high quality designs, many of their reference points remained based on the imagery of the earlier imports. The influence of Indian 'tree of life' designs can be seen to this day.

Print designs are often categorised by the imagery within them, much of which can be traced back centuries to that early global trading. The following classes of subject matter are in fairly common use:

- Floral – any design that incorporates flowers or other flora. A mainstay of printed textile design, florals exist in a wealth of different styles, reflecting both historical and contemporary design sensibilities.
- Geometric – abstract designs that may comprise simple shapes or more complex forms derived from representational imagery. Although the stripe, check (plaid) and spot (dot) are so frequently used to often warrant their own classes, they are technically geometrics.
- Conversational – representational or figurative designs that do not include flowers. This may include styles sometimes given their own categories such as animal prints or camouflage.
- Graphic – designs that feature branding or text, with the possible incorporation of imagery. In fairly common use in the fashion sector, especially in sport, swim, street and jeanswear.

- Historic or geographic styles – as trade in textiles has been worldwide for many centuries, patterns relating to different cultures or time periods have long been widespread. Textile design features a highly diverse spread of imagery from all over the world, often drawing on more than one reference point. Non-Western derived designs are often referred to as 'ethnic' while imagery taken from European or peasant cultures is referred to as folkloric (Udale, 2008, p. 99).

5.4 Contemporary principles and applications of printed textile design

5.4.1 Shift from traditional (hand painting/drawing) to digital design and the effect of this on technical parameters

Printed textile design is at a particularly interesting point in its history. In the past, it has had to react to a series of changing printing technologies. The methods used to create designs, and the style they exhibit, have been dictated to a large degree by the possibilities and boundaries of each subsequent printing process. It might be presumptuous to assume that the current shift to digital technology offers more potential for these boundaries to change than any previous ones, but there are a number of reasons to suggest that many traditional assumptions about the parameters of printed textile design could be challenged, particularly with regard to the design process (see Fig. 5.10).

Since the late 1990s, printed textile designers have shifted from the traditional methods of hand drawing and painting to the use of digital media. While it would be almost impossible to put a percentage on how many designers are now working in this way, it is rare, for example, to see a job specification for a designer that does

5.10 Visualisation – a placement design, shown printed onto a tee-shirt.

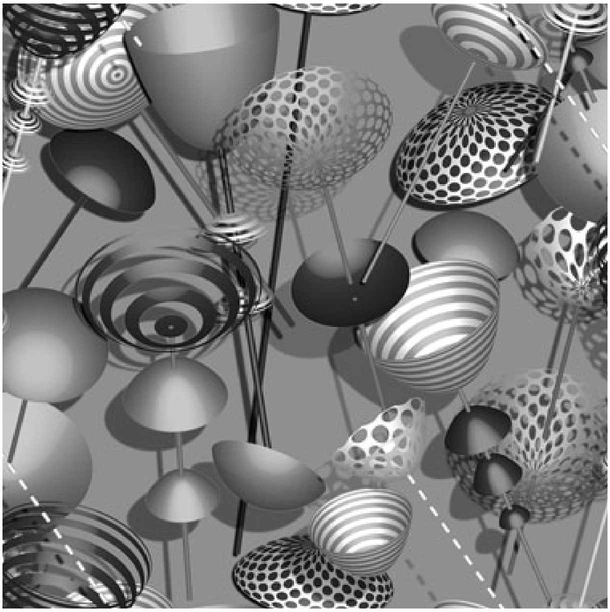
not make mention of software. In comparison to some other design disciplines, for example graphic design and typography, printed textile design was fairly slow in adopting digital technology. This was for a number of reasons, including the subsequent manufacturing process remaining largely based on non-digital printing (rotary screen) and the perceived uniqueness by buyers and commissioners of a hand-painted design as opposed to an easily reprinted digital one.

The initial use of digital technology in the design process within the sector tended to be via specialist software from companies such as Lectra Systems or Nedgraphics. More recently, however, there has been a move towards Adobe® software; first Photoshop® and lately Illustrator®. The earlier, specialist software tended to focus on translating the methodologies of traditional textile design to a digital workspace, using terminology such as repeat or colour palette with which designers were already familiar. However, the expense of buying or licensing such software, and in some cases the complexity of use or the systems required to run it, meant that they were out of reach for many designers, particularly those freelancers who make up a substantial percentage of the workforce. In time, designers discovered that Photoshop® and Illustrator® offered many if not all of the same functions, albeit with different nomenclature. In part it is also likely that this shift was due to the prevalence of Adobe® software in art and design education. The new designers of the last few years are not necessarily aware of the laborious traditional methods of (say) putting a design into repeat via halving or quartering and are instead completely accustomed to use of the Transform or Offset features of Photoshop®. However, it is important to note that whilst the technology can speed up the creation of a design, its quality is still related to the skill of the designer. Becoming adept at traditional design techniques such as putting a design into repeat can only be achieved by practical experience; the complex compositional decisions required are likely to be different for every design, regardless of the technology used. Although digital technology invariably is now used in the design process, detecting to what degree may be almost impossible when looking at the final printed fabric particularly if it is screen printed, as most of it still is (see Plate IV between pages 166 and 167 and Figs 5.11–5.15).

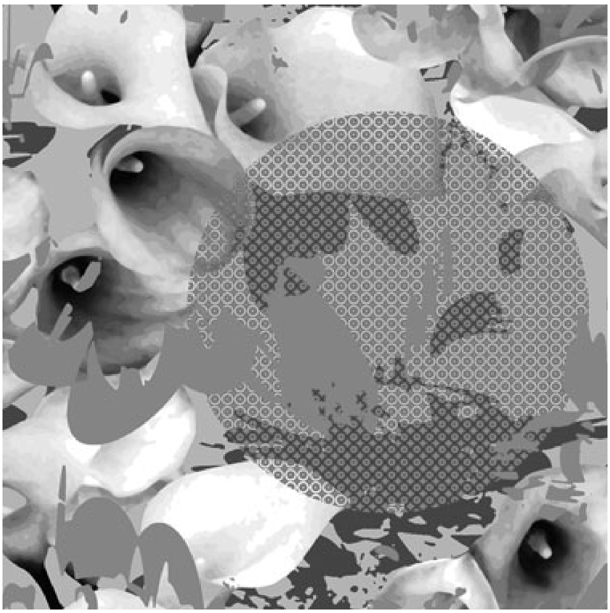
5.4.2 The role of software in textile design and printing

Adobe® Photoshop® is pixel editing software; large designs at good quality have a correspondingly large file size. A 64 × 64 cm design at 300 ppi in layered Photoshop® (PSD) format could be 200 MB or more. Powerful hardware is required to efficiently work on images of this size and files are almost certainly too big to send via e-mail (although FTP or large file sending companies such as YouSendIt.com can be used instead). Whilst Adobe® Illustrator®, vector editing software, is generally perceived as being harder to work with, the infinite scalability and ease of editing it offers means it is becoming increasingly common in use. It is worth noting the influence this software can have on the aesthetic of designs.

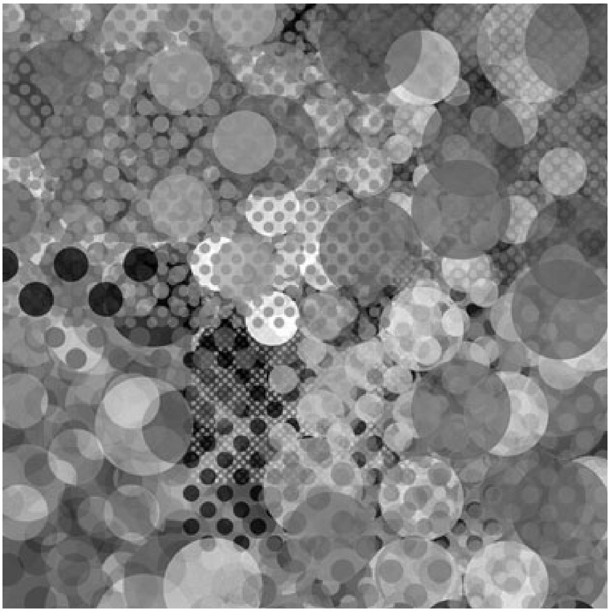
The current imbalance between the number of designs that use digital technology in their creation and in their printing can be seen in the retail environment. It is not difficult to find examples of digital printing, but use of the technology has yet to challenge the dominance of rotary screen printing.



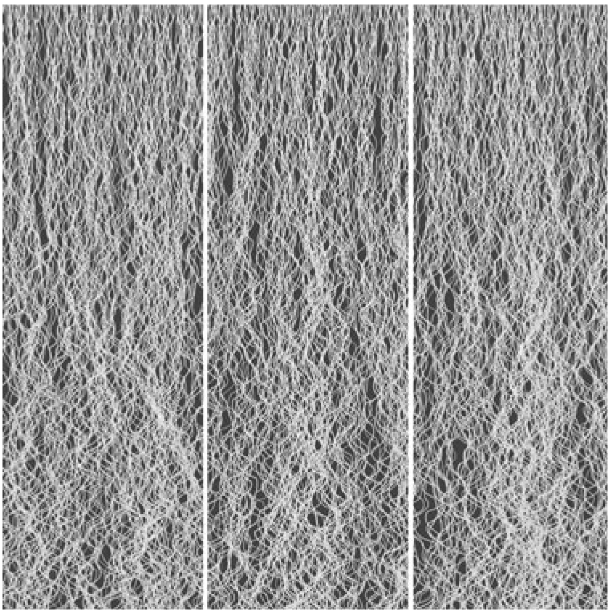
5.11 Calyx Remix – a design based on Lucienne Day's Calyx design, exploiting the potential of 3D software.



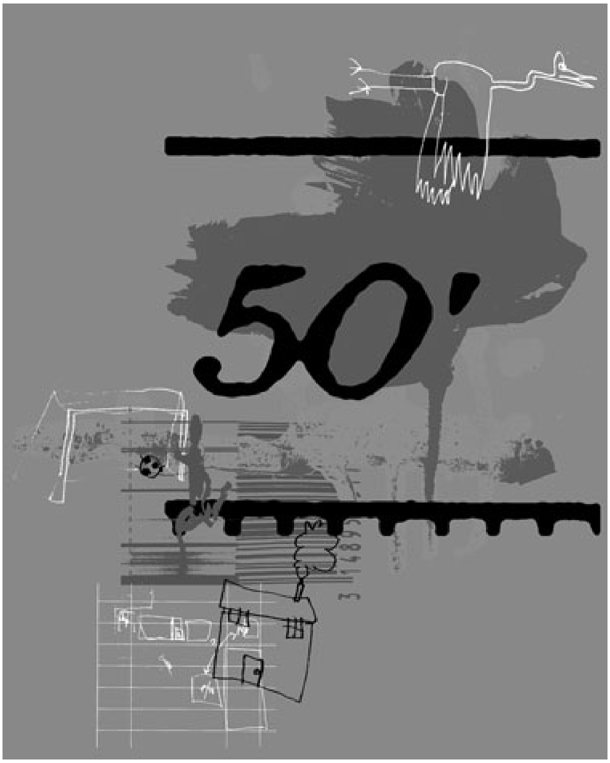
5.12 A design for digital fabric printing, using photographic imagery.



5.13 Patterandom Worn Spot 002 – a non-repeating, generative pattern, created by programming for digital printing.



5.14 Hilary Carlisle research explores non-repeating imagery in relation to digital print.



5.15 A graphic fashion print, designed as a placement print.

As designers and manufacturers make more use of digital systems, so the exploration of the technology will increase. Previous changes in printing technology did alter styles of design, but not fundamentally the methods by which they were created. As noted before, within the last fifteen years, the typical design process has gone from hand drawn or painted to the use of Photoshop® and Illustrator®, both programmes from Adobe's® Creative Suite® package. Although this software does offer designers a very rich range of possibilities, it is perhaps worth noting that a very high percentage of the creative industries are operating within a framework defined by a single corporate entity.

Although the underlying technology is very complex, a uniquely digital printing path from design to manufacture offers the opportunity of a significantly simplified and quickened workflow. At the time of writing, digital fabric printing is too slow and expensive to replace rotary screen printing as the main production technique. This situation is unlikely to last and once the entire process is digital, the opportunities for increasing integration or customisation within the design to manufacturing process will abound. However, the process has presented a new set of problems, such as colour management, in addition to factors already mentioned such as limited dyestuff penetration. Furthermore, the complex infrastructure within the fashion and textiles sector means that the benefits of a simpler workflow make little impression on the (typically) international logistics of manufacture. Although typical production lead times (particularly in the fashion sector) are falling all the time, substantially changing the technology within the chain, and hence its structure, can be slow, particularly when many parts of it may be contracted out.

5.4.3 The position of textile designers in industry

Printed textile designers occupy a range of employment positions which are described in Goworek (2006). Within the furnishing textiles sector, the term printed textile designer is generally well understood. This is often not the case within the fashion area, however, when in many cases the role is termed graphic designer. In common with many people working in the creative industries, this increasingly involves the portfolio career model, with designers undertaking a variety of different types of employment, often simultaneously (McRobbie, 2004, p.382). Broadly speaking, print designers tend to occupy one or more of the following three positions.

Freelancers

These designers generally work through agencies or directly with buying/commissioning clients. They may work to briefs set by the agency or client or create a portfolio of designs speculatively to sell at trade fairs or by appointment to potential customers. Given the timescale required to market and sell designs, relatively few designers work without any agency support and those that do tend to be well established and have a good range of contacts within the industry.

Agencies/independent studios

These either employ designers (possibly on a base salary with commission for designs sold) or use freelancers (taking a cut for designs sold, typically 40% to 50%). They normally have a large portfolio, produced by their designers. These may be created in response to very specific briefs set by those in charge of the agency or be produced on a more informal basis. In addition, agencies accept commissions from clients, offering the work to those in their design team they feel are suitable. Some agencies specialise in a single sector (designs for childrenswear, for example), whilst others cover a number of different outputs that may cover areas beyond straightforward textile design such as fashion illustration or trend prediction. Recent years have seen an increasing number of established studios selling vintage fabrics or garments as design material. Examples include: Keeler Gordon (London, UK), Colorfield (London, UK and New York, USA) Artemisia Disegni (Italy), Mosiac (Como, Italy) and Sidefive (Madrid, Spain).

In-house design studios

Many companies, particularly in the retail sector, employ their own designers. They are generally set briefs and managed by a studio/design director or similar; the use of trend prediction or forecasting information is fairly common. Further input may come from any number of sources within the company (such as marketing or merchandising) and the in-house team may buy or commission work from freelance designers, in some cases to adapt them or use them as inspiration, rather than simply putting them into production alongside their own designs. In-house designers may also be employed by print manufacturers/converters, to adapt or re-work designs as necessary for manufacture. In almost all cases, this latter process involves preserving the look of the original design. Those employed in this sector may also be particularly responsible for colourways (re-colouring existing designs), although designers in all positions will generally be familiar with this. Examples of retailers include: Liberty, and Marks and Spencer, while a manufacturer with a conversion studio is Standfast and Barracks.

In terms of day-to-day work, designers spend most of their working hours either creating new designs or adapting existing ones. Printed textile designers work most frequently either within the home/interiors sector, which may include floorcoverings, wallpaper and tableware in addition to fabrics, or the fashion sector, creating designs for garments or accessories. However, they may also apply their skills to visualising or developing pattern and imagery for other outcomes. This may include branding, trend books, giftware and illustration (not necessarily fashion).

5.4.4 Design training and education

In the UK, printed textile designers originally trained within the industry itself, essentially being apprenticed to in-house design studios, often within manufacturing companies. The trigger for the inception of a number of design schools was the Industrial Revolution; the increase in production leading to a demand for designers. Design schools were generally part of art colleges (although some were linked to technical colleges). The majority of these became part of Polytechnics (generally in the 1960s); all of these became Universities in 1992. Most printed textile designers in the UK are educated by this system, either on courses specifically related to the subject, or on related programmes such as surface pattern design. Some designers (mostly in the fashion sector) come from a graphic design route.

Although most current programmes provide students with a grasp of the historical and cultural contexts of the discipline (and often of art and design in general), the majority focus on the practical skills required of a professional designer. This is overwhelmingly tacit knowledge, learnt through application to design practice. Most courses are fairly structured (often diagnostically) at first and may include weave, knit and embroidery in addition to print; most end with a final project that is frequently authored by students, generally within the framework of where their main interests and ambitions lay after the earlier stages. The profile of students on textile design courses is typically more than 90% female.

5.4.5 Profile of printed textile design in relation to other design disciplines

In almost all cases, printed textiles designers remain anonymous. Indeed, Meller and Elffers (1991, p. 13) suggest that textile designers do not create new designs but instead rework existing themes. As previously seen, many print designers spend much of their time adapting or reworking existing designs. In some cases, this may be to compete with a successful style or line sold by a competitor without any risk of breach of copyright law.

Furthermore, most printed textile design is only a component of a product, the form of which may have more bearing on its sale or profile than the pattern that covers it. Most people unconnected with the industry could list a selection of fashion designers; very few would be able to name more than one contemporary textile designer. There is evidence that this might be beginning to shift and print designers like contemporary designers for fashion printers Fleet Bigwood, Rory Chrichton are celebrated in Fogg (2006) and Udale (2008) while prints for interiors boasts Timorous Beasties, who produce challenging and dramatic fabric. Zandra Rhodes and Celia Birtwell (Fogg, 2006) are evident in both historic and contemporary contexts. A significant figure of printed textile design is the late Lucienne Day, who is celebrated in many books about printed textiles and classic design.

Even within the design industry, textile designers tend to have a significantly lower profile than designers in other disciplines. This may in part be due to the way that designs are sold. An illustrator (say) will license an image for a specific use or time period, but will retain copyright and, in many cases (such as editorial work), will be credited. A textile design sale generally gives the buyer copyright in perpetuity; if the designer is required to sign a non-disclosure agreement or similar contract, this may deny the designer any right to claim to have even created the design. (Curiously in the light of this last point, it often also holds the designer responsible if the design is found to be in breach of copyright.)

This retention of copyright may partly explain why, until recently, there were so few illustrated books or reference sources on contemporary printed textile design. Books on the subject tended to focus on historical design (and hence out of copyright) or on craft techniques. Essentially, there were only two ways to get hold of visual information on contemporary printed textile design. Firstly, via trend reports or prediction, generally available only within the industry due to the high costs involved (and not always accurately indicative in sales terms) and, secondly, via market research, a potentially highly time-consuming activity. It remains to be seen if the current interest by the book publishing industry in contemporary printed textile design and pattern is a trend or sustainable in the long term (see Section 5.6 for examples), but the raised profile this gives to printed textile design via the provision of easily accessible examples of contemporary practice is encouraging. As is the rise in commercial contexts where print and pattern are strong drivers as seen in the work of Orla Kiely and Kath Kidston who have both had a dramatic impact on the high street in recent years. However, in considering designers listed on the Design Museum library, out of 176 designers, two are textile designers, Lucienne Day and Timorous Beasties, while seven are fashion designers. Public and professional admiration perhaps have some way to go.

5.5 Future trends

5.5.1 Continuing impact of digital technology on design process

There have been many cost and efficiency savings with the advent of digital printing; however, they only demonstrate one half of the story; where inkjet printing can make a real contribution is in relation to design and the environment. From a design perspective the ability to print full-colour, detailed designs using any scale using repeat or non-repeating elements, engineered printing gives this method plenty of scope to have an impact.

5.5.2 Colour and image

The capabilities of inkjet printing presents no real difficulties in capturing and reproducing a diverse range of image qualities 'From a design perspective, the ability to print full-colour, detailed designs using any scale, repeat or non-repeating elements and engineered prints opens up a wealth of creative possiblities' (Bowles and Issac, 2009, p.178). Millions of colours are capable of being printed. Due to the ability to print photographic imagery the subtleties and nuances of the original images may now be translated onto fabric.

Therefore, inkjet printing has burgeoned the use of photographic imagery within fashion, interior and art textile contexts. Previously the only way to use full photographic imagery was to use transfer printing (fabric choice limitations) or use four colour process printing (expensive and specialised). It has also enabled a more creative use of photographic imagery through image manipulation.

5.5.3 Scale and pattern

Repeat and image continuity are vitally important to textile production and design; CAD and digital printing enable repeat to be looked at in a different way and for concepts of non-repeating patterns to emerge as commercially viable options. Facilitated by the possibility of developing software programming to make small random variations in the formation of pattern, research has begun that investigates the possibilities of digitally printing longer lengths of fabric with patterns that do not repeat in the traditional sense. The ability to use repeat and pattern in this way may enhance a garment or interior product through the creative use of variation in design, and could potentially reduce fabric wastage in pattern cutting.

5.5.4 Engineered prints

In general the mass market utilises print to 'fill' in the garment outlines rather than to interact with the garment and body. Print is placed on top of garment shapes rather than being developed in unison. This often creates a clumsy and inappropriate use of print. Inkjet printing can enable a stronger relationship between the product and image. By printing the image to exact specification of a garment or product print designers can be more engaged with the relationship between form and image. However, by a more integrated approach to garment production the relationship between the 3D garment or product and the 2D image or pattern can be conceived simultaneously resolving in a more considered and creative relationship between the 2D and 3D factors as well as creating image continuity around a garment. Research into this relationship has been part of research within both commercial and educational contexts. This will be discussed in more detail in Townsend and Goulding Chapter 13.

5.5.5 Environmentally friendly

It can be argued that inkjet printing has more environmental advantages than conventional printing methods and that a more sustainable future is possible with the increase of this production method over others.

This is primarily due to there being less residue waste in terms of over production of a specific dye as the ink printed on demand, fabric can be printed as all over fabric or to specific shapes or placements and therefore waste printed fabric is significantly less than conventional printing methods. Inkjet printing is reported to use 30% less water and 45% less electricity than conventional printing methods. These savings have less impact on the environment than traditional print processes. The use of pigmented inks uses fewer chemical adherents and the use of ultraviolet curing fixes the ink without the emission of harmful chemicals and odours. (Fletcher, 2008).

5.5.6 Influences of digital printing on production from a design perspective

The growth of the technology is developing at a vast rate and it is fair to say that this will continue. Printers capable of mass-production were first released in 2003 and can typically print between 20 and 150 linear metres per hour at around 360 to 720 dpi and use 12–24 heads depending on the manufacturer. The best known manufacturers are Dupont (Artistry) Reggiani (DReAM), Robustelli (Mona-Lisa), Mimaki (TX2). However, Osiris have produced the first full 'roll to roll' production machine capable of 1800 metres an hour, around 30 metres a minute with their ISIS printer and thus creating a new industry standard. The speed of printing is likely to continue to increase and the technology to thrive.

5.6 Sources of further information and advice

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5.6.2 Journals and magazines

Drapers Record
Textiles Magazine
View-publications

5.6.3 Business news

www.just-style.com
www.wgsn.com

5.6.4 Trend prediction

www.peclersparis.com/
www.trendstop.com

5.6.5 Trade fairs

www.premierevision.fr
http://heimtextil.messefrankfurt.com/frankfurt/en/aussteller/willkommen/erleben.html

5.6.6 Archives and collections

www.belovedlinens.net
www.vam.ac.uk/collections/textiles/index.html
www.whitworth.manchester.ac.uk/collection/textiles/
www.wellcomecollection.org/whats-on/exhibitions/from-atoms-to-patterns/image-galleries.aspx

5.6.7 Digital printers

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Plate III Photograph of Ria Thomas's work (courtesy Chris Moore).

Plate IV Amanda Briggs-Goode has worked with photographic imagery and digital manipulation in her textile work.

6
Embroidered textile design

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Abstract: Various forms of embroidery have become prevalent on all manner of clothing and household textiles. This chapter provides an overview of the different mass-production methods commonly used, and discusses the commercial applications of embroidery.

Key words: commercial mass-production embroidery, Schiffli embroidery, multi-head embroidery, embroidery digitising, mass-customisation, branding/corporate clothing.

6.1 Introduction

Embroidery design is inextricably linked to the specific method of production, so this chapter provides an overview of the processes currently used for embroidery production. It provides an account of the recent changes in technology that have radically altered the use of embroidery, and includes sections outlining the key areas embroidery is used in. Finally there is a section suggesting likely future trends in embroidery.

Embroidery has always been a key feature of both household textiles and clothing, in recent years embroidered decoration has become even more predominant. This is for two reasons: the advances in embroidery technology have made it much cheaper and easier to produce embroidery, also increased globalisation and the easy access to cheap labour means hand-stitched embellishment is now created for mass-market clothing as well as for the more expensive end of the market. There is a third reason that has led to a huge increase in the amount of embroidery on clothing, and that is to do with the huge growth in branded goods over the last twenty years or so.

The commercial mass-production of embroidery is a surprisingly complex area. Embroidery is not a discrete process. It encompasses all types of stitched decoration, from all-overs on household textiles, to placement logos on caps and sweatshirts, to complex designs combined with print and sequin embellishment.

Commercial embroidery is produced in a whole range of different ways, from huge factories with the latest computerised 20-metre long schiffli machines stitching metres and metres of all-overs, to tiny sweatshops in the third world where children hand stitch embroidery for a pittance.

Although we are now well into the 21st century, the technology of production currently being used to create commercial embroidery includes both the very latest, most efficient machines, as well as machinery that has changed very little since the beginning of the 20th century.

In order to create designs for embroidery it is necessary to have an understanding of the different production processes. Depending on the production process used the embroidery design process varies greatly. Designing for schiffli production is more complex than designing for multi-head production.

6.1.1 Definition of embroidery

The word embroidery has many meanings and connotations, in this chapter it is used to denote commercial embroidery, i.e. that done on or applied to garments or household textiles for retail sale, as opposed to embroidery done for commission, as one-off pieces. The types of commercial embroidery covered in this chapter can be defined by method of production, i.e. tambour, Irish machine, Cornely machine, schiffli machine, multi-head machine. (These different production processes are described below.)

The generally accepted meaning of the word embroidery is decoration of fabric with stitches formed by thread, by piercing the fabric with a needle. These stitches can be made by hand or machine. However, as well as being made with a needle, stitches can also be made with a hook. This is known as tambour work when it is done by hand, Cornely when done by machine, and results in the formation of a chain stitch.

A vast range of different specialist machines have been utilised over the last 180 years to create embroidered embellishment on clothing and household textiles. These machines have ranged from individually controlled machines that stitch only one item at a time, such as the Cornely and the Irish, to the machines that employ a multitude of needles to literally mass-produce embroidery: currently the schiffli machine and the multi-head machine; historically the hand embroidery machine.

The main division is between hand-stitched and machine-stitched embroidery. Given the advances in embroidery technology since the advent of computerisation, it can be considered amazing that it is still economically viable to create embroidery by hand. And yet that is still the case. A television documentary in the UK highlighted how much hand production is still used to create embroidery for sale in mass-market high street stores (Primark on the Rack, BBC 1 Monday 23 June 2008).

6.1.2 Types of embroidery

Embroidery can be created in many different ways; it can also be used in many different ways. The schiffli machines can create metres and metres of all-overs that can be used for household textiles or fabrics for clothing. These machines can also used be used for the creation of badges that are then attached to clothing when large quantities are required. They are also used to create embroidered trimmings. Multi-head machines are mostly used for placement embroidery, most commonly logos and branding; however, they are also used extensively for feature embroidery on all manner of clothing and household textiles, especially towels.

The main focus of this chapter is embroidery that is mass-produced, i.e. that produced on machines with a multiple of needles. However, it is necessary to have an awareness of the other, more labour-intensive methods of commercially producing embroidery, since they directly affect changes in technology in the mass-production of embroidery, and occasionally companies use both individual and mass-production methods side by side. Also many of the machine processes deliberately emulate a hand-stitched look.

6.2 Commercial production methods for embroidered textiles

Commercial production methods can be broadly divided into two, those that essentially consist of one person working on one piece of embroidery at a time, where the labour required is intensive and skilled: hand embroidery, tambour, Irish machine, Cornely machine; and those that result in the production of more than one piece of embroidery at a time: schiffli machine, multi-head machine.

6.2.1 Tambour

This is a method of producing a chain stitch by hand using a hook instead of a needle. The fabric to be tamboured is stretched tight in a frame. This method of working is much faster than the traditional way of using a needle. Usually one person will work on one frame at a time, but large frames can be tamboured by more than one person. Tambouring can also be used as a way of attaching beads or sequins to a fabric, and this is what it was predominantly used for in the 1920s and 1930s, when all-over beaded dresses were the height of fashion, and this is its main application in the clothing industry today, since this method of applying beads or sequins provides more versatility than other machine methods. Tambouring is still used extensively in India to apply embroidery, beads and sequins to clothing sold in the West.

6.2.2 The first embroidery machine

A machine to mass-produce embroidery was invented in 1828, and in widespread use before the lockstitch sewing machine was developed to join fabrics together. This machine was known as the hand embroidery machine, because the action of stitching replicated the way hand embroidery was done, the thread was passed back and forth through the fabric. Rows of double-pointed needles, which had an eye in the middle for the thread, were passed simultaneously right through the fabric, and then back again, to form stitches. There was no bobbin or shuttle thread. The hand embroidery machine was in widespread use right up until the 1950s. It is quite incredible that a machine was able to decorate fabric, before there was a machine to stitch two pieces of fabric together. All manner of different types of threads and base fabrics were used: thick wools that are traditionally associated with real hand embroidery; silks, satins, sheer chiffons, metallic threads, chenille, raffia. Mechanisms and processes were ingeniously devised so that all types of hand embroidery could be replicated: a boring attachment enabled the creation of broderie anglais; beads and sequins could be attached during the embroidering process; a process was developed to create 'chemical lace' by the burning away of the base, background fabric. All these developments still form the fundamentals of schiffli embroidery today.

Switzerland: the home of embroidery

Although the hand embroidery machine, the first mass-production embroidery machine, was a French invention, machine-produced embroidery was significantly developed in Switzerland during the 19th century after the invention of the schiffli machine, and Switzerland is considered to be the world's centre of embroidery. At some stages during the 19th and 20th centuries embroidery was Switzerland's biggest export. St Gallen, in the east of the country, is considered to be the 'home' of embroidery. A fantastic legacy remains in the wonderful 'Textilmuseum' in St Gallen, which also includes an outstanding textile library of pattern books.

6.2.3 The Cornely machine

The Cornely machine can be used to produce a chain stitch, or a looped stitch, known as mossing. With the addition of various attachments, it can be used to apply braid or cord or fine ribbon to fabric. Each machine is controlled by a skilled operator, who uses a handle beneath the machine to manoeuvre the fabric in order to form the required pattern. Thus only one piece of embroidery is produced at a time.

Various chain stitch sewing machines had been patented in the 1830s, 1840s and 1850s, in various countries, but the particular machine that came to be used successfully for chain stitch embroidery was patented in France by a Mr Bonnaz, the machines being manufactured by the Cornely company. Many variations of the first machine were subsequently developed by the Cornely company from 1865 to 1950, providing different stitch effects. A comprehensive account of all the different Cornely machines can be found in Risley (1973). Many of these old machines are still in use.

In the late 1980s there was a new development that radically altered how the Cornely machine was operated. Until then, each individual machine was operated by one person, and there was a considerable amount of manual skill involved in the operation of the machine, since the production of the pattern was determined by how the operator turned a handle. In the late 1980s, a multi-head Cornely machine was developed which consisted of several Cornely stitching heads mounted side-by-side, the movement of the fabric to create the design being controlled by computer.

Cornely production

The nature of the Cornely machine is such that stopping and starting the machine results in lots of thread ends that must be finished off by hand, thus it is much more cost effective to produce designs that consist of continuous lines. Consequently typical Cornely work, whether chain stitch, braiding or cording consists of flowing lines.

6.2.4 The Irish machine

The Irish machine is basically a swing needle lockstitch machine that has been developed specifically for embroidery. Whereas an ordinary lockstitch machine can be used for embroidery by dropping the feed, the Irish machine does not have a feed, so it is not suitable for stitching two pieces of fabric together. As with the Cornely, the creation of successful embroidery is dependent on the skill of the operator. The fabric is manipulated freehand by the operator under the needle to produce the required pattern. Prior to the invention of the swing needle, horizontal stitches were embroidered by the operator rapidly moving the fabric to and fro, the swing needle meant the width of the stitch could be controlled by the movement of the operator's knee.

Irish production

The Irish machine used to play an important role within the schiffli machine industry. Irish machines were used to produce samples, or prototypes before a design was put onto the schiffli machine. Also Irish machines are used to rectify any faults, or omissions in schiffli embroidery after it has been removed from the machine.

In addition, some embroidery companies use the Irish machine when very small runs of complicated designs are required, since this method can be more cost-effective than processing complex designs. Although the use of the Irish machine has declined significantly in the UK, it is still used extensively in India and the Far East to produce vast quantities of commercial embroidery.

By deft manipulation of fabric a wide variety of stitch effects can be produced on the Irish machine; however, its characteristic production is a flat, smooth satin stitch, often used on household textiles, blouses and shirts.

6.2.5 The schiffli machine

The schiffli machine combines the basic principles of the hand embroidery machine – long rows of needles stitching into fabric stretched over a vertical frame – with the principle of the lockstitch machine, utilising a row of bobbins or shuttle threads. The largest machines are approximately 19 metres long, and contain over 1400 needles. The embroidered fabric can be used as an all-over, or it can be cut up into trimmings, motifs, or garment parts such as collars after it has been removed from the machine.

Schiffli production

Schiffli production is ideally suited to large runs, and all-overs. The schiffli can be used to create three special types of all-overs: broderie anglais; guipure, or aetz lace; and embroidered net. As well as creating embroidery for these applications the schiffli machine is often used to create embroidery for lingerie.

There used to be a considerable amount of schiffli production in Switzerland, Italy, Austria, the UK and France but since the 1990s many schiffli companies have moved their production to places where it is cheaper to run a factory, such as Turkey, Sri Lanka, Bangladesh, Vietnam, China. Similarly there is still a sizeable schiffli industry in the USA, however much American schiffli production is now also done off-shore.

Broderie anglais

This is where a boring attachment is fitted to the machine, to create small holes in the fabric, which are then embroidered around. Broderie anglais is usually, but not always, white. It is predominantly used for home furnishings, and children's wear.

Guipure

This is also known as burnt-out lace, or aetz. The embroidery is stitched, very densely, onto a fabric that can then be dissolved away, leaving only a lacy fabric. This is relatively expensive to produce, since it is costly in terms of thread. This type of fabric is often used for bridal wear and evening wear.

Stitching onto net

Schiffli machines can be used to stitch onto net or other fine fabrics to create lace-type effects.

Designing for schiffli production

Designing for schiffli production is a much more specialised task than designing for multi-head production due to the constraints of the production process. The needles are set a fixed distance apart, known as a schiffli inch (actual measurement 27.07 mm or 1.065 Imperial inches). This means any design has to fit within this parameter. Changing thread colour on a schiffli machine is time consuming, so fewer colours of thread are generally used in schiffli production than in multi-head production. The design to be stitched is digitised, further information about this can be found below.

6.2.6 The multi-head machine

The multi-head machine operates in a different way from the schiffli machine. It consists of several machine heads mounted side-by-side, each head containing up to 12 needles. The fabric to be embroidered is stretched horizontally in a frame, as in conventional domestic machine embroidery. This frame is controlled by a patterning device so that the same design is repeated across the row of machine heads.

Whereas the schiffli machine is ideally suited to the manufacture of 'all-overs', the main use for the multi-head machine is to stitch directly onto garments. It is predominantly used for caps, sweatshirts, household textiles, etc.

Although a single head can be used to stitch just one piece of embroidery, it is more usual in industry to link up to 30 together, and mass produce the same design. As with schiffli embroidery, all the designs that are to be stitched on the multi-head have to be 'digitised'.

The number of multi-head embroidery manufacturers has grown rapidly, worldwide, in the last few years. Multi-head production is used for a vast range of applications, ranging from stitching logos for local community groups to creating complex, elaborate designs on children's wear and womenswear.

Summary of significant technological changes in multi-head embroidery production

1. Introduction of several needles on one stitching head: the first multi-heads had only one needle per head, from the late 1960s this was gradually increased until today multi-head machines have 12 needles per head, allowing for 12 colours in each embroidery.
2. Introduction of electronic, rather than mechanical control, 1970s.
3. Development of computerised punching, early 1980s, see below.
4. Development of cylinder arm/drop table, late 1980s, this meant it was possible to easily stitch directly onto a specific garment or part of a garment such as caps, sleeves, etc.
5. Increased speed of stitching: machines in the 1950s operated at about 180 stitches per minute; in the 1970s at 300 stitches per minute; in the late 1970s at 600 stitches per minute. In the 1990s the usual rate for a single head was 1200 stitches per minute, and a 4-head 800 stitches per minute. Currently the latest 16 heads can operate at 1600 stitches per minute.
6. Increased field size: the maximum field size is usually approximately 550 × 550 mm, this allows large-scale embroidery such as jacket backs to be stitched easily.

Multi-head production

Whereas the schiffli machine is used to stitch a large expanse of fabric, which (unless it is an all-over) is then cut up into garment pieces, badges, motifs or trimmings, the multi-head can be used to stitch directly onto made-up garments or household textiles, or garment pieces.

Traditionally multi-head machines were used primarily for badges, motifs and logos, more recently they have been used extensively to stitch directly onto all types of made-up garments such as baseball caps and leisure wear. Since exact positioning on a garment is possible, it is economically viable to produce types of embroidery that are not feasible on a schiffli machine.

It is much easier to automatically produce multi-coloured embroidery on the multi-head than on the schiffli machine. It is possible to include as many different colours in a design as there are number of needles in a head. Appliqué is also used extensively within multi-head production in order to create larger areas of colour without using vast quantities of thread.

The number of multi-head companies grew rapidly worldwide in the 1990s, and the use of embroidery on clothing became much more prevalent. Due to the lessening costs and increased ease of production embroidery was seen as an 'add-on' feature that increased the perceived value of an item. Due to durability, and connotations of exclusivity it is seen by the consumer as a more 'quality' feature than printed decoration and thus items with embroidered decoration retail for more than items with printed decoration.

However, many of the new companies were 'novice-led'. Whereas the schiffli manufacturing companies employed trained designers, a considerable number of new multi-head companies were what is known as 'mom and pop' businesses, and over half of domestic American sales in the 1990s were to 'start-up enterprises'. The successful digitising of embroidery designs is a very skilled process, yet the software manufacturers sold their products as being easy to use. Good digitising is not only about creating an aesthetically pleasing design, but one that will run with the minimum of 'down time' caused by needle and thread breaks. Melvin Ackrel, Technical Services manager at Geoffrey E Macpherson Ltd, commented: 'There are too many people punching who don't understand about embroidery, such as small stitches on top of each other leading to thread breaks . . . there are too many people setting up punch houses and punching badly.'

'Possession of a computerised digitising system does not automatically a puncher make . . . The artistic quality and runability of any design will always be directly proportional to the talent, training or level of experience of the puncher . . . As a punching instructor, I encourage potential students to get at least six months of experience operating an embroidery machine before they learn to digitise . . . There will always be those, however, who purchase a system without seeking instruction and they will basically be using their clients as guinea pigs while they learn the trade.' Frank Gawronski, The hidden costs of flat-rate punching', *Stitches* magazine March 1994.

Operators new to digitising probably see the translation of a design into an embroidery as basically marking the outline and then filling it in with solid stitching. However, fabric and thread are flexible media, it is not a simple task of 'painting by numbers'. Embroidery designs have to be modified to take into account the distortion that occurs as stitching takes place. Different ground fabrics and different threads will create very different results.

6.3 Digitising embroidery designs

Although schiffli and multi-head machines operate in different ways, the computerised digitising systems for inputting design information are very similar. The terms 'punching' and 'digitising' refer to the same process – the process of converting a design into a machine-readable format. This can be direct to machine, or stored on a disc. The term 'punching' originated from when holes were manually punched into a paper or cardboard roll. Until the 1990s computerised systems were also commonly referred to as 'punching' systems and the term 'punching' remains in use in some sectors of the embroidery industry.

6.3.1 Development of computerised systems

Several different machine manufacturers developed electronic punching systems at the same time. Coleman Schneider claims to have been the first person to formulate 'the concept of electrically punching for embroidery . . . a computerised electronic punch machine . . . in 1967' (Schneider 1978); however, it was several years before the system was developed by Schneider, IBM and Cataletto of Italy. Meanwhile, actually making an appearance in 1967, also according to Schneider (1978), was 'the first electronic punch machine in the embroidery industry . . . operated by Saurer . . . (of Switzerland) . . . and known as the "Punch-O-Mat".' At the same time other companies were also developing electronic and computer systems: Gunold in Germany, August Heinzle in Austria, Pfaff, Tajima and Eltac in Japan. The first system using a graphical interface, and thus designated a so-called 'CAD' system was developed by Wilcom in 1979/80.

There is currently a whole range of different software packages available for digitising embroidery designs. The main players within commercial embroidery are currently the following: Wilcom, ZSK, Gunold, Pulse, Compucon. The main multi-head machine makes are Tajima, Barudan, Brother, ZSK, SWF, Happy and Melco.

6.3.2 The digitising process

In order to stitch out a design, it has to be digitised. This basically means converting an image into stitches. In the past every single stitch had to be marked out by hand and 'punched'; however, with the increased sophistication of the digitising process, complex fill stitch patterns can easily be created and manipulated.

6.4 Pattern control in embroidered textile designs

All machine embroidery is carried out by the movement of a piece of fabric beneath, or perpendicular to a needle or set of needles.

6.4.1 Cornely and Irish

Embroidery done on these machines requires a considerable amount of skill by the operator. The movement of the fabric to create the design is controlled freehand by the machine operator. There is sometimes an implication that embroidery created by machine is in some way inferior to that created by hand, as if less skill is involved. In fact the creation of embroidery on the Irish and Cornely machines is very skilled.

6.4.2 Schiffli and multi-head

These machines call for different skills on the part of the operator. The movement of the fabric is controlled either mechanically or electronically, the required stitch information having been previously punched or digitised.

6.5 Applications of commercial embroidery production

Although a certain amount of information about what is produced by the different methods has been provided in the above sections on production methods, it is useful at this point to reiterate some of the applications of commercial embroidery focusing primarily on the schiffli and multi-head industries.

A wide range of different types of threads and fabrics can be stitched on all these types of embroidery machines. The threads used can range from thick wools to fine silks, the fabrics stitched can range from sheer chiffons to thick plastic, for certain fabrics special backings or toppings may have to be used.

Embroidery is often combined with other decorative processes, such as print, the application of sequins, and appliqué.

The end uses of embroidery vary enormously, but can be categorised as follows.

6.5.1 Household textiles

This includes, but is not limited to, towels, tablecloths, napkins, bed and table linen, and curtains. The use of embroidery on household textiles has become commonplace; once it was limited to only high-end textiles, and mostly stitched on the schiffli machines; however, with the lessening production costs cheaper ranges of household textiles also use embroidery.

6.5.2 Clothing

Although in theory the application of embroidery to clothing is limitless, it tends to be used extensively in the following areas: childrenswear; womenswear, lingerie, sportswear, corporate clothing/workwear.

Childrenswear

Since the 1990s embroidery has been used extensively by manufacturers of children's clothing, at all market levels, from the low end, such as Primark, to upmarket brands such as Burberry. Stores such as Marks and Spencer use multi-head embroidery on a very large proportion of their childrenswear. The signature look of both Oilily, and Monsoon is highly embellished, decorative clothing. Both these brands use a range of textile techniques to achieve this look, embroidery is a significant part of this.

Licensed characters

Again, an area that has grown hugely in the last fifteen years. A large proportion of the figurative decoration on children's clothing, whether printed or embroidered, is now licensed characters, from films and TV shows. Warner Brothers and Disney characters abound, other perennially popular ranges includes, for example, Thomas the Tank Engine. In the Night Garden, the Teletubbies, High School Musical, and so on. The increased sophistication of multi-head production means complex designs can be created and manufactured relatively cheaply, often combining print, embossing, embroidery, sequins and stones.

Princess ranges

A phenomenal amount of clothing available for girls is pink. Again, ten years ago this was not the case, now it can be hard to find childrenswear for girls that is not the obligatory pink. The development of the Disney Princess range can be seen to be aligned with this. Disney had created 'princess outfits' for a number of years; in 2000 they set up a specific Disney Princess franchise, which included the creation of eight princess outfits (now nine), as well as other types of merchandise. These are heavily embellished and decorated with embroidery, sequins and rhinestones. This range was created in direct response to the preponderance of 'generic princess products' worn by the audience and observed by Andy Mooney at a Disney on Ice show. These generic princess products, created by many different brands, often utilise embroidery. This 'princess fever' is not popular with all parents, see What's wrong with Cinderella? By Peggy Orenstein, the *New York Times*, 24 December 2006, and 'Princess pedestal: how many girls are on one?' by Martha Irvine, *The Daily Herald*, 29 May 2009. A further example is the 'Pinkstinks' campaign, which was launched in the UK in 2008, and set up a website in December 2009. Its aim is to show girls there are alternatives to the 'pink princess' aspirations fostered by mainstream clothing and toy ranges.

Womenswear

Whilst many clothing ranges include elements of embroidery occasionally, there are a small number of companies for whom embroidery is a key part of their identity. Monsoon and Whistles are both upmarket companies whose garments often utilise different types of embroidery.

Lingerie

Women's underwear has featured embroidery since before embroidery was automated. The schiffli embroidery manufacturers, such as Bischoff in St Gallen, Switzerland (www.bischoff-textil.com) have developed incredibly sophisticated ways of stitching onto complex stretch fabric bases.

Branded sportswear

Performance clothing designed specifically for sports has been around for a very long time, one of the first instances is the short skirt worn by Suzanne Lenglen to play tennis at Wimbledon in 1922. However the wearing of branded sportswear as everyday clothing is a more recent phenomenon. Casual clothing, especially for men, in the teenage–30 years age group, predominantly consists of branded sportswear. The big brands, Nike, Adidas, Reebok and Fila, link their image to particular sports personalities and teams, and the look of the brand image is vitally important in retaining their market share. Part of the appeal of specific brands to their loyal consumers is the use of distinctive logos to identify the make. Both print and embroidery are used to ensure the logo is highly visible. The huge rise in the popularity of branded sportswear coincided with the development of embroidery technology in the 1990s. It is hard to separate out the two, they very much operated in tandem.

Branded clothing

In the past there were a small number of makes that did utilise a logo to signal the name of the brand, for example Fred Perry tennis shirts with their distinctive laurel wreath logo were first marketed in the 1940s, cashing in on Fred Perry's Wimbledon success in the 1930s. However, it was in the 1980s that the use of logos and 'designer' names became really prevalent.

For certain sections of youth culture, wearing the 'right' label is very important, and clothing ranges capitalised on this by developing a clear brand image.

The 1980s saw the rise of branding, whereby what was sold was not a product, but a brand. Consumers bought into the brand, and a big part of the branding process was to have a globally recognised sign, such as the Nike swoosh, the golden arches of McDonald's, the three stripes of Adidas. The development of embroidery technology went in parallel with this, and enabled clothing and sportswear makes to easily 'brand' their ranges with embroidered names and logos. Brands became known internationally. This links to contentious issues around multi-national corporations and globalisation. For a full discussion of these aspects see Naomi's Klein's groundbreaking book, '*No Logo*', 2000.

Corporate clothing/workwear

Another area multi-head embroidery is used extensively is corporate clothing/workwear/schoolwear. Since the 1990s it has been very easy and cheap to have bespoke embroidery carried out on workplace clothing and uniforms. This type of 'labelling' has been done for decades, in the past it would have been done either by having badges mass-produced on schiffli machines, which were then attached to clothing; or by individually controlled Irish machines. However, as multi-head embroidery became so prevalent far more organisations now have 'bespoke' embroidery carried out on uniforms/corporate workwear.

Mass-customisation/personalised embroidery

The concept of mass customisation was conceived by Stan Davis in his book '*Future Perfect*' in 1987. It has been defined as 'effectively postponing the task of differentiating a product for a specific customer until the latest possible point in the supply network' (*Operations Management for Competitive Advantage*, Richard B Chase, F Robert Jacobs, Nicholas J Aquilano, 2006). With the development of flexible computer-aided manufacturing systems it has become increasingly prevalent in some aspects of clothing production, for example Nike id allows the individual shopper to customise their trainers according to their own colour preferences and design details.

The advances in embroidery technology and information systems mean it is now possible to economically stitch out personalised designs for individual customers. This service is particularly popular with items for babies and children; however, all manner of specialised merchandise is offered. More unusual products include personalised coffin linings and pet food bowls that depict an embroidered photograph of an individual pet. There are huge numbers of companies operating online, offering all types of bespoke embroidery. It is also common to find small 'mom and pop' companies offering similar services.

6.6 Location of embroidery production

As with nearly all aspects of textile and clothing production, embroidery production increasingly takes place in countries where labour costs are cheap. Twenty years ago a significant number of embroidery companies operated in Western Europe and America. Although some manufacture does still take place, the bulk of production is now overseas. It is common for the design to take place in the West, but the production to take place elsewhere.

6.7 The embroidered textile design process

Obviously it is hard to make generalisations about the design process for embroidery, since there are so many different manufacturing processes and embroidered products. This section will briefly outline the design process within schiffli manufacture, and multi-head manufacture.

6.7.1 Schiffli: the design process

Designing for schiffli manufacture is much more complex than designing for multihead manufacture simply because of the constraints of the production process. The needles are set a fixed distance apart on the schiffli machines. (This measurement, known as a French inch, is 27.07 mm or 1.065 Imperial inches.) Also, there is a limit to the width of the design that can be embroidered, this limit is governed by the movement of the frame holding the fabric. Consequently schiffli embroidery designers have very specialised knowledge of the production process, and design for manufacture accordingly. Companies such as Bischoff and Jakob Schlaepfer in Switzerland provide in-house training for their designers.

Design for many aspects of the schiffli market is relatively 'safe', the same types of floral designs are used over and over again. However, the better companies will use these motifs in innovative ways, combining unusual colours, threads and production processes.

6.7.2 Multi-head: the design process

Some of the larger clothing companies do employ specialist embroidery designers, but for the most part the embroidery is designed by people who do not necessarily understand embroidery digitising and manufacturing processes. Consequently the embroideries that are created tend not to exploit the complexities of the software that is available. The digitisers who are asked to convert designs into embroidery *do* have a sophisticated understanding of what their systems can do; however, their job is just to interpret what they have been given.

So there is a dislocation between what can be done with embroidery, and what usually is done. Whilst there is some truly innovative and interesting embroidery in the mass marketplace, there is also a whole heap of derivative, dull embroidery. A small number of companies do exploit embroidery to create much more interesting work. These tend to be only at the top end of the market, some of them are discussed in the next section.

6.7.3 Upmarket companies: the design process

Karen Nicol (karennicol.com) creates embroidery for fashion and interiors using a whole range of different processes: the Irish machine, Cornely, multi-head, beading, ribbon work and hand embroidery. Clients included Chloe, Clements Ribeiro, Julien

Macdonald, John Rocha, Betty Jackson, Matthew Williamson and Michiko Koshino. Karen is usually given a starting point by the individual designers, which she then interprets to create complex embellishments and embroideries that enhance their collections. Karen's own stitching and embroidery skills are superb, she creates innovative embroideries that are difficult to replicate. She has also created her own range of embroideries and laces, and has created work for exhibition and commission.

Hand and Lock

Based in London, Hand and Lock (www.handembroidery.com) create all types of hand embroidery for a diverse range of customers including couture, fashion and bridal designers; military tailors; film, opera and theatrical costumiers, and ecclesiastical clients. Hand and Lock are specialists in one-off and small production runs, their staff are skilled in many different embroidery techniques including gold and silver wire work, tambour sequin and beading, ribbon work and Irish and Cornely embroidery.

Lesage

Lesage is known as the creator of the exquisite embroideries for the couture collections in Paris. Lesage has been in existence since the middle of the 19th century, in 2002 Chanel bought Lesage, and five of the other specialist workshops in Paris in order to secure their future. Lesage have worked with all of the French couture houses to create spectacular details on all manner of womenswear. Lacroix, in particular, has made extensive use of Lesage embroidery.

There are other small workshops/ateliers that also operate at the cutting edge of embroidery, providing embellishments for the French couture ranges, such as Cécile Henri Atelier in Paris, under the direction of Sébastien Barilleau.

Another designer who utilises exquisite hand-made decoration for her ranges is Marcia Ganem, a designer based in Brazil. She collaborates with indigenous craft workers from her home town of Bahia, combining traditional processes such as lace making with modern materials such as polyamide fibres.

Further information about these designers can be found in *Textile Designers at the Cutting Edge* by Bradley Quinn, Laurence King 2009, and *Fashioning Fabrics* by Sandy Black, Black Dog Publishing 2006. For further information about Lesage see *Haute Couture Embroidery: the art of Lesage* by Palmer White, 1988.

6.8 Future trends

As is evident from the other chapters within this book, the design and manufacture of clothing and household textiles is a very complex area. A huge amount is invested in complex manufacturing and retailing systems: there are unlikely to be far-reaching changes within mass production embroidery in the next few years. However, with the growing awareness of the detrimental impact of textile production on the environment, it is likely that there will, slowly, be some changes in the public's buying habits, that will impact on embroidery. It seems likely that there will be more value placed on owning a smaller number, of more special garments. Rather than endlessly buying new clothes and throwing them away after only a few wears, consumers are starting to value items that last longer. The ideas within Carl Honore's book *In Praise of Slow* (2004), are starting to filter into many areas of cultural production. These ideas are supported by companies such as 'Keep and Share' led by Amy Twigger Holroyd and the Alabama Project led by Natalie Chanin. Keep and Share focus on creating knitted garments that will last for more than just one season: 'The Keep and Share approach to ethical fashion revolves around long-term wearer satisfaction. We find it abhorrent that the vast majority of clothing is discarded before the end of its wearable life, and seek to reverse the effects of throwaway fashion by encouraging our customers to buy less, more special pieces, and to keep their items in use for longer' (www.keepandshare.co.uk/index.html cited 12 October 2009). A similar view is espoused by workers at the The Alabama project, set up by Natialie Chanin in 2000 to create hand-stitched garments for her fashion range. Local craft workers create hand stitched garments and accessories using locally available fabrics, especially worn T-shirt fabric. The philosophy of the label centres on the 'celebration and preservation of uniquely American traditions while building a sustainable business model (http://alabamachanin.com).

Consumers are increasingly aware of environmental and ethical issues within clothing production, and it is very likely that over the next few years more consumers will question the whole life cycle of garment production, and try to buy more ethically. According to *The Craft Blueprint* published in the UK in 2009 by the Crafts Council: 'there has been a shift in recent years from consumer demand for basic products competing on price and availability, to products whose value rests in their individuality, design value and aesthetic appeal'. Alongside this more and more designers are aware of the issues within sustainability and ethical production, so it is likely there will be some design-led changes in embroidery production.

6.9 Sources of further information and advice

It is problematic investigating the embroidery industry due in part to the following three factors: embroidery's status as an amateur pastime, not a commercial or professional occupation; the relative newness of multi-head production; and the fact that embroidery is not a discrete process, but is added to a garment or household item.

> 'The commercial embroidery industry . . . has always lacked statistics – hard-core numbers about the size, profitability and financial influence wielded by commercial embroiderers . . . Financial analysts cannot believe, for example, that no-one can say how big the embroidery industry is in dollar volume. Well, let's see . . . would that be the licensed sports product market? Or home furnishings or monogramming? How about corporate identity or fashion? Part of the lack stems from our industry's relative youth and the skyrocketing growth we have enjoyed in the past 10 years. And part of it can be traced to the very market diversity that makes us so interesting: we are loosely organised, thus details are hard to track.' Stitches magazine 'Top 75 embroidery shops' August 1993.

Although written in 1993, the essence of this remains true today.

There is very little contemporary published material about the commercial production of embroidery. Some research has been done into historical aspects of embroidery (Edwards 1969), and into the past industry in Switzerland (Wanner 1992, Tanner 1992); however, very little has been written about current production. Apart from Barker (1898), Iklé (1930), Edwards (1969), Risley (1961, 1973), Schneider (1978, 1991), and Miller (1997), little published work of any depth is available, in English, on the embroidery industry. Written in French, *La Broderie Mécanique* by Ernst Iklé (1930) is an unparalleled, beautifully illustrated account of the history of the mass production of embroidery up until 1930.

Although relatively 'old' by contemporary standards, Christine Risley's *Machine Embroidery*, Studio Vista 1973 remains the classic textbook outlining the different machine production methods, most of which are still in use today. Coleman Schneider's two books, *Embroidery: schiffli and multi-head* (1978) and *The Art of Embroidery in the 90s*' (1991) provide useful historical and technical information. *Machine Stitch Perspectives* by Alice Kettle and Jane McKeating published by A and C Black in 2010 is a welcome addition to the field. *Mechanical Drawing – the schiffli project* Miller and Hill (2007) provides an interesting account of the use of a pantograph schiffli machine to create a range of artefacts, demonstrating how machinery intended for one specific use can be utilised for a range of different purposes.

6.9.1 Journals/magazines

Eurostitch magazine
Stitches magazine
Printwear and Promotion

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6.10.1 Television broadcast

Primark on the Rack, BBC 1 Monday 23 June 2008

6.10.2 Useful websites

Bischoff embroidery company www.bischoff-textil.com
Jakob Schlaepfer innovative fabric company www.jakob-schlaepfer.ch/en
Karen Nicol embroidery designer karennicol.com
Hand and Lock embroidery production company www.handembroidery.com
Amy Twigger Holroyd www.keepandshare.co.uk/index.html
Natalie Chanin 'the Alabama project' http://alabamachanin.com
Embroidery Trade Association www.embroiderytrade.org

7
Designing through dyeing and finishing

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Abstract: The prime objective of dyeing is to produce levelled shades on various textiles. However, the judicious implementation of technical or mechanical modifications and changes in fibre type or composition may enable us to produce an unlimited number of fancy dyeing effects. The effects vary from simple spot marks to progressive lighter or deeper shades, woven dyeing, tie and dye, cross, and ring effects, surface dyeing, space dyeing, ombré dyeing, etc. There has been a similar focus on finishing, where the sole objectives are not only routine physical or functional modifications, rather various innovative effects are being introduced through calendaring, brushing, and differential washing effects, as well as speciality chemicals which intensify the look of apparel and appeal to customers. This chapter details numerous scientific approaches to the production of coloured designs and differential effects using manual as well as mechanical means, through dyeing and finishing, and highlights the future prospects of the same.

Key words: designing, dyeing, finishing, fancy effect, wash down, speciality chemicals.

7.1 Introduction

Dyeing guarantees the formation of levelled shades on textiles in exhaust or continuous methods. Cotton and other cellulosics are dyed with either direct, reactive, vat, naphthol or sulphur colours through their respective dyeing technologies. The selection of a specific dye depends on its cost, brightness of shade and fastness in relation to the intended end use of the textile. Being cheaper and having poor wash fastness, direct dyes are mainly applied to cotton textiles that require no domestic wash, e.g. curtains, carpets, etc.; good to excellent fastness and brilliant shades are obtained by dyeing with costlier vat dyes; naphthol colours develop shades which remain fast except when rubbed; reactive dyes produce fast and bright shades of moderate to good wash fastness, whereas sulphur dyes produce dark shades at a lesser cost and overall good fastness, except against chlorine. Nylon, wool and silk, which contain amino and carboxyl groups at their terminal ends, demonstrate dyeability with dyes containing acid or basic groups, including direct, basic, acid, metal-complex, reactive dyes. Dyeing with metal-complex and reactive dyes is the most effective way to ensure superior fastness. Acrylic fibres generally retain anionic sites, permitting dyeing with basic dyes, whereas non-ionic polyester is dyed with disperse dye. All man-made fibres can be dyed with disperse dyes but they tend to produce poor wash fastness in nylon and only light shades in acrylic, effects which restrict the application of such dyes to these fibres. Natural dyes can be applied to all textiles, but the shades produced lack brightness and have poor fastness. The main hindrance to their versatile application is inconsistency in their tinctorial characteristics and reproducibility, and this is paving the way for synthetic dyes to dominate in the dyeing industries. However, natural dyes are mostly bio-degradable, and bright fast shades can be developed using mordants. Such natural dye–mordant combinations are many in number; even only a single natural dye with many mordants, or vice-versa, is capable of producing various hues during dyeing (Chakraborty *et al.*, 2005). Dyeing technology is different for different classes of dyes, and the related parameters have to be carefully controlled in order to maximize dye uptake. After dyeing, dye has to be fixed onto the fibres to render the shades fast against various external agents, e.g. light, detergent, perspiration, chlorine, rubbing, etc. (Chakraborty, 2009).

It has been observed that dyeing in a specific hue has become less attractive over the years. This has prompted the formulation of innovative ideas and experiments, for example to discover if designing could be made possible through dyeing. Such practices exist unsystematically and do not receive due attention, mainly because of the complications involved in producing such designs, and the inconsistency associated with reproducing those effects. In various design and fashion schools across the globe, the fact that numerous fabric and apparel designing practices which involve dyeing are manually controlled, together with the use of costlier ready-to-use colours, is confining it to laboratory practice for reasons of feasibility. Tie and dye, batik, shade to shade dyeing, dip dyeing and ombré dyeing are very popular techniques, but they are not commercially viable. These techniques will also be included in this chapter. Industries produce fashion-wear and other light dress materials in many ways, occasionally by blending fibres from different origins, e.g. polyester–cotton, nylon–wool, polyester–wool or similar fibres possessing dissimilar pretreatment, fineness, etc. For example, various coloured effects can be formed on polyester–cotton blend. Polyester and cotton possess affinity for disperse dye and cellulosic dyes, respectively. Thus, the application of disperse-direct, disperse-vat and other combinations in contrasting hues produces cross shades. The differential affinity and uptake of a specific dye for variously pretreated cottons (such as scoured, bleached and mercerized) produces fancy coloured effects when blended and dyed. The modification of dyeing techniques and/or mechanical settings constitute alternative options in this context. A change to the mechanical settings, such as an uneven nip appearing in the padding, squeezes out the picked-up liquor to varying extents, thus varying the add-on to produce a differential coloured effect. In single colour multiple shade dyeing, different parts of a textile are immersed in the same dyebath for different lengths of time to produce shade variation. It is important to clarify at this juncture that uneven dyeing is the result of lack of control, over influencing factors or insufficient or overdosing of chemicals; the shade thus developed remains uneven without any specific order and looks ugly. In contrast, systematically produced dyeing effects can be used to create a charming look on level dyed ground which follows a pattern. In-depth knowledge is essential to produce these effects, which may be termed artistic dyeing technology.

Mechanical finishing imparts various physical aesthetic improvements such as lustre, softness, dimensional stability through calendaring, softening and sanforizing/blowing/heat setting; functional finishing creates special characteristics on fabrics, based on the needs of the end-product. Examples of these include anti-crease, water repellent, soil release, or flame retardant fabrics. Emboss calendaring has been in practice for a long time; special washing techniques using pumice stones or enzymes (or both) are used to develop a differential look on garments. The use of speciality chemicals has also been found to be effective in producing amazing differential effects.

It should be noted that designs produced in different processes (i.e. weaving, printing, dyeing and finishing) possess a few basic differences; aesthetic standards and look are mostly incomparable. Designs produced through dyeing and finishing can have very different results and the techniques used to produce them are many in number. Unlike weaving and printing, designing through dyeing and finishing is a relatively new concept, and no attempts have been made previously to review the area under discussion; for the same reason, supporting research papers are also limited. Only the approaches to scientific reproducible designing which have commercial importance will be documented in detail here. However, to enrich the subject, designing through hand dyeing will also be included in an attempt to discourage the use of ready-to-use dyes, as similar effects can also be produced with commercial textile dyes at nominal cost, and to remain in competition with commercial designing.

7.2 Designing through dyeing

Coloured patterns obtained through dyeing cannot be termed 'designs' in the true sense, but are mainly restricted to effects, for example spots, checks and stripes, cross and shadow shades, ring marks, progressive deeper or lighter effect, woven design effect, shade dyeing, or unsymmetric/symmetric coloured effects. These effects remain equally prominent on fabric as those created using other means of designing. An essential prerequisite is that a textile in any form (i.e. fibre, yarn or fabric) must be thoroughly pretreated (i.e. singed, desized, scoured, bleached or mercerized, as the case may be) to ensure the best possible cleaned white state for level dyeing. A large number of books deal with dyeing technology and are available worldwide (SDC, 1995; Peters, 1975). To avoid repetition, only the names of dyes and dyeing processes will be mentioned here.

7.2.1 Fancy effect through fibre dyeing

Dyeing is generally carried out in yarn or fabric form. In selective cases, where the production of fancy shades in contrast hues becomes difficult, dyeing is performed in the fibre stage, and is followed by blending. Thus, nylon and wool fibres, due to their inherent affinity for the same class of dye, cannot be blended and dyed in contrast hues, as the two different hues from the two different classes of dyes (say red from reactive dye class and blue from metal-complex dye class) show affinity for both fibres, thus permitting only a single composite hue for the blend. That is why nylon and wool are dyed with contrast hues separately in fibre form, and later blended. This is also the case for polyester–triacetate, wool–silk and cotton–viscose blends. This problem does not arise when the component fibres do not have an affinity for the dye used on the second component, e.g. polyester–cotton blend. Polyester has affinity only for disperse dye, while cotton possesses an affinity for vat, reactive dyes, etc., which permits blending followed by dyeing. This eliminates the costlier and more time-consuming processes of scouring and bleaching polyester and cotton fibres, which are essential for the production of fancy coloured effects on nylon–wool and similar blends.

The risk of structural change occurring in a fibre during the high temperature dyeing of second component while in blend makes it mandatory to dye in the fibre stage, before blending, for example in the case of a polyester–wool blend. Wool is partially decomposed during dyeing of polyester at 130 ± 2°C and to avoid this, polyester and wool fibres are separately scoured and bleached in the fibre stage, preferably in top form (carded sliver), before being dyed and blended. Dyeing in fibre form is to be avoided as this necessitates a second pretreatment in order to remove any additional impurities that have been gained through spinning and weaving during the conversion of fibre to yarn and fabric; this incurs a substantial increase in cost, as well as greatly reducing productivity. In spite of all these drawbacks, fibre dyeing has been a popular technique for dyeing different fibres in different hues before bending to form yarns and fabrics that possess fantastic multi-coloured effects, which are difficult to produce by other means.

7.2.2 Fancy designs through yarn dyeing

Multi-coloured yarns create a differential coloured effect on apparel and hosiery products. Designed knits are often manufactured using space dyed yarn, while decorated embroideries are manufactured using coloured yarns dyed in dip dyeing, loop dyeing, shade to shade dyeing, tie and dye and resist methods.

Space dyeing technology is used to produce a unique, multi-colored periodic effect on yarn skeins or packages in which two or more different colours typically repeat throughout the length of yarn. Such an effect is created through multiple injections of dye liquor of different hues from various sides of a package by an out-in technique (Plate V between pages 166 and 167 (a)). Kettle dyeing is a more advanced technique, manipulating dye in the vat to produce a number of different looks (Zogu, 2002, Albrecht *et al.*, 1972).

In dip dyeing or loop dyeing, certain parts of hanks are given the shape of a loop tightly tied to restrict the spreading of colour, and dipped in a dyebath. The dyed loops are opened and another set of loops are formed at different location and dipped in another dyebath of a different hue. Large numbers of cotton hanks are dyed from several natural, vat or reactive baths, with contrasting hues by hanging from steel supports, which are shaken occasionally to facilitate level dyeing (Plate V (b)). In ombré dyeing, each end of a fabric are dip dyed in two separate dyebaths, while the middle part oscillates between these two baths to create a fantastic gradation of two colours; the fabric may also be dyed from deep to white, i.e. in a single colour with a gradual fading effect (Plate V (c)).

Shade to shade dyeing is similar to dip dyeing, the difference being that it uses only one dyebath of one hue for different shades. One set of loops with a large number of hanks are dyed by dipping, but is not taken out of bath. Rather it is dipped more inside the bath, which causes fresh parts of the hanks to enter the bath from either side, creating shade variation. The loops that are dyed earlier develop a deep shade, due to spending more time in the dyebath, while parts that are dipped subsequently form a lighter shade of the same hue. Using this method, the whole hank can be dyed with an identical hue, but at different depths (Plate V (d)).

In terms of producing different hues with a single dye through reaction with different mordants, space, dip or loop dyeing can also be achieved by mordanting yarn hanks or packages at several locations with various mordants (in the same way as dyeing is done) followed by dyeing in either a package or a hank dyeing machine with a single dye to produce multi-coloured effects. In all these methods, the object is never to develop uniform dyeing patterns, rather to use differentially coloured yarns to develop non-reproducible designs on knitwear or embroidery products.

In the tie and dye method, selected parts of cotton hanks are covered with hydrophobic films, tied at the ends of films, and then dyed by dipping in a bath. Such a dyebath may be prepared with vat, reactive, sulphur, naphthol or natural colours. Once dyeing is over, the films are removed and the dyed parts are covered with films before the fabric is tied and dyed in another bath with a contrast hue. In this way, a loop dyeing effect can be developed through the tie and dye method with more pronounced marks among different coloured effects (Plate V (e)).

7.2.3 Designing through fabric dyeing

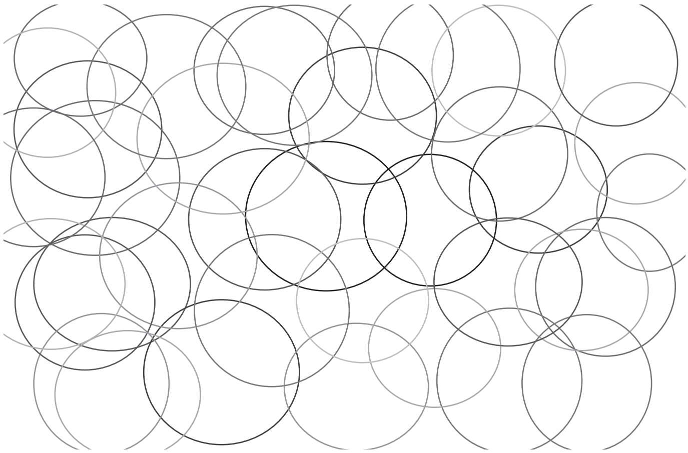
Most decorative designs are produced in fabric dyeing; some are produced during dyeing by controlling the dyeing parameters or technology, or through the work of dyeing machines. A few are developed through pretreatment and subsequent dyeing, and the rest through the chemical modification of the fibre before dyeing.

7.3 Designing through dyeing techniques

7.3.1 During the dyeing process

Varying pH

Denim is dyed in 6-dip 6-nip padding with intermediate airing; a pH of 10.8–11.5 is maintained in order to retain indigo in its mono-phenolate form, with consequence of a high strike rate and minimal diffusion to produce the so-called ring dyeing effect (Anon, 1989; Etters, 1993). In ring dyeing, indigo remains mostly on the yarn surface, leaving the inside undyed and producing deeper shades with less dye (Etters, 1995). An increase in the pH value leads to the formation of bi-phenolates, increasing diffusion and resulting in lighter shade. Ring dyeing helps to achieve differential wash down effects through rubbing out indigo or digesting cellulose. However, varying diffusion by varying pH also creates opportunities for lighter-deeper dyeing effects. Dipping in a reduced and solubilized indigo bath (3 g/l) for 30 s, followed by padding at 80% wet pick-up, and airing for 60 s, completes one indigo padding cycle. Six of these consecutive cycles complete the indigo dyeing process (DyStar, 2009). Dyeing at a higher pH (~13) in all padding baths causes denim to develop a lighter shade, the loss of NaOH in the bath leads to an increase in strike rate and a fall in pH, which results in the denim shade becoming progressively deeper (Etters, 1996). However, in no case should the pH value be allowed to fall below 10.5 as this would enable the indigo to revert to its leuco state.



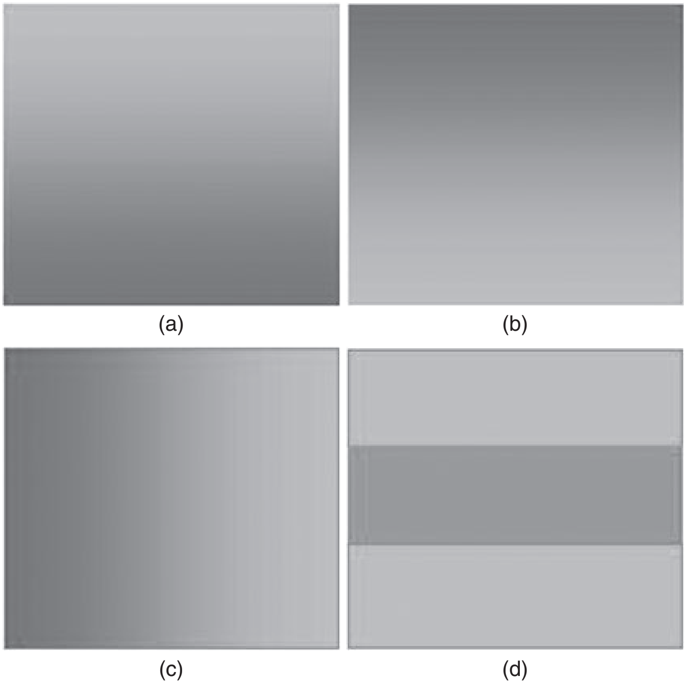
7.1 Short time foam dyeing effect.

Foam dyeing

Foam dyeing is a low liquor dyeing approach aimed at reducing wastage of energy, dye and chemicals. Foam remains in the gas phase, separated by a thin film or lamellac. The stability of the latter is crucial for level dyeing. The generation and application of foam, and parameters influencing it have been well documented (Cooke, 1983). Passing fabric through a dye liquor in the form of stable foam for a reasonably short time creates a pattern of circles as the foam collapses on the fabric surface (Fig. 7.1). Vat dyes used in combination with dispersing agents produce stable foam. This creates all-round fast foam effects and brilliant shades on fabric surfaces, which are only slightly affected by wet rubbing (Magda *et al.*, 1997). Foam generated with reactive dye can also be used to produce coloured circles of good fastness (Shakra *et al.*, 1989). Prolonged dyeing tends to level the shade, suppressing the look of the design, and so is to be avoided. To produce multi-coloured circles, which overlap each other, a fabric may be passed through several such foam baths containing dyes of contrasting hues, with intermediate drying. Light to deep interacting coloured circles can be produced easily compared to the difficulty faced in producing deep levelled shades, as a shorter dyeing time aids the stability of foam, even for deep effects. One-sided design effects may also be developed by passing the fabric over foam.

Varying padding pressure

The percentage pick-up and add-on of pad liquor on fabric is controlled by adjusting the time for which it is immersed in dye liquor and the pressure on the top roller in continuous dyeing. The pick-up of pad liquor can be progressively increased by proportionally reducing pneumatic pressure to produce a progressively lighter dyeing effect, or vice-versa. This process of changing working pressure with time can be controlled on-line and made periodically effective over a specific length of fabric (Fig. 7.2(a), (b)). By changing the shape of the padding rolls from that of an



7.2 (a) Progressive lighter lengthwise; (b) progressive deeper lengthwise; (c) gradually deeper across width; (d) bar effect.

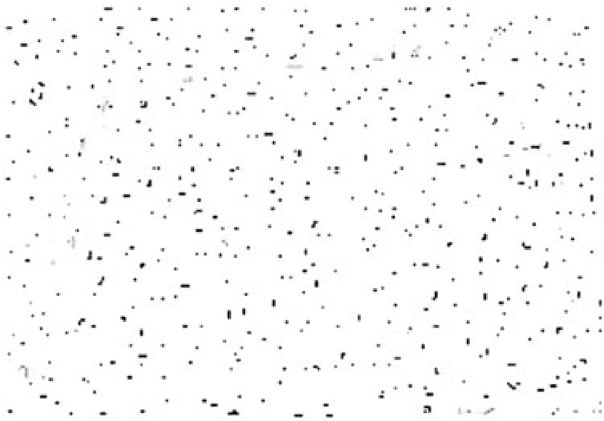
exact cylinder to that of a frustum with a negligible difference in diameter at either end, the working pressure across the width of the fabric can be gradually increased/decreased, and hence the pick-up also. The progressive increase in nip height across the width helps to develop a gradually deeper/lighter shade from one selvedge to another, and leaves no demarcation line (Fig. 7.2(c)). Changing the padding pressure periodically makes it possible to create a periodic bar effect in which light and deep bars are produced across the width of the fabric (Fig. 7.2(d)).

Spray dyeing

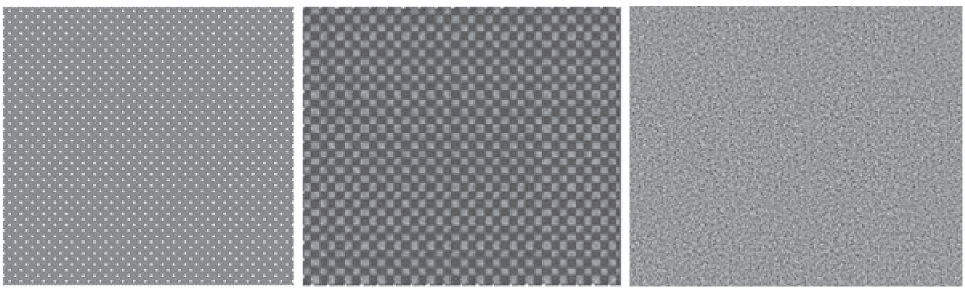
The controlled spraying of dye liquor on fabric, while the latter moves at an adjustable speed, reduces the overall dyeing time and cost. Multi-coloured spot effects can be produced on one or both sides by adjusting the spray intensity and the variety of hues, as well as the concentration of spray liquor. Less heat energy is wasted during drying also (Fig. 7.3).

Ink jet dyeing

Ink jet dyeing is a non-contact colouration technique. There are two methods of ink jet dyeing, drop on demand and compound jet, both of which enable us to develop artistic designs. The key to developing various effects is the steady ejection of homogeneous ink droplets, consistent in size, speed and direction, in response to a elec-



7.3 Spray dyeing effect.



(a) (b) (c)

7.4 (a) Reserve effect; (b) cross effect; (c) shadow effect.

tronic signal (Smith and Simonson, 1987; Graham, 1989). The absence of a thickener in the dye solution does not restrict the capillary action to developing designs without sharp boundaries. The selection of hues available can be quite large, and so can the dyeing effects.

Dyeing of blends

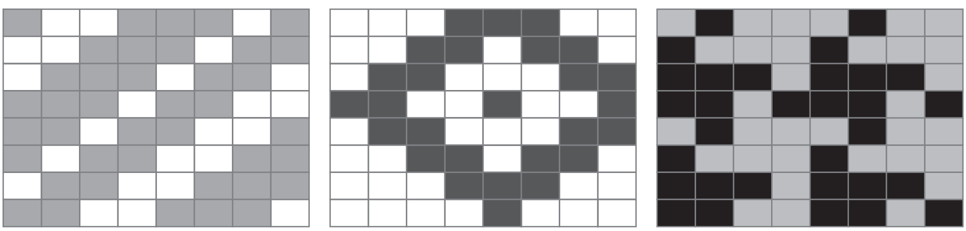
The dyeing of blends can produce various fancy effects, including reserve, cross, shadow and solid shades (Shore, 1979). The reserve effect is created by dyeing just one component of the blend and leaving another undyed, producing a final effect of white or coloured spots on coloured or white fabrics, respectively (Fig. 7.4(a)). The cross effect is obtained by dyeing different components of a blend in contrasting hues (Fig. 7.4(b)). In the shadow effect, both the components of the blend are dyed in the same hue, but at different depths of shade, e.g. dyeing a polyester-cotton blend with a 3% and 1% shade on polyester and cotton, respectively, using different classes of dye that possess the same hue. It is important to keep in mind the tinctorial strength of the individual dyes to make the effect prominent or achieve a sharp contrast (Fig. 7.4(c)). Solid shades are obtained by dyeing different components of the blend with same hue, shade and tone, and hence will not be discussed due to the fact that this technique does not produce a fancy effect. Appropriate dyeing technologies should be followed for each dye-fibre system.

Woven designing effect

Woven designs, such as twills, diamonds, checks and stripes, are produced by introducing coloured ends and picks of different hues in a specific order during weaving. The same effect can be produced by dyeing white woven fabric constructed with yarns made of different fibres. It is possible to produce coloured twill and other shapes (e.g. diamonds) on a white background using white polyester and cotton yarns in warp and weft in a specific order during weaving, then dyeing the polyester part of the fabric at 130 ± 2°C with disperse dye. Cross dyeing, by dyeing polyester with disperse dye and cotton with reactive, vat or sulphur dyes, will produce coloured and weave effects (Fig. 7.5). Other fancy woven effects can also be developed by varying coloured patterns and fibre combinations. Other instances of such effects include terry towel made of cotton pile yarn and polyester, or nylon ground yarn, stitching end in double, or backed, or treble fabrics, where ground yarn belongs to another fibre class. The judicious selection of various yarns, based on their affinity for different dyes, is the main criterion for producing the effects described above.

Restricting jigger movement

Jigger is widely used in the dyeing of woven cellulosic fabric. After loading the entire fabric onto the jigger machine, its two ends are tightly fixed on take-up, or let-off rollers and locked in such a way that after one complete turn, the let-off roller stops due to locking, and then the take-up roller, before the reverse movement of the fabric starts. This added advantage of arresting fabric movement beyond a certain length can be exploited by locking the required length of fabric for a variable dyeing time to produce periodic bar effects or progressive lighter or deeper shades throughout the length. The whole length of fabric can be loaded in one go, but each part of it is only allowed to pass through the dyebath for certain amount of time. This gradually reduces the concentration in the dyebath to produce a lighter shade on the desired length of fabric, equivalent to shade to shade dyeing.



7.5 Woven design effects through dyeing.

Surface dyeing effects

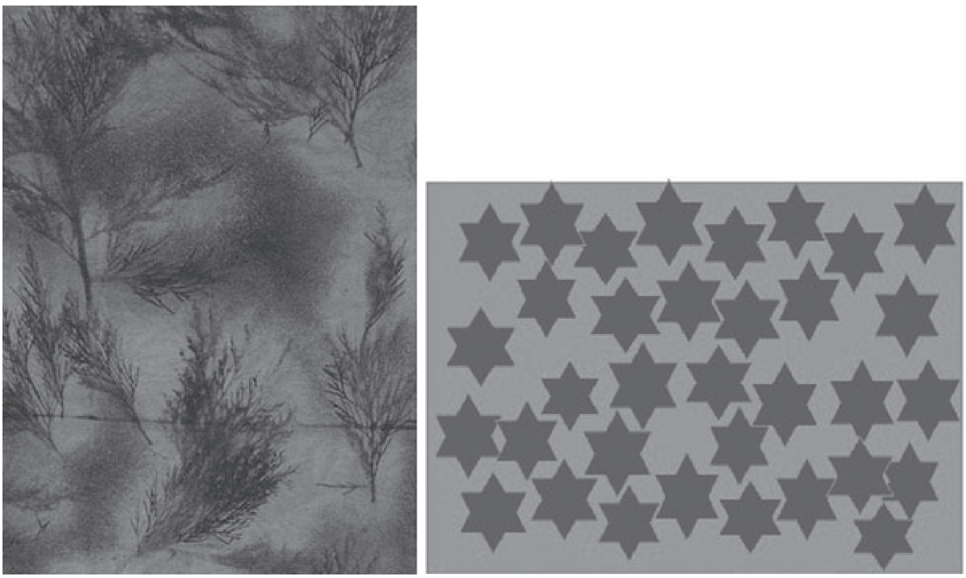
Dyed fabric is spread over a table and covered with tree leaves, hard paper designs or other designed material. Sodium hypochlorite, sodium hydrosulphite-sodium hydroxide or potassium permanganate solution is sprayed onto the fabric, which partially discharges colour from the uncovered areas, either at room temperature or on subsequent heating, producing artistic ‘surface dyeing effects’. Dyes that are dischargeable against hypochlorite, like sulphur and limited reactive dyes, or those that are dischargeable against hydrosulphite-hydroxide, like direct, naphthol colours, are used to produce this effect on cotton (Fig. 7.6(a)).

Alternately, cotton fabric is dipped in dye solution, squeezed, and covered with designed paper of the same dimension. The design is produced on paper by removing a part of it, according to the effect required. When the dyed fabric–designed paper combination is passed through the nip of two squeezing rollers at high pressure, the paper absorbs the dye from the covered areas, showing lighter ground with deep designs on the open areas (Fig. 7.6(b)).

7.3.2 Designing by physical modification

Using differently pretreated cotton yarn

A shadow effect can be produced by mixing cotton yarns with different pretreatments. Accessible free volume and reactivity are minimal in scoured cotton and maximal in mercerized cotton; dye uptake is in proportion to these factors. Three different types of cotton yarns, scoured, scoured-bleached and scoured-bleached-mercerized, are placed in a particular order of warp and weft during weaving in order to obtain shadow, check and stripe or other effects when dyed with vat,



(a) (b)

7.6 (a) Surface dyeing (courtesy: *Treads* magazine); (b) surface designing.

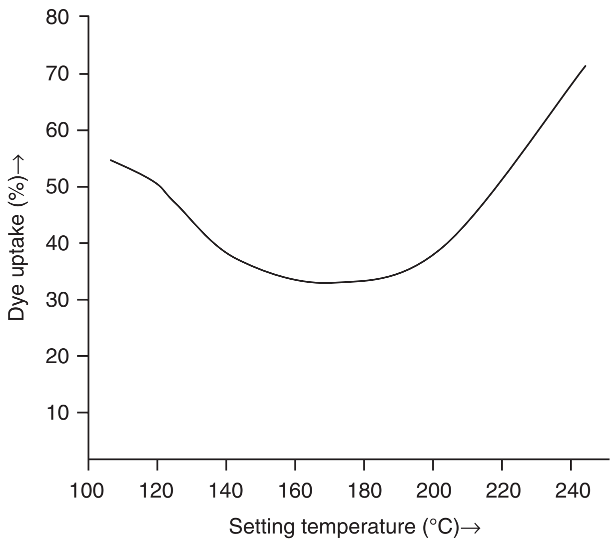
reactive or other cotton dyes. It is even possible to produce a light black fabric with medium black check/stripe marks and deeper selvedge by placing mercerized yarn on selvedges, scoured-bleached yarn at regular intervals in warp and weft, and using scoured yarns for the rest of the fabric. Viscose is cheaper and possesses the highest dyeability, hence it can also be either blended or used in warp and/or weft to synergize the coloured effect. The yarns, in ascending order of dye uptake, are scoured, bleached, mercerized cotton and viscose.

Changing fabric compactness and yarn twist

The diffusion of dye varies with twist in component yarns and with compactness of fabric; the greater the compactness or twist (or both), the lower the dye uptake. Yarn spacing in warp and weft can also be varied at different points in the fabric, in order to vary dye uptake and dye yield, both facilitating the formation of light and deep coloured effects accordingly. Open end cotton yarns are coarser, having a lower twist than ring spun yarns. Due to their different dye strengths, such yarns can easily be used to produce shadow effects if placed suitably in the fabric (Iyer *et al.*, 1998).

Changing heat setting temperature

The heat setting of polyester is carried out in order to stabilize its structure and to avoid post-dyeing shrinkage. However, heat setting under tension increases crystallinity, which leads to fabrics having a lower dye uptake. Unset polyester demonstrates approximately 20% more disperse dye uptake, which falls gradually with an increase in setting temperature, up to 140°C. It then remains constant up to 180°C, and slowly increases up to 200°C, beyond which point a drastic increase is observed, as explained in Fig. 7.7 (Marvin, 1954). By placing set and unset polyester yarns in



7.7 Effect of heat setting temperature.

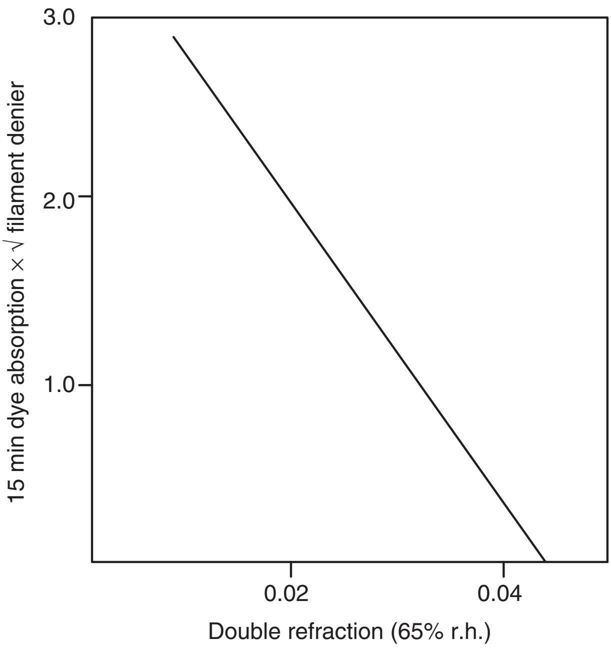
the required order, or polyester yarns set at different temperatures, to weave fabric on dyeing with disperse dye, it is possible to produce self-shades of varying depths. However, such a woven fabric may exhibit differential shrinkage during subsequent curing processes (Mittal and Trivedi, 1983).

Changing draw ratio during fibre spinning

A change in the draw ratio of a filament varies indirectly with its dye uptake: the higher the draw ratio, the lower the dye uptake, due to a reduction in the effective amorphous nature responsible for retaining dye *in situ*, as shown in Fig. 7.8 (Burdett, 1975). Man-made fibres, drawn at varying drawing forces, are converted to yarn during spinning. The fabric is then woven from a mixture of differentially drawn fibres which, upon dyeing, will produce a shadow effect at desired locations.

Using micro-fibre along with conventional fibre

Micro-fibres are remarkably finer, and possess approximately four times higher surface area, than that of conventional man-made fibres (Fong, 1995). At identical dyebath concentrations, micro-fibres will develop a shade five times lighter than that of conventional fibres (Partin, 1991). The positioning of micro-fibre yarn and conventional man-made fibre yarn in a specific order in woven fabric creates self-coloured effects on dyeing.



7.8 Impact of increasing draw ratio on rate of dyeing.

Resist dyeing

Tie and dye, batik, monochrome and polychrome effects are versatile dyeing effects in which pretreated hank or folded woven/knitted fabric is covered with polyethylene sheets in selective areas or tied up at sheet ends, or a protective layer of hydrophobic material such as wax is applied, to resist the uptake of dye on the protected area. The fabric is dyed by dipping in a dyebath; the cover films are removed and placed over the dyed areas, before being tied and dyed again in another bath of contrast hue in order to produce periodic coloured effects (Plate VI between pages 166 and 167 (a), (b)). Alternatively, tying just one end at selected points, then dip dyeing, produces one colour dyeing with periodic white marks (Plate VI (c)). Batik dyeing is achieved by dipping the dyed/white fabric in a hydrophobic liquid (molten wax), twisting the fabric to develop cracks, then dipping in dyebath. The dyed fabric is then packed and twisted again to develop cracks at another location, and re-dyed. Multi-coloured inter-crossing lines are produced (Plate VI (d)).

Tecnorama have made it possible to create resist effects mechanically with two patented machines, the Batikrama for monochrome effects and the Cromorama for polychrome effects. Tie and dye, washed-out or crushed effects are created by impregnation, succeeded by two-dimensional squeezing and dyeing (Tecnorama, 1987).

7.3.3 Designing by chemical modification

Blending cationized/anionized fibres

The development of carrier free dyeable polyester (CFD-polyester) and cationic dyeable polyester (CD-polyester) has facilitated the atmospheric dyeing of polyester, as well as the production of dyeing effects with greater ease. Conventional polyester is dyed with disperse dye at 130 ± 2°C. The compactness of CFD polyester has typically been reduced by changing reactants (T_g ~75°C) and is dyed at boil for all shades with disperse dye without carrier. In CD-polyester, anions are introduced during polymerization to make it dyeable with cationic dyes. These three types of polyester fibres (conventional, CFD and CD types) are dyeable with different shades when dyed with disperse dye at or above boiling temperature, due to variations in compactness. In the case of woven or knitted fabrics produced by mixing these three types of polyester yarns, dyeing at boiling temperature will not result in the dyeing of conventional polyester, but CFD-polyester will be dyed with a deeper shade, and CD-polyester will produce an intermediate. Dyeing with basic dye will affect only the CD-polyester in the mixture, leaving other polyesters undyed. Various coloured effects can be produced by manipulating the locations of these three fibres during weaving and/or by selecting a dyeing process.

When CD-polyester and polyester terpolymer (manufactured from a mixture of dimethyl terephthalate, ethylene glycol, dimethyl glutarate and sodium salt of sulphonated dimethyl isophthalate, respectively) are mixed with the fibres or yarns of a polyester co-polymer (manufactured from dimethyl terephthalate, ethylene glycol and polyethylene oxide) produce attractive tone on tone and cross dyeing effects (Anon, 1990). These effects are due to the variation in dye uptake in different types of polyester, which is in proportion to their compactness.

Pure polyacrylonitrile is not dyeable and is a rigid polymer. It becomes dyeable only when anionic or cationic co-monomers are introduced to the structure during polymerization to develop a basic dyeable or an acid dyeable polymer. An anionic PAN is generally chosen over a cationic one because it costs less to produce and has greater dyeability (Vaidya, 1988). The process of blending both types of PAN, or suitably placing them in warp and weft, followed by dyeing with basic and acid dyes separately, produces a contrasting coloured effect.

Acrylic fibre copolymerized with dimethyl amino ethyl methacrylate shows excellent stable dyeability with acid dye over a wide acidic pH range because of the strong basicity of alkylamino groups. When such acrylic copolymers are blended with normal cationic dyeable acrylic polymer in fibre or yarn state, a differential cross dyeing effect is produced in one bath, via a two stage process (Sawa and Hoten, 2001).

Pretreatment of cotton with ionic reagents

The pretreatment of cotton with aqueous Hercoset 57, a cationic water soluble polyamine-epichlorohydrin precondensate (Hercules, USA) and 10 g/l of Sandozin NI forms a cationic resin on the fabric surface, which enhances the anionic dye yield (Chong *et al.*, 1995). Specific concentrations of Hercoset 57 and Sandozin NI are sprayed over desired locations on cotton fabric, dried and cured, then dyed with anionic dyes (such as vat or sulphur dyes) applied through reduction to develop a shadow effect.

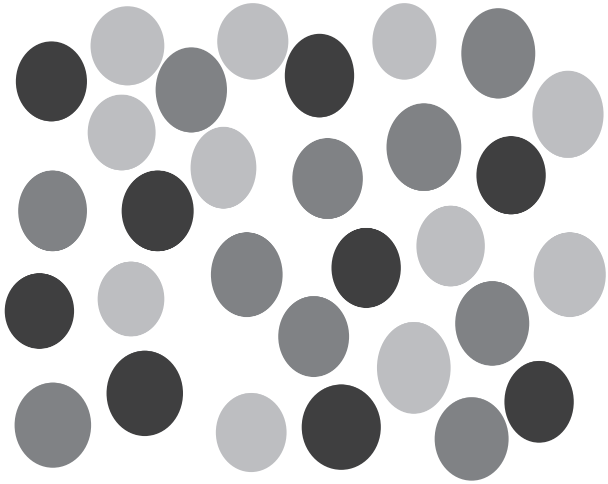
Cotton fabric can be locally pretreated with selective metal salts at varying concentrations, which are then converted to insoluble metal hydroxides by treatment with NaOH. The padding of such a treated fabric in an anionic dyebath promotes dye uptake; iron and cobalt (II) salts were found to be highly effective, even at very low concentrations. Dye uptake is greatly increased when vat dyes are used, and when the fabric is padded then aired (Chavan and Chakraborty, 2000, 2001).

The pretreatment of cotton with various concentrations of NaOH at different points develops differential reactivity; dyeing of treated fabric through padding with any cotton dye and then applying after treatments, produces coloured effects at different depths, as shown in Fig. 7.9 (Chakraborty *et al.*, 2004).

Cotton yarn pretreated with cationic reagents demonstrates a greater uptake of acid and direct dyes than untreated yarn. In contrast, treating cotton with an anionic reagent makes it dyeable with basic dyes. The process of mixing such treated/untreated yarns with each other during dyeing, can be used to create varieties of tone on tone, as well as cross dyeing effects, in a single bath with very little cross staining (Clipson and Roberts, 1989).

Mixing fibres of varying weightage in functional groups

The dyeability of nylon can be varied by manipulating the weightage of end groups and through structural modification (Dawson, 1971; Vaidya, 1988). The introduction of excess —NH_2 groups, through the addition of N:N′-bis (3-aminophenyl) piperazine to nylon salt before spinning, enhances the basicity of the fibre and produces ‘Deep acid dyeable nylon’, which retains end —NH_2 (100 meq/kg) and —COOH



7.9 Self-coloured dyeing effect.

(7–8 meq/kg), compared to those in normal nylon as 40 meq/kg and 65 meq/kg, respectively. Similarly, deep basic dyeable nylon is produced by incorporating monomers which contain —SO_3H groups, such as 5-sulphoisophthalic acid, sulphanilic acid, etc., during polymerization, resulting end —NH_2 and —COOH groups of 7–8 meq/kg and 100 meq/kg, respectively (Vaidya *et al.*, 1977). Placing normal, deep acid dyeable and basic dyeable nylon yarns at required positions during weaving or knitting produces fancy shades and designs after dyeing with various dye classes. Disperse dyes produce levelled shades on all nylon, but a mixture of disperse-acid or disperse-basic dyes would result in a two-coloured effect. This technique is used exclusively in the carpet industry.

Treatment with plasticizer

The application of an external or internal plasticizer loosens the structure of a man-made polymer, reduces the glass transition temperature, and promotes dye uptake at a relatively lower temperature (Billmeyer, 1994). Due to a reduction in the effective cohesive force among polymer chains, compact polymers become highly flexible, facilitating the smooth diffusion of dye molecules. Polyester, which has been treated with plasticizer during melt spinning (internal plasticizer) or subsequent treatments (external plasticizer), is mixed with conventional polyester yarns during weaving to obtain fancy dyeing effects (Shukla *et al.*, 1991).

Varying degree of polymerization

The dyeability of man-made polymers varies inversely with their degree of polymerization; the higher the DP, the higher the dyeing temperature will be. The use of man-made fibres spun from polymers of differential degrees of polymerization in weaving or knitting produces a self-coloured effect at varying depths at desired locations. The effect can be further manipulated by varying the dyeing temperature and opening the polymer structure.

7.4 Designing through garment dyeing

Garment dyeing is a strategy of rapid response, minimizing lead time in the supply chain. Garments are dyed in two ways, either grey fabric is made into a garment before being pretreated and dyed, or the fabric is pretreated and made into a garment before being dyed. The commercial manufacture of a garment from dyed fabric in order to avoid the problem of uneven pretreatment and dyeing due to its differential construction does not belong to garment dyeing, rather it is a manufacturing process. Producing fancy effects may be made more attractive by stitching different types of coloured fabrics, which might not be feasible when dyeing in garment form. Out of the two methods of garment dyeing described above, the loss of fabric is less in grey garment manufacture and its processing. To create a fancy effect, fabric pieces made of various fibres, and possibly with different pretreatments, degrees of polymerization, etc., need to be stitched at desired locations to create differential self-coloured or two-coloured dyeing effects. The optimization of dyeing time is a prerequisite for a given dye-fibre system to obtain thorough and levelled effects on differential constructions, such as collars, cuffs or ribs.

The effects of dyeing on garments may include shrinking, abrasion, creasing, deformation, and unlevelled dyeing of seams. Trimmings, buttons and zips may cause problems. When designing garments, notably sportswear, it is essential to envisage and provide for garment dyeing to be possible; this calls for close collaboration between garment designers, manufacturers and finishers.

Designing with fashion-oriented stitches, using multi-coloured sewing threads obtained by fancy yarn dyeing, may also make a garment appealing; in order to achieve this, it is important to use the best co-relation among fabric, sewing thread and sewing style (Lin, 2003). In the era of high fashion, designing apparel and surviving in a global market has been a complicated task, in spite of assistance from computer modelling (Ng *et al.*, 1993).

7.5 Designing through finishing

Wet and dry finishing enhance the aesthetic and functional characteristics of a fabric, depending on the type of finish applied. Each finishing process promotes the look, feel, handle, stability or performance of textiles in terms of crease recovery, soil release, flame retarding and water-repelling, etc. The finishing process, as such, is incapable of producing any specific coloured effect as it promotes the end use of the textile but not the design. However, in a few cases, finishes are applied to produce designs on fabrics and apparel.

7.5.1 Designing during calendaring

Calendaring develops a flat and polished look on the surface by passing the fabric through calendar rolls. In calendaring, there are several influential parameters that control the quality of the product, such as the plasticity of the fabric (which is developed by passing it through steam), the temperature, pressure, nature (metallic/compressible) and diameter of the calendar rolls, the smoothness, speed and direction of their rotation, the nip height and direction of fabric movement. Many different calendaring machines are employed, depending on the end use of the product, for example, a swizzing calendar for light weight dress material, a chasing calendar for heavy fabric, or a friction calendar for very light and cheap fabrics such as tracing and book binding cloth. In a Schreiner calendar, all three rollers have the same diameter and the top roll is engraved with very fine lines (250–300 lines/in) running parallel at 20º, which are transferred on the fabric (Hall, 1966). In an Emboss calendar, the top roll is engraved with a design, which is transferred onto the fabric during calendaring. Padding fabrics with an anti-crease finish prior to Schreiner or Emboss calendaring makes these effects permanent.

7.5.2 Designing by raising

The ancient method of imparting softness by raising fibres through combing is a unique approach to developing design. The raising of fibres through brushing or combing at desired locations forms designs on the fabric surface (Hall, 1966). A fabric which requires a local raising effect is passed through rollers which carry integrated metal brush wires. These are arranged locally to pull out fibres while the fabric is passing through them. Alternately, a molten dope dyed polymer can be sprayed onto the fabric in order to obtain a coloured effect while the area covered by the polymer remains raised.

7.5.3 Differential effects on denim

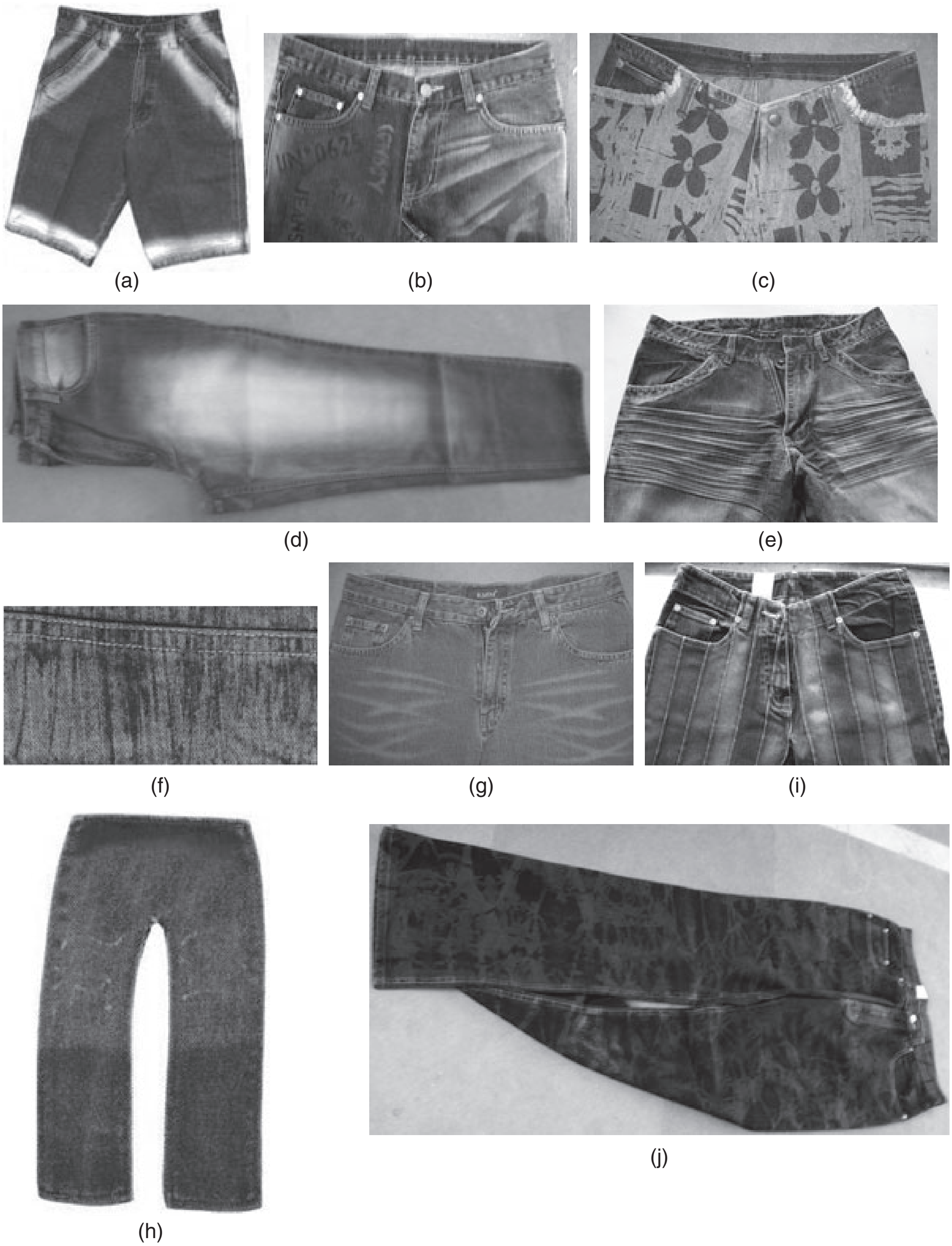
Denim has successfully established itself as a simple but fashionable fabric across the globe. Over the years it has appeared in multiple varying shapes, designs, and styles; the latest stretch denim enables us to produce stable, easy care and best fit garments. There are different dyeing and washing strategies in place to create marvelous textures and dyeing effects. The worn-out look is growing in popularity amongst fashion conscious consumers. New lightweight denim fabrics have been designed for both men's and women's formal suiting (Prescott, 2004). The appearance is continually being modified so as to appeal to the varied fashion trends, the demands of different generations and to suit the varied tastes of consumers, such as aqua washed denim, black denim, crushed denim, destroyed jeans, reverse denim, worn out denim, vintage denim, petroleum wash, snow wash, sand blasting, peach skin effect denim and a few more (Parmar *et al.*, 1996).

The effects or designs are experimented on ring dyed denim, in which indigo remains mostly on the surface layers. Indigo dyed denim is often over-dyed with sulphur dye to create simple fading effects with better contrast. The differential fading effects are obtained either by applying speciality chemicals at desired locations on jeans and other denim garments, or alternatively by washing denim products with stones, enzymes or other techniques.

With speciality chemicals

Speciality chemicals can easily be used to produce differential effects on denim. Such chemicals are manufactured and available worldwide, but the specifications of these chemicals are patented. Americos (AATCC corporate member) chemicals produce pioneering effects on denim, which are difficult to achieve even through washing techniques (Aim, 2009). A quick 'snow white effect' is produced when Americos Deni XL solution (derived from sodium permanganate) and Americos Deni modified paste (viscosity builder) are mixed uniformly and applied to a denim garment using a spray/brush/screen method, dried and subsequently neutralized with Americos Deni OX (Fig. 7.10(a)). Americos DPDF colours (a non-pigment based direct colour fixer) are sprayed on the denim garment, dried at room temperature, and then dipped in a bath containing Americos Deni OX (neutralizer), Americos washstore (booster) and Americos fixer ST (fixer) to produce variable fading effects. The colour spray technique is inexpensive and affordable for most denim garment processors, saving water, energy and time (Fig. 7.10(b)). Designs are engraved on denim using a resist mechanism, keeping the indigo intact on selected areas. The resist effect is achieved during washing or by dry spraying. In the dry system, resist chemicals such as 'Americos Deni OX' and 'Americos ball wash resister' are sprayed onto the selected portion, followed by application of discharging chemicals like potassium permanganate or sodium hypochlorite. The wet concept develops design by applying resist chemicals to denim, then drying, curing at 150°C and treating it with sodium hypochlorite or potassium permanganate in a wash wheel; resist effects develop on the treated portion only and the remaining portion becomes a light background of indigo, developing a beautiful contrast between the dark blue portion (resist portion) and the light indigo background (Fig. 7.10(c)). Americos Denim White is a ready-to-use white pigment with various print auxiliaries, which can be used to develop a snow-white effect with minimum harshness on denim garments (Fig. 7.10(d)).

Wrinkled jeans can be created by spraying Americos Wrinkle A-75 on selected areas of a denim garment. Creases or folds are created manually, dried and cured at 150°C to form wrinkles that are permanent and stable after multiple home launderings (Fig. 7.10(e)). A complicated scratchy look can be created using Americos scratch chemical with a very fine brush, then drying and curing at 150°C. Americos Deni DPDF Supra colour is sprayed onto the fabric, dried at room temperature and then treated with Americos Deni OX, Americos Deni Washstore and Americos Deni Fixer ST (colour fixing agent) to develop a unique scratchy effect on the portion to which it was applied (Fig. 7.10(f)). The 'used and worn out look' is created through tinting on enzyme washed jeans. Americos Dy-Soft is a blend of colour and softener, specially designed to tint and soften jeans in one go. Denim garments are heated up to 50°C in a drum washer, Americos Dye booster is added and the machine is run at 50°C for 5 min. Americos Dy-soft is added and the machine is further run for 5 min. Sodium chloride is added, the temperature is raised to 75°C and the drum washer is run at this temperature for 10–15 min. Garments are rinsed in water, hydro-extracted and tumble dried (Fig. 7.10(g)). The idea of 'wet look' fabric is to make the garment look as though it is wet, or as if water has been



7.10 (a) Snow white effect; (b) differential fading effect; (c) resist designs; (d) white effect; (e) wrinkled effect; (f) scratchy look; (g) used and worn out look; (h) wet look; (i) shaded fantasy effect; (j) cloudy effect.

sprinkled on it. This is achieved by applying Americos Wet look chemical, drying and curing at 150°C, then treating with diluted sodium hypochlorite in a wash wheel (Fig. 7.10(h)). Fantasy or sparkling effects are popular in children's and ladies' garments. Americos produces a ready-to-use micro-emulsion of metallic sparkle in a range of shades, from traditional gold and silver to the latest fluorescent green and yellow (Fig. 7.10(i)). Americos 'tri-functional colours' are specially designed to create a cloudy effect. The garment is tied with threads at different points, according to the design to be developed, and dyed with these colours in a garment dyeing machine. It is then bleached with diluted sodium hypochlorite and treated with acetic acid; more than two coloured effects can be easily obtained from one tri-functional colour (Fig. 7.10(j)).

With smart colourants

Smart colourants change hue according to fluctuations in temperature, light or environmental changes and are categorized as: i) thermochromic, ii) photochromic, and iii) glow in the dark. Thermochromic colours change hue with variations in temperature, and photochromic colours upon exposure to UV light or sunlight, while glow in the dark colours become bright in the dark, like fluorescent colours.

Through washing

Indigo is used exclusively in the dyeing of denim due to its brilliant blue colour and excellent fading characteristics after washing and abrasion. It is possible to achieve a variety of washing effects on indigo dyed denim, which vary with the changing fashion trends of various generations. Dyeing of denim at pH 10.8–11.5 develops a ring dyeing effect. This fulfils two crucial objectives: the diffusion of indigo is suppressed by restricting it to the surface of the denim in order to create a deeper shade with less indigo, and the subsequent white fading effect can be easily developed by removing the surface layer of the denim through various washing techniques, such as stone washing, acid washing, bleach washing and enzyme cum stone washing.

In stone washing, pumice stones rub against denim garments to scoop out the surface layer, along with the indigo dye, producing a 'worn out look'. Colour fading is more apparent but less uniform, specially in the areas like waistband, pockets and the seam, creating a 'used look'; the extent of fading depends on washing time, stone ratio, stone size, liquor ratio and garment load (Fig. 7.11(a), (b), (c)). There are many problems associated with stone wash, for example: i) it is difficult to achieve consistency in quality, ii) stone residues become trapped, leading to yellowing and a harsh feel in washed garments, iii) washing drums become damaged as a result of repeated stone abrasion, and iv) garment accessories can also become damaged.

Acid wash, which is also known as snow/ice/white/frosted wash, is based on the dry tumbling of desized garments in the presence of soft porous pumice stones that have been pre-soaked in a solution of NaOCl (5–10%) or $KMnO_4$ (3–6%) to affect local bleaching. The result is a non-uniform sharp blue-white contrast (Fig. 7.12(a), (b)). The contrast can be further enhanced through subsequent treatment with an optical brightener (Rucker *et al.*, 1991). Ironically, dry tumbling permits only a fraction of the rated capacity of the rotary washer (~25–33%) for free tumbling, with a drop distance for the stones; and $KMnO_4$, the preferred bleaching agent used to create special looks ranging from slight random bleaching effects to complete white, results in the yellowing of faded areas during storage (Naik *et al.*, 1997).

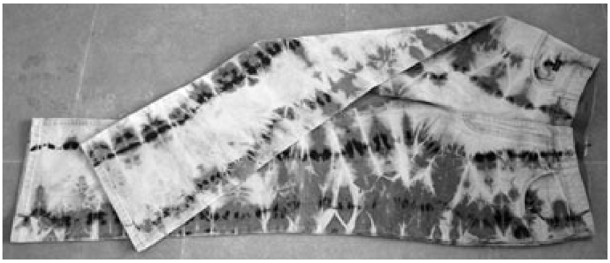
(a) (b) (c)

7.11 (a) Stone washed (courtesy: Kuyah); (b) stone washed (courtesy: Shri Lakshmi cotsyn); (c) stone washed and sand blasted.

(b)

(a)

7.12 (a) Acid washed jeans (courtesy: Ugly earring); (b) acid washed denim vest (courtesy: Celeb look).



7.13 Bleached jeans (courtesy: Ecadsemy).

Strong oxidative bleaching agents, such as NaOCl or $KMnO_4$, are used in bleach washing, with or without stones (Chong, 1994). Discoloration is usually more apparent, depending on the strength of the bleaching agent, the liquor ratio and how long the garment is bleached for; the use of strong bleach over a shorter time is preferred as this tends to result in a better contrast of bleached colours (Fig. 7.13). Anti-chlorination, rinsing with optical brightening agents and softening are essential steps towards minimizing the subsequent yellowing and tendering of indigo distressed denim.

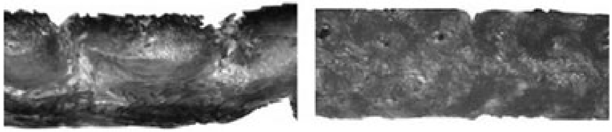
Bio-washing or bio-polishing with enzymes is a highly effective means of producing a differential coloured effect; processes that combine the use of pumice stones and cellulase enzymes are very popular (~80%) though the trend towards stone free processes is growing in favour. The enzymes hydrolyze cellulose at the surface, reacting with β-1,4–glycoside bonds and resulting in the loosening of indigo from the surface of the denim without acting on starch; the friction between the garments and the washing machine is sufficient to remove indigo into bath; the denim surface becomes smoother with a soft feel due to the loss of surface fibres (Fig. 7.14(a), (b)). An optimized concentration of chemicals and the right working parameters are essential in order to obtain a wash down effect with minimum weight loss and to avoid back staining. A typical enzyme washing process comprises the desizing of denim for 10–15 min, then rinsing, washing with the acid cellulase enzyme for 30–60 min at 60°C at pH 4.5–5.5, hot rinsing at around 80°C and treating with softener. The washing of denim with cellulase is more effective and accurate; the resulting quality, reproducibility and accuracy of fading effects are very high, as is productivity. Cellulase can be used to develop a greater level of softening than that which can be obtained using pumice stone and is eco-friendly. Since cellulase is only reactive on cellulose, sizes and other impurities must be removed before cellulase treatment.

7.6 Future trends

The production of designs through dyeing and finishing is a challenging job; control over the dyeing process and technical expertise are essential. The use of fatigue over single colour dyeing has shifted people's mindsets towards innovative and artistic dyeing effects. Hand dyeing techniques can indeed be used to produce unlimited artistic designs, but they are confined to the laboratory and other small-scale

7.14 (a) Enzyme washed (courtesy: United garment industry); (b) enzyme washed jeans (courtesy: Chongging).

practices; they have limited impact in the highly competitive global market due to their inconsistent reproducibility and the higher cost arising from the use of ready made dyes, as well as the inefficient use of dye liquor. The keys to succeeding in future global competition are producing hand designs by mechanical means and using commercial dyes in the place of costlier ready made dyes. The future will see the commercialization of manually developed designs. However, most of these designing methods are based on exhaust dyeing, in which a substantial amount of dye and chemicals remain unused and are discharged at the end of dyeing. This generates a tremendous waste water load. Heat energy is also wasted in drying the dyed materials. Controlled application techniques, such as spray, foam or ink-jet dyeing, and continuous techniques like kiss roll padding will emerge in the coming days, owing to their cost effectiveness, energy saving and environment-friendly characteristics (Anon, 1984). In addition to this, cleaner technologies will also become preferable and work will continue in the direction that has already been initiated. One such technology is 'The Transcomp process' (AirDye, Colorep Inc), which produces localized dyeing effects, such as logos on athletics T-shirts and sportswears using Sibius™ dyes and hot air only. This is basically a sublimation transfer dyeing process. without printed paper. Hot rollers carry forward the garment, sublimized dye inside the final roller is transferred to the desired location on the garment, causing diffusion and developing superior fastness (Fig. 7.15). Fibre dyeing in sliver state, applying dye locally by hand, requires no afterwash, as well as no draining of dye liquor (Plate VII between pages 166 and 167). In the future, the thirst for a newer garment look will boost ways to formulate more innovative designing ideas, which will supplement the existing techniques.



7.15 Air dye effect (courtesy: AirDye).

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(a)

(b)

(c)

(d)

(e)

Plate V (a) Space dyed woollen yarn (courtesy: palomatextiles); (b) dip dyed yarn; (c) ombré dyeing effect; (d) shade to shade dyed yarn and (e) tie and dye yarn ((b), (d) and (e) courtesy of Julie Theaker, SC).

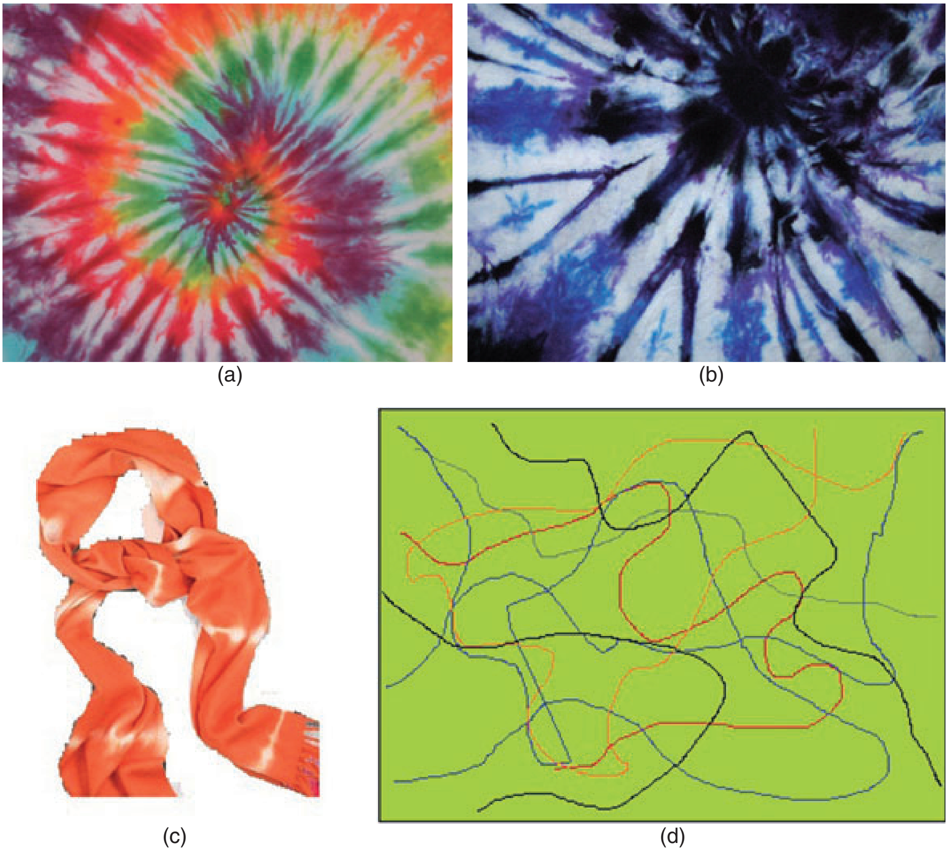

Plate VI (a) Tie dye silk (courtesy: Fashion peach); (b) tie and dye (courtesy: Greengabbo); (c) tie and dye; (d) batik design

Plate VII Manually coloured hank.

8
The use of colour in textile design

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Abstract: This chapter outlines the perception of colour and its relationship to light and gives insight into the theoretical aspects of colour. The context for the development of a colour palette is discussed along with the focus of colour in textile design for fashion and interiors. The relationship of colour to trend prediction and manufacture is explored along with the technical aspects of communicating colour within industry. Sustainable and ethical approaches to colour application within design and manufacture are explained and future trends discussed.

Key words: colour theory, colour perception, colour and trend, colour in design, communicating colour, sustainable dyeing.

8.1 Introduction

Understanding the theoretical and practical elements of colour is so important to the designer who endeavours to select yarn, thread and cloth in order to produce exciting printed, embroidered, woven and knitted fabric artefacts. 'In visual perception a colour is almost never seen as it really is – as it physically is. This fact makes colour the most relative media in art' (Albers 1975: pg 1).

Ancient trade gradually expanded the perception of colour through an ever-increasing palette representing tradition, social value and commercial enterprise. Today, we are presented with an alluring collection of emotive and seductive colours, the range of practical application is still tempered by the relationship of dye and pigment to fibre, surface, texture and light.

Cultural references, early industrial development and natural dyes have been supplemented and overtaken by commercial research and considerable developments in computer technology and software. Producing fabric and applying colour to cloth has always involved waste and pollution, with a careless use of water and over use of chemicals. To counteract and possibly control this, new practices are shaping the future of dyeing in relation to the fashion and textile industries.

It is our brain that interprets colour individually and our culture, knowledge and experience which tempers our visual response. In helping us to understand what we see, colour is a prime communicator; one that identifies the visual world. Our personal response to colour, however, is emotional and subjective, based on culture and experience. As the human eye can distinguish over sixteen million colours, how colour is perceived and how it interacts and is identified, is important equally to design and creative practice.

8.2 The perception of colour

8.2.1 Light

Light contains the visible spectrum of colour; energy that travels at different wavelengths. As the waves of light enter the eye and strike the retina they are interpreted by the brain as colour. These individual wavelengths are communicated to the brain from colour receptors – the rods and cones which separate response. Rods only recognise black and white and not hue, whereas cones recognise red, blue and green from which the brain can translate the full gamut of colour.

Only the wavelengths reflected from an object allow us to see colour. A white sheet of paper would reflect all the wavelengths and a black one absorb them. When a ray of light hits a red object, only the red wavelengths reflect back to the eye and are perceived as red; other wavelengths being absorbed by the object. In textiles the nature of the surface can be designed to best effect. For example, shiny surfaces make colours appear darker in hue and more saturated, whereas matt finishes appear lighter, less saturated.

Isaac Newton's investigations into the fundamental qualities of light led to the discovery, in 1672, that when a ray of light was projected through a prism, it split into its spectral range of colour. This, a blended range, moves seamlessly from one colour to another through red, orange, yellow, green, blue, and violet as the colours we recognise in a rainbow. In recording these Newton added a seventh colour indigo (blue violet) to the 'rainbow' as he felt the range to have an association with the musical scale.

Newton placed the spectral colours logically in a circle, in the varying proportions in which they appeared in his observations, joining violet and red. This was the first colour circle or structure involving the spectral range and it has become a model for the exploration of colour relationships and ultimately a valuable tool for research.

This visible spectrum, the range of colour in wavelengths, can be scientifically measured in nanometres. A spectrophotometer, working along the lines of the human eye, gives a numerical identity to colours which ranges from red at 780 nm to violet at 390 nm. Colour therefore is perceived from reflected light waves and can be given an accurate measurable identity as utilised in digital technologies and colour matching systems such as Datacolor.

As a product of a light source, colour is perceived in the mind and subject to varying conditions and personal interpretation. Although the intensity of light is important to the viewing and identification of colours, colour in fact has a transient relationship with the viewer dependent on the type of light source and its quality.

Additive colour refers to colour within light and when the primaries of red, green and blue, RGB, are mixed together, they create 'white light'. When additive primaries are mixed together they are always lighter and therefore have more luminosity. The additive secondary colours are cyan, magenta and yellow.

Subtractive colour refers to the mixture of pigment. When the pigment primaries of red, yellow and blue are mixed together they create not a black but in reality a dark brown. The secondary pigment colours are green, orange and violet. The mixing of any pigment colours result in colour that is in terms of luminosity, its lightness and darkness, somewhere in between the colours used.

Hue identifies a colour; blue, red, green, purple, etc., and value expresses how much light is reflected from a colour. Value is sometimes referred to as light intensity expressing its lightness and darkness. This term can be applied in the absence of a hue and referred to as greyscale. Saturation explains how much pure colour is present; high saturation relating to a strong pure hue, whereas low saturation to a weak hue.

As the main medium for designers, pigments, as chemical substances, i.e. paint, print medium or dye, are manufactured in reference to pure 'white' light to generate a reflection of a given colour. In practice they are subject to all the vagaries of normal lighting and environment with a resultant affecting of the colour *in situ*.

Natural light varies according to geographical location but generally at midday, when the sky is clear, we see colour at its purest; as the full range of wavelengths are present. Whereas in a poorly lit environment, the range is considerably reduced. The relationship between a colour and its light source determines what we see and experience and is so important to the end user whether it be design for fashion, lifestyle product or gallery.

Artificial lighting endeavours to mimic natural light, emitting different wavelengths with qualities ranging from warm to cooler tones. This has an increasing effect on our perception of colour in ever-changing environments. Incandescent bulbs, for example, cast a warmer light that is strong in the yellow to red frequencies; a preferred quality for interior use, as it recreates the warmth of the sun and is more relaxing. Fluorescent lighting emits the cooler frequencies of blue and green and makes cooler colours appear stronger and warm colours appear duller. As incandescent bulbs are gradually being phased out to be replaced by energy efficient lighting, improving technology is engaged to recreate the warmth of incandescent light; reflecting consumer preferences.

8.2.2 The analysis of colour

Following Isaac Newton's lead, many artists and scientists have shaped our understanding of colour and for textile designers a number are key to understanding how it performs in practice.

Colour became a dominant focus of artists in the second half of the nineteenth and early twentieth century. Many removed black, as being unnatural, from their palette. The Impressionists questioned colour, its application and effect, and tested luminosity by using violet, the complementary of yellow, the colour of sunlight and tinted shadows.

Seurat and the Neo-impressionists, exploring the optical mixing of colour, were much influenced by theories explored in *The Laws of Contrast of Colour: and their application in the arts* by Michel Eugène Chevreul (Chevreul 1860), colour chemist at the Gobelins tapestry works. His observations on colour interaction resulted in the law of 'simultaneous contrast'. This analysis of how colours affect each other, especially with their complementary, enabled him to reduce his range of coloured threads from 30,000 to 1420, to create better designs and also reduce cost.

Colour was now a means of expression, a subject for analysis in its own right. Paul Cezanne, the Neo and Post Impressionist's use of a broken palette influenced a range of designers and artists, Roger Fry and Sonia Delaunay are two who here perceived a direct relationship between painting and decorative textile artefacts and fashion.

Johann Wolfgang Von Goethe, the German poet, focused on the visual qualities of colour rather than the physics of colour contained in light. His colour wheel and triangle placed the primary triad colours equally distanced with secondary colours in between and primary opposite complementary. He also recognised the relative luminosity or value, of hues attributing them each a number. White 10, Yellow 9, orange 8, red 6 green 6, blue 4, violet 3, and black 0. His investigations into colour relationships, exploring complementary colour, simultaneous contrast, shadow and proportional colour relationships led to the publication of his *Theory of Colours* in 1810, which over a century later influenced teaching at the Bauhaus (Goethe 1982).

How we perceive colour and the human response led Ewald Hering, a German physiologist and psychologist, to establish an opponent theory of three primary pairs of colour; that of red and green, yellow and blue and white and black, which are the basis for the NCS, Natural Colour System used today to identify colour. Both Albert Munsell and Wilhelm Ostwald developed three dimensional colour structures that relate to numbers and tonal spacing, again models for today's colour identification systems.

The progressive German Art School, the Bauhaus (1919 to 1933) was instrumental in producing influential painters and educators who gave real foundation and understanding to the visual effects and dynamics of colour. Wassily Kandinsky the painter, saw a strong relationship between music and colour and Paul Klee compiled his lectures and theories into two influential Notebooks, *The Thinking Eye* (Klee 1992) and *The Nature of Nature* (Klee 1973).

Johannes Itten explored the relationships of colour within his teaching at the Bauhaus in the 1920s and later in 1960 in his seminal book '*The Art of Colour*' (1973). This important book still forms the basis of teaching colour theory in Universities today. Itten, like Goethe, based his colour circle on a structure that relates to complementary colours. His fascination with harmony, complementary effects, simultaneous contrast, after images and contrasts of extension examines relationships and proportions of hue and acknowledges the physical reactions of the eye and mind to colour. Through his teaching, he noted the individual or subjective responses of his students to palette selection related to personality type.

Following Itten at the Bauhaus, Josef Albers believed that in order to develop 'an eye for colour', practice came before theory. Vision and seeing being more important in understanding the effects that colours have on each other. His book, *Interaction of Colour*, published in 1963 and 1975 sets out a most comprehensive exploration and questioning of the effects that colours have on each other. His observations refer to concepts of the relative relationships of colour, its hot and cold values, spatial effects and the illusion of transparency. An illustrated series of practical exercises give the user insight and understanding into colour and tonal perception.

Albers paintings *Homage to a Square* express surprising and questioning colour relationships that are both beautiful and astounding. Influenced by Giotto, who he saw as having the ability to use a small number of hues to express energy, he focuses the viewer on the dynamic of colour. His paintings show in sparing simplicity, a limited palette expressed through simple geometric formations.

Research continues but by far the majority of developments are now the provenance of the commercial sector which has to retain a strong manufacturing base and retail status.

8.3 Palette development

Colour is a dramatic communicator and colour proportions are important relationships. Small amounts of accent colours can activate a palette, or harmonious groups express calm, contrasts adding vibrancy, setting the mood to a collection. A successful palette is relative to the design, with consideration for season, product, process of application and fabric type. Within most textile collections a variety of colourways for each design are created to add variety and choice for the consumer.

Many elements, though, may influence a palette at a particular time. Technical discoveries; the first mauveine or analine purple by William Perkin, in 1856, suddenly made available a wider range of colour; purple becoming extremely fashionable in the 1850s. With a multitude of synthetic colour following one hundred years later in the 1950s, turquoise became synonymous with this period in textiles influencing fashion and homewares.

Designers tend to work within the constraints of a limited palette. Sydney Harry, designer and educator developed a range of designs in the 1960s and 70s that explored the potential of a limited colour range exploiting simultaneous effects. He typically selected three or four colours that interact within the structure of the design, creating the illusionary perception of a broader palette/colour range. Harry was instrumental in setting up the Colour Museum Bradford in 1978, now The SDC Colour Experience.

Colour considerations for textile design relate to the end use, mainly as fashion or furnishing fabric. In fashion, colour is a subjective choice that can relate to a range of factors; trend, season, gender, and age, a desire to conform or express individuality. When used in interiors, colour defines space and creates atmosphere, where these effects are important as research has shown most people spend more time inside than outside.

Design studios, whether independent or attached to a company or brand usually focus on creating colour ranges in advance of sales; dependent on fabric type, process of colouration and product. Variations in lead times relating to the processes of production for woven, knitted or printed fabrics impose an additional aspect to the designer's brief.

The function of a colour palette highlights seasonal change and the opportunity to define difference. Printing processes limit the palette to usually a maximum of ten colours due to cost; but at the higher end of the market this can be increased considerably. The proportion and relationship of colour in a design is as important as the colour palette. Basic elements such as exchanging a proportionally dominant colour for another within the same palette, can change the whole feel of a collection and the designer's role is to consider variants and permutations.

The fast turnover of collections in High Street stores has led to consumer demand dominating pace and the generation of a multitude of new colour palettes and variations. This increasing pace of fashion could so easily focus the designer on furthering short cuts. To counteract this, Japanese designer Issey Miyake suggests that now is an opportune moment for designers to consider investing in time, to find unusual combinations and to look further than the mass of colour that surrounds us in the media. 'We need real materials and real colours, instead of taking things from magazines or web sites. Nowadays there is so much diversity in the world but I think we need to get the real things in this way.' (Issey Miyake, 2009)

Exploring and looking for colour was the concept behind Miyake's 2009 spring/summer collection 'Colour Hunting'. During an expedition to the Amazon jungle, creative director Dai Fujiwara matched colour samples, textures and swatches to leaves, flowers, trees and the river extracting 3000 colours. These created a dynamic base for the collection with a subtle range of translucent and opaque overlays.

Effort and analysis is valued in the quest for originality and ultimate identity. Liberty Art Fabrics studio, in London, may start collection concepts nearly three years in advance of the seasons for fashion fabrics but colouration and design is generated approximately two years in advance of sales. As a leading studio and retail store, Liberty sets its own trends and identity.

> 'We create our colour palettes based on original research. We don't follow trends but create them. Working to tight deadlines means there is no time to change colouration. Flexibility is important relating to individual customer requirements for colour selection from the collection. Customers also have the option of using special colours that are not in the range or to have their own colourations created for them if they wish to have exclusivity on colour. We would create between 50 and 100 colourways per design in CAD format and select eight from these to send to the printers for striking off.' (Emma Mawston, Liberty Art Fabrics, personal communication, March 2010)

This expresses how important colour is in providing a textile collection with edge and the amount of exploration, depth and consideration required in the production and selection of a colour palette.

8.4 Design

Colour was thrust to forefront of art in the twentieth century, a subject for exploration by the artist in tandem with the work of the chemists and theorists. Roger Fry, a painter, art critic and progressive thinker, rejected the traditional approaches to art and design by embracing the concept of the design studio and of revaluing the handmade, founding the Omega workshop in 1913 with a group of like-minded artists who were influenced by the broken colour of Cezanne's painting technique.

In the early twentieth century influencing the use of colour in fashion was Parisian painter and designer Sonia Delaunay who pre-empted the Op Art movement of the 1960s, some 40 years later. Delauney's radical 'simultaneous' paintings and later hand-painted and printed 'simultaneous' fabrics and fashion pieces use bold geometric patterns that structure the body shape in complementary and contrasting colours. Her establishing of colour as abstract form, without the focus of the figurative, had a far-reaching influence on fashion, textiles and art in the century.

Mirroring Delaunay are contemporary London fashion and interior furnishing designers Eley Kishimoto whose ethnographic and historical eclectic references to pattern and colour cut through and overlay the body; adding distinctive expression to their collections. Not succumbing to, or following fashion or fad, they see their garments transcending trend. Dynamic contrasts of colour is the focus within all their work and their skill in juxtaposing pattern with pattern, expresses the individual platform from which they seek to communicate their ideas. 'Pattern lab' part of their 2010 collection, referenced their fabrics on revolving frames allowing the viewer a dynamic and physical vision of the mix of colour and pattern inherent in their printed fabrics and garments.

Interior colour has a distinctive quality that can relate very much to brand. If positive thinking could be said to be expressed in colour then Marimekko the Finnish textile manufacturer founded in 1951 by Armi Ratia, has cut an individual approach, having a fresh enlivening feel through bold contemporary designs that are reflective of northern European textiles. Their direct use of a clear pattern format and typical bright palette is one that responds to the seasonal contrast of light in the northern hemisphere. Their range includes fashion, interior textiles and accessories and all products in presentation feature the name of the designers who create them. 'Marimekko embraced bold shapes, colourful abstract patterns and the lifestyle concept before such a term even existed'. (Moira Jeffrey, HeraldScotland, May 2005)

At Designers Guild, London, floral and geometrics are presented within the design parameters of more flamboyant formal settings. Whilst the design is based on a solid English tradition, colour here provides a vibrant foil and contemporary edge to their range. Designer Tricia Guild admits to being influenced by the colour and collage work of Henri Matisse who is also increasingly acknowledged as a major influence on a number of designers.

Ronan and Erwin Bouroullec have created innovative flexible approaches to colour choice in interior products. Their zipped wool felt rugs for Vitra of Switzerland allow the user to reconfigure the coloured rectangular block structure within the rug, creating a collaborative relationship with consumer and designer. More recently their work with leading Danish textile manufacturer Kvadrat has taken the idea of interactive design further and created a modular fabric tile system, 'The North Tile'. This replaces any wall surfaces with a flexible solution. It allows the user to configure their own selection from over 100 colours and to create sound-absorbing walls; temporary or permanent solutions for large spaces. The overall impact illustrates how colour can define space and create infinite combinations of pattern and structure. The Bourellec's new project with Kvadrat uses seven colour combinations. 'Clouds', another modular system developed for Kvadrat's own showroom in Copenhagen, is formed three-dimensionally in a variety of spaces. Colour here combines with fabric to work on the senses, softening hard spaces but still retaining impact. Colour has become as relevant to the designer now as it used to be to the fine artist, a distinctive tool to define brand or a personalising element within a product.

8.5 Culture

Colour in textiles has enabled and advanced the expression of cultural identity. The unique characteristics and differences in consumer colour choices are acknowledged by global retailers who aim to develop completely contrasting palette types for similar products in different countries. This underpins culture through colour and identifies where tradition, climate and technologies have moulded a society's distinctive colour preference.

Remote communities may retain a strong cultural identity. However, with globalisation, the appetite for travel and increased exposure through the media; the average consumer world-wide is much more aware and influenced by a range of colour palettes associated with other countries and of course the new culture centred on brand.

The significance of colour association certainly differs from country to country but this is being eroded and evidence expresses change. An example is in China, where white traditionally relates to funerals; contrasting with the West where it relates to weddings. Global influences are such that there is departure from red, considered good luck as a strong colour that casts aside evil spirits, to white which is now becoming a popular colour choice for wedding dresses in China (chinadaily.com).

The idea of a globally homogenised colour palette is hard to accept; where the historic and traditional collections in museums and galleries may become the only physical cultural references available. At the moment the retro aspect of design is well established to deal with valuing historical identity through consumer interest but in the future there may be fewer examples of ethnical originality to reference.

As an expression of belonging, contemporary artist Yinka Shonibare uses the colour in his work to express an African identity. The strong colourful batik fabrics certainly would not have the same ethnic message in pastel colours. This is a direct reference to what might be called cultural authenticity. Even though they are socially and politically based, the work is expressed through the beautifully coloured fabrics; bold saturated earth colours and patterns we associate with Africa.

Designers also use colour to suggest tradition and cultural references. Glaswegian textile company Timorous Beasties, run by Paul Simmons and Alistair McAuley, use the narrative concepts from the eighteenth-century Toile de Jouy. Their contemporary versions, of scenes of city life in Glasgow utilise the original madder and indigo colours. Colour here is synthesised with design to suggest tradition through reinforcing and supporting the familiar.

8.6 Trend and product

If black is style and sophistication then colour is fashion. Today there is a less doctrinaire approach to trends in both colour and style; with the broader ranges of collections being tailored to a variety of fashion outlets, compared to the set seasonal looks of the past.

Black still defines a definite form in fashion; representing power and timelessness. Chanel's little black dress, associated with longevity, exists alongside all the standard neutrals; navy, beige and cream. 'Colour' increasingly, however, is a vehicle that refreshes each season's palette creating its nuance, brand identity and product.

Mapping trend/fashion on the Internet are style fashion sites, where the immediacy of the 'blog', creates a platform for expressing individualism. The 'Sartorialist' is such an example of a very active forum that has developed a cult for personality, the democratising of style and a means of identifying developing trend and colour choices. 'COLOURlovers', another, is directly aimed solely at colour and is the focus for comment and instant pattern interpretation. Here colour palettes can be given identity, individually rated and views expressed.

In production terms industry has responded to the demands of the market and consumer. The lead-time, which is the time it takes to get a product to market, generally requires palettes to be predicted early on in the manufacturing sequence. For the fibre and yarn producers, at the beginning of the supply chain, these colour decisions have to be decided on earlier in the production process and are important to get right.

Companies who follow rather than create a trend can control a response to the market through good communication within the supply chain and a quick turnaround of product. These can analyse their colour ranges, replacing or repeating colours as sales demand.

A shorter lead-time can be achieved through the dyeing of garments, piece dyeing rather than that of fibre, yarn or fabric. At this later stage it is much easier to read colour trends and follow this by a quick response to manufacture. Fashion brand Benetton are an example who produce collections of white knitted garments, initially dyeing only a test range to be sold in key outlets. Colour decisions can then be positively based on known preferences and sales.

As an investment, getting a colour palette right for the fashion and textile industry brings more of a tailored focus to brand and product identity. Trend prediction companies present colour palettes and trends in design up to two years in advance offering a variety of services from books and magazines to specific services relating to the requirements of an individual company.

Global Color Research™ is a forecasting company based in London, whose focus on colour trend prediction is primarily interior related. The breadth of its business, however, permeates and influences fashion, as well as the wider industry that needs to understand and rely on colour directions. They publish *Mix Trends* twice a year for Spring/Summer and Autumn/ Winter alongside a quarterly magazine. Their exquisitely photographed *Trend* books form the basis of the business and are designed two years ahead of the season they are targeted to, presenting generally four main colour themes.

Added to this business is a bespoke colour service for a range of clients. Justine Fox of Global Color Research™ explains that their main markets are varied and include industrial, architectural, electronics, pigments/dyestuff, textiles and a wide array of product as well as interior design. In terms of fashion they look more towards cosmetic trimmings and textile dyestuff rather than clothing, though this is dependent on the bespoke needs of their clients; with many fashion retailers subscribing to their magazine *Mix* to obtain a rounded view of seasonal colour and trends.

Fox sees the colour stories as a progression from the last book:

> 'Interior colour forecasting is more of a development of colour than fashion forecasting. We do keep in mind the season that they're directed to in terms of the types of products our subscribers will be developing, but again this influence is less than in Fashion. When our panellists are formulating the stories, they're talking about developments in colour technology (our panel members are all colour experts within their own fields and come to us from around the world). Changes in legislation, e.g. recent energy efficient bulbs

change the way colours appear to us, what's happening politically, socially and economically – these all affect the colour choices that consumers will make in the future.' (Fox, personal communication 2010)

Fox also sees the colour prediction business as a mixture of intuition, obviously based on experience and analysis. She notes, 'The market is full of trend spotters who are really just reporting on emerging trends, but we're looking to take that information and project beyond it to make accurate colour forecasts that our subscribers and clients can rely on. The wrong colour choice is a massive loss in capital and can be the decider between success and failure.' (Fox, personal communication 2010)

This emphasises the importance of colour within a range of products and Fox sees materials as key to colour, 'rather than a promotion of the colour, they affect how we see the colour and the effects that create the mood'. (Fox, personal communication 2010)

Materials and colour are the exciting challenge for the designer to create a relevant design but it is the synthesis of the two elements that creates the product and the price of that product determines the level at which and when it enters the market.

Fox acknowledges how trends hit different levels of the market at different points, 'We see it as a curve. The key is to make sure that you select the right trend for the right product at the right time . . . a recent client saw an approval rating of 90% in consumer research on a new colour and texture range we made for them. We can achieve this level of accuracy by pinpointing the trends to specifics.' (Justine Fox, Global Color Research™, February 2010).

Simon Siegal, from the retail and contract Interior design company Atomic Interiors, Nottingham perceives new collections of colour ranges for furnishing fabrics in a similar way to Fox; as an 'editing process'. From the extensive sample collection this 'editing process' is the measure of a current season's trend direction, based on comparison with the previous season. Changes to key colours define trend direction; neutrals and popular colours such as red tend to be subjected to more subtle changes. An all round view of colour is gained from an understanding of how a variety of materials and products function in terms of colour in an environment. Atomic deal not only with a range of high end furnishing fabrics such as Kvadrat, Gabriel and Bute Fabrics; materials that are standard for architects and interior designers, but also upholstery leather by Elmo and Spinneybeck, plastics and laminates and key colours for chairs, sideboards and wardrobes by leading companies such as B&B Italia. This holistic view of colour within a variety of materials allows for an understanding of the context of colour within an interior, an important focus for the interior textile designer.

8.7 Communicating colour

8.7.1 Colour technology

Digital technology has offered much to the textile designer with the ability to resize, distort repeat or generate new colourways, it continues to offer but not always present perfect creative solutions. With many software packages, input resolution not only affects detail but colour accuracy. Working from digital cameras and scanners, with such varying specifications, requires use of only the maximum optical resolution available as anything beyond this involves mathematical interpolation. This does not create extra data but stretches the available data to the detriment of the image quality so essential to the end process.

Many higher end studios utilise both the computer and hand painting when creating designs; offering the designer a broader range of effects. Scanned photographs and images can be broken down and analysed to create colour proportions for palette development. Colourways can be stored, databases created and cross referenced for future use; not only for design but also for the management of colour.

Research has shown that intuitively our general understanding of colour mixing is based on our familiarity with subtractive colour; the pigment primaries of red, yellow and blue. Colour mixing on computer monitors, however, using the additive light primaries of RGB, is more difficult to estimate.

The range of colour that is available in any system is called a gamut. It is important to understand that the visible spectrum of colour that can be viewed on a computer screen, the RGB gamut, differs from the range of colour that can be printed graphically from the computer: the CMYK gamut, C standing for cyan, M magenta, Y yellow and K black. Black is added to obtain a wider range of tones and also to achieve a saturated black. A print driver or raster image processor, RIP, can convert additive RGB data to subtractive CMYK data, necessary when printing from a computer for either graphic printing or digital printing onto fabric.

There are limitations to the CMYK gamut, in creating the difficult bright reds, yellows and blues; this can be improved by increasing the ink range. Systems such as Pantone Hexachrome provide a green and an orange enabling a brighter range to be printed. Digital textile inkjet printers have options to offer an even broader range of inks to extend the obtainable colour gamut. This can extend from 6 to 12 colours, a range that can include paler CMY, to obtain better pastel shades alongside the normal secondaries.

As current technology enables studios to despatch designs instantly, communicating the correct colour is crucial, especially in a global environment with such diverse supply chains. Variations in colour perception from computer screen to computer screen and printing from a computer screen is acknowledged as a problem and computers need to be calibrated to counteract this effectively.

Large companies such as Marks and Spencer have developed specialist colour management systems over the last 30 years. These calibrated systems deal with data that can communicate the correct colour throughout the supply chain; not only for fabric colouration but also for trimmings, zips and buttons and give dye recipes for specific materials. The majority of Marks and Spencer's colour is communicated in this way with the remainder sample and paper based. M & S technologists, including colour chemist Chris Sargeant, developed colour measurement and communication systems enabling instrumental colour control of merchandise internationally on an industrial scale. Initially M&S needed to achieve the accurate colour matching of fabrics so that men's suits could be sold on a 'mix and match basis' where customers could select from racks of jackets and trousers to find their particular sizes but know they would match accurately. Up until this time, jackets and trousers were always cut from the same piece of fabric, to ensure matching, making it necessary for retailers such as Burtons to hold hundreds of size combinations in stock to service their customers. This development enabled the colour matching of one size of jacket with another size of trouser to a high level of colour accuracy enabling M&S to substantially reduce the stock held.

In other areas of clothing a global production environment where 20 suppliers may be involved with one range, a comprehensive numerical system to specify and control colours speeded up production and proved a more accurate method attaining the right colour. This reduced waste and time, saving thousands of pounds. This also enabled M&S to pin point and deliver sometimes short seasonal fashion colours, which if managed in the traditional way, could miss the season and turnaround of three to four weeks could be cut to two to three days. Innovation in the management of colouration has proved important in terms of both profit and sustainability.

8.7.2 Colour specification

Colour communication is very relevant to the designer and here technology and colour data identification systems are useful. Both Pantone and NCS colour are systems that can be used to visually identify a specific colour and provide a consistent reference.

Pantone colour libraries in Photoshop provide a colour guide for printing and also offer CMYK breakdown of the colours for the four colour printing process. Their colour guides, chromatically arranged in colour families, fans and charts, offer an easily accessible and comprehensive range of colour matching products.

The Natural Colour System or NCS, established in Sweden 1952, is an international standard for colour selection and specification. This system is based on Herring's theories and the three dimensional colour models of Munsall and Ostwald. All colours have an exact description in the NCS colour space identified through a numbered system that is based on how much the colour relates to the six pure and elementary colours; white W, black S, yellow Y, red R blue B and Green G. NCS produce a range of products which identify colour through RGB, CMYK, LAB and Adobe references for printing. As a logical system it provides a creative structure of comparison to hue, value and saturation or chroma and the 1950 colours can be referenced as books and fans as well as online. Palettes may then be selected from their Navigator system with full reference to the relevant systems. NCS is used by a range of companies including IKEA, Heimtextil the International Trade Fair for home and contract textiles and Global Color Research™ (Plate VIII between pages 166 and 167).

The logistics of communicating the desired colour can still require the use of information additional to the digital format. Hard copies and colour chips are provided to make sure that colour can be replicated as near perfectly as possible, reinforcing the designer's input.

If a design is sent electronically, Emma Mawston of Liberty Art Fabrics always gives a hard copy to their printers, with colour chips attached. Izzie Matthews of 'Peagreen' textile print studio, who works with a wide range of companies such as GAP, Habitat, H&M, Ikea and Topshop, provides as much physical reference as possible to support the specified colour, deemed essential for product quality and consistency, so important where the company is renowned for the vibrant and dynamic colour used within their designs.

8.7.3 Colour assessment

Light is key to seeing colour, and creating standard viewing conditions is essential, so that samples can be compared accurately. To facilitate this VeriVide are world leaders in the design, development and manufacture of highly specialised colour and visual assessment equipment. Their colour assessment cabinets and work stations, fitted with a variety of standard lighting with matt grey neutral interiors, enable samples to be viewed in controlled conditions and assessed visually.

One is able to compare the colour appearance of items when putting a range together. Here the eye is still the best judge of how the same colour may look as different textures and materials or how a dominant colour appears with the rest of a colour range. It also helps to identify metamerism, effects where two colours can look the same under one specific lighting condition but different under another. Most colour is checked in artificial daylight CIE D65 but point of sale lighting is also important as a comparison.

Items such as lingerie may have as many as 20 different component parts with contrasting materials. The colours of plastics and textiles often have to be fully assessed to enable them to be matched and work together. Getting it right, the correct colour, is a refining process and in the hands of the designer part of the creative process.

8.8 Environmental and commercial issues

The social, economic and ethical focus of sustainable production is increasingly a concern for consumers and the priority of a number of global companies and designers. In the UK, the work of independent special interest, RITE group, ('reducing the impact of textiles on the environment'), has created a platform for questioning practice, sharing innovation and best practice.

Textile and fashion designer Becky Early has a radical approach to textile production. Her research and involvement is with a range of projects, that question concepts related to sustainable design and the impact that textile production has on the environment. Early recognised the potential of exhaust methods of printing, using the photogram utilising disperse dye and recycled fabric, to produce scarves. The 'no waste' sequential fading results of this method give a new perspective to the limited edition where the image diminishes in intensity and colour saturation. Early's ability as a designer is matched with her resourceful approach and research into aspects of social behaviour. Her views on post-consumer waste as discarded items that are not valued emphasise her belief that materials are 'here for us to borrow again and again'.

Another pioneer of recycling and upcycling, Orsola de Castro, established her London based fashion outlet 'From Somewhere' in 1997. Utilising the enormous amounts of pre-consumer waste from the cutting room floor of Italian manufacturers, De Castro considers colour collectively as greens, browns and reds, storing her fabrics until she has enough for a range. Her flair is in selection and composition; creating exciting combinations of colour that give her work a distinctive edge.

Christopher Raeburn is an equally innovative designer who uses recycled nylon parachutes, in his fashion collections. These offer a surprisingly varied group of camouflage colours, created by the Ministry of Defence for specific geographical landscapes. Raeburn uses the translucent qualities of the fabric to introduce pattern through layers of laser cut material so obviating the need to print. His 'Digital Rainbow' collection shows colour to be at the heart of this work alongside the beautiful structures of his garments (Plate IX between pages 166 and 167).

Silk and wool were traditionally valued in fashion and interiors but increasingly the twentieth century saw a boom in the desire for cotton. Its cool, crisp qualities, comfort and use in denim has made it so popular that it dominates the world market and creates considerable environmental problems. As a crop, growing on high grade land, cotton requires excessive amounts of water and chemicals in its production and for colouration, dyeing cotton requires the same quality of water required for drinking.

Alternative raw materials to replace cotton have been actively sourced and a range of cellulose, plant-based fibres from trees, hemp, bamboo and nettles alongside the more traditional flax are forming a new wave of materials with a 'conscience'.

Lyocell, trade name 'Tencel', is a cellulosic fabric created to challenge the quality of cotton. It is used within interior and home ware as well as the fashion industry and the important denim market. Developed by Lenzing in Austria to become totally sustainable, its fibre is made mainly from eucalyptus trees and requires only a fifth of the land used in growing cotton and a twentieth of the water, using natural irrigation. The trees can grow on marginal land that does not compete with agriculture and no pesticides or insecticides are used in production. Tencel is naturally white, requires no bleaching for most shades and takes less dye at lower temperatures to reach an optimum colour, so is an ideal replacement.

However, cotton is still very much a part of the textile landscape and a large percentage of the 20,000 deaths attributed to pesticide poisoning a year are thought to relate to cotton production. Better Cotton initiatives are promoting a more responsible use of pesticides and water whilst Fair Trade are securing 20% better pricing and practice along with their support a growing percentage of organic farmers.

Other solutions to the cotton problem are perhaps within natural coloured cottons. Sally Fox in the US has developed over the past twenty five years, indigenous naturally pigmented cotton plants, to produce Fox Fibre. Fox developed the colour range to include greens, browns and beige but the experimental challenge and time involved, 10 years to produce a new colour, limits the success of this company. This was pioneering work at a time and in a culture that did not fully appreciate the importance of its relevance. To date Fox Fibre for knitters is available through the Natural Colour Cotton Company.

REACH, the regulation for the registration, evaluation, authorisation and restriction of chemicals, came into force in 2007 and regulates the use of hazardous substances. Legislation limiting a range of dyes that can be used in the European Union has generated mixed responses. Responding positively; for Climatex the pigments used for dyeing are selected in accordance with their biological regenerative profiles. Only 16 out of the 1600 possible dyes fulfil the strict requirements they themselves impose and virtually with the exception of jet black, all colour variations can be created.

DyeCat and Dr Richard Blackburn at Leeds aim to reduce the environmental impact of the dyeing and colouration processes. Their continuing research into alternative 'green' chemistry has the potential to remove the wet processing coloration step altogether. Whereas dyeing currently occurs after the polymerisation step, involving numerous chemicals and gallons of water requiring treatment, the use of DyeCat technology in the process would result in pre-coloured polymer.

Coffee as a dyestuff has been 'simmering beneath the surface' for years. The use of spent coffee grounds, from Starbucks, with polyester fibre adds not only UV protection, odour control and fast drying qualities but also a range of natural colours. Singtex Industrial, Taiwan, have patented this core technology to produce two shades of 'S.Cafe' yarn; a natural cream-coloured hue and a pure white. Fashionably named as 'latte' and 'decaf' this emphasises the origin and adds a recognisable status for the consumer.

8.9 Future trends

The dyeing and printing of textiles has invariably involved a hidden cost to the environment. How we now approach manufacture and production, in an attempt to protect the planet, presents concerns for everyone. Changing attitudes in manufacture and the creation of new directions for research is shaping the future of the dyeing and printing industries. Primarily the impetus for this has been instigated by Western companies but concerns have spread to the new manufacturing centres in the East. Textile testing company Texan lab, based in Mumbai India, is supporting research into the biodegradability of dyestuff at Indian Universities. This proactive research, within a country that is prominent in textiles production and where manufacturing practice has been questioned, reflects a positive changing balance of interest.

Most companies who deal with textiles are actively seeking ways to reduce their carbon footprint and ecological status. Marks and Spencer, as a global company, seeks to be carbon neutral by 2012 and be sending nothing to landfill through its Plan A scheme. A strict awareness of dyes and materials throughout the supply chain is paramount to this happening which meets their own best practice guide for wet processes; there is no Plan B.

Regulation and identification through labelling is encouraging the industry to enforce better practice. Supporting the future is legislation through REACH and labelling such as Bluesign and GOTS, the global organic textile standard. Alongside organisations such as Fairtrade, who promote the social and ethical aspects of textile production, they define a range of substances including dyestuff that have eco accreditation.

Designers who are adapting and utilising waste textiles extend into the mainstream of mass production. Many large organisations are positively recognising the lead set here and beginning to understand the commercial and ethical value of utilising waste. Orsola de Castro is helping Tesco deal with their waste materials, proactively bringing her colour signature into garments that are using up the fabric normally thrown away in the production of their standard ranges. De Castro as founder of Estethica, the British Council sustainable initiative at London Fashion Week, continues to promote the growing number of pioneering designers.

Adapting to fast fashion may require garments to be manufactured using bio-degradable dyes on bio-degradable textiles or the 1960s paper dress could function to deal with the throwaway society and the estimated two million tons of clothes that are discarded every year in the UK. These are radical approaches that would meet Becky Early's tailored focus relating to short- and long-life products.

Innovation poses exciting technological developments for the future and has delivered new structures in fabrics that explore the notion of 'none dyed' textiles. Japanese textile company Teijin's Morphotex, named after the morpho butterfly, produces a polychromatic light interactive fabric that mimics butterfly wings; with iridescent colours that change in reaction to various light conditions. This biomimetic fibre was developed through nanotechnology, layering polyester and nylon fibre to specifically react with the coloured wavelengths in light.

Thermochromatic dyes activated by heat have further potential for the designer; products that respond to temperature change and personal intervention. Timorous Beasties created 'The Valentine Textile' for Valentines Mansion, using heat sensitive inks, for their printed fabrics that react to the temperature of the sun. Their outdoor range of products; deck chairs, wind breaks and parasols respond to the environment. As the day warms the image appears and as it cools, they disappear.

The position of craft, the handmade, has seen a resurgence. Designer maker Kate Blee's fabrics communicate, through their colour, a visceral relationship with surface. Colour relationships of dye to fabric, surface to shape and image to form relate strongly to the materials chosen; linen and silk and the subtle quality and nuance of the hand painted application of dye. If painting onto cloth sets colour free then weaver Ptolomy Mann uses colour within the constraints of a finely woven structure. Her use of colour is an intense experience for the viewer creating rhythmic three-dimensional pieces with edged accents. With structures reminiscent of the sculptural pieces of Donald Judd who saw colour as a 'material', Mann here expresses her colour through material, with phenomenal control.

The handmade certainly contrasts with the manufactured and the 'most of everyday things'. Buying less but selecting well, better made better designed, in the future may counteract the growing mass of waste textiles.

We can learn much from cultural practices which have evolved to work with nature. In Japan, tradition alongside innovation is greatly valued. Fashion and textile artist and designer Akihiko Izukura constructs seamless one piece garments; using natural dyestuff to colour his silk fibres. These skills were passed on from generation to generation of a family of Kimono and Obi makers to the Imperial family and his range of dyes extracted from plant and insect sources, such as cloves, cinnamon, indigo and cochineal are very much part of his Japanese inheritance. SENSHOKU-Do, the Tao ceremony of natural weaving and dyeing is an intrinsic element of his fashion company Hinaya. inc. Kyoto, Japan. Izukura's philosophy of 'zero waste' where everything is valued and utilised, is evident in the dyeing of his fabric where like Becky Early's exhaust prints, the inconsistency of exhaust dyeing is valued. Even fibres that are the residue of the spinning process are valued. As a pure substance they are a source of protein and may be used as a food source, in papermaking or as a ceramic glaze. This utilitarian perspective, its focus on the value of materials, sharply contrasts with the results which are sumptuous and individual; colour adding a dynamic that utilises the softer strength of natural dyes (Plate X between pages 166 and 167).

This enviable philosophy of 'zero waste' is a model that industry in the West is trying to adopt, whilst questioning, how do we live in our environment and make a profit? Technology, chemistry and the availability of dyes has opened up colour choice but the designer is still the pivotal influence in sourcing colour inspiration and expressing this through the language of cloth.

8.10 Sources of further information and advice

www.colour-experience.org
www.colour.org.uk
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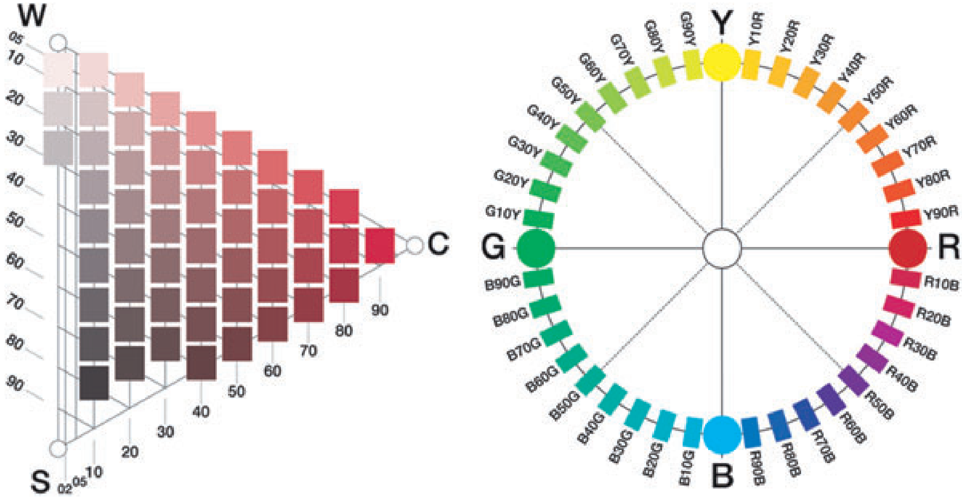

Plate VIII NCS colour triangle: colour circle (NCS – Natural Colour System®©. Property of NCS Colour AB, Stockholm).

Plate IX Christopher Raeburn, Digital Rainbow, men's hoodie, parachute nylon, Spring/Summer 2010 (Image courtesy of Christopher Raeburn studio. Photography: Sam Scott-Hunter).

Plate X Akihiko Isukura: natural weaving and dyeing, silk coasters, 2010 (Image courtesy of Nottingham Trent University. Photography: Debbie Whitmore).

Plate XI Jo Cope (2008) yellow coat (© Cope 2010).

9
Colour trend forecasting and its influence on the fashion and textile industry

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Abstract: Colour forecasting is an integral part of the trend forecasting industry, published up to two years in advance of each season, it contributes significantly to the overall product design process, influencing fashion, textile and accessory development. This chapter will discuss its inception, development, role in range planning, and the development of seasonal colour palettes featuring new fashion colours. The available colour forecasting formats will be explained, plus how trends are compiled, highlighting key timescales, information gathering techniques and intuitive colour selection. Core fashion colours, long and short term colours and their applications will be investigated. The future of colour forecasting and challenges faced by traditional forecasters in response to fast fashion are also discussed.

Key words: colour, trend, forecasting, product development, creativity, design.

9.1 Introduction

Colour forecasting is an integral part of the fashion trend forecasting industry, published up to two years in advance of each season, it contributes significantly to the overall product design process, influencing fashion, textile and accessory development. This chapter will discuss its inception, development, influence on designers, role in range planning, and the approaches used in the development of seasonal colour palettes proposing new fashion colours. The current colour forecasting formats and how they have developed over the past decades will be explained, plus how contemporary trends are compiled, using examples from key trend forecasters. The timescales to which the colour forecasters work, and their information-gathering techniques will be explored, plus the role of intuitive colour selection within the trend development process.

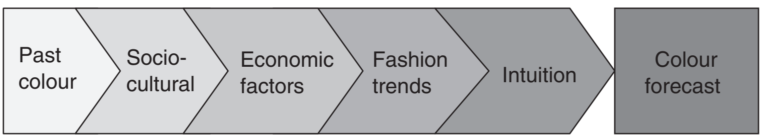
How the fashion and textile industry uses colour forecasting information effectively, and which products it can be applied to will also be explored. Core colours, long- and short-term colours and their applications will be discussed, illustrating how the industry utilises each of these colour groups from season to season. The future of colour forecasting and challenges faced by traditional forecasters in response to fast fashion are covered in the future trends section of the chapter.

9.1.1 The development of colour forecasting

Colour forecasting for fashion and textiles, as it is understood today, dates back to the 1930s, although the development of a fledgling concept had been started somewhat earlier in 1915 by the Colour Association of the United States (CAUS). The Association provided some colour information to the American apparel and textile industry a decade earlier, although it could not be described as colour forecasting, as it was a simple card of colours, not specifically grouped or intended to be used as a design tool, more of a technical manual. Today colour forecasting is a fundamental element in the creation of textile and garment collections, and a tool employed by manufacturers, designers and retailers in the development of their apparel collections. It is used in the initial stages of the design process, so has to be available considerably earlier than other trend information, typically two years ahead of the season under development. Colour forecasting involves the systematic evaluation and synchronisation of past seasonal colour influences, socio-cultural and economic factors, fashion trends and the forecasters' intuition, to create several colour palettes applicable to a variety of market sectors each season. As illustrated in Fig. 9.1, all these factors combined result in the final developed colour forecast.

Examining the sources of creative inspiration in clothing design, Mete (2006) placed particular emphasis on fashion research and forecasting, noting that 'Colour is usually the starting point of each season and often acts as a springboard for materials/fabric direction and trend research' (Mete, 2006 p. 289).

From the early 1900s the fashion industry followed the traditional designer trends of the renowned couture houses in Paris, first Worth and Vionnet, and after World War Two, Dior, Chanel and Givenchy, gaining inspiration from their twice yearly seasonal presentations. There were several key milestones in the development of colour forecasting; the first in the late 1920s, when an American visual merchandiser, Tobe Coller Davies, developed her style reports for American department stores, appropriately named The Tobe Report. Shortly after Coller Davies' initial style publications were produced, national colour councils were established in both the US and the UK, which subsequently developed to provide a colour prediction service for their domestic apparel and textile industries. A hiatus was experienced during and after World War Two, when the Paris fashion industry was thrown into disarray. It took some time to recover, although the French forecasting agency Carlin, was established during this period in 1947. There was a subsequent boom period in the 1960s and 70s, when a wide variety of influential forecasting agencies were established, including the French Promostyl, Peclers and Nelly Rodi, in Britain, Deryck Healey International (DHI), The International Colour Authority (ICA), Design Intelligence and Nigel French, and The IM Report in the US. These were the major names in forecasting and quickly established themselves as influential forecasters within the industry. However, a change was taking place in textile and apparel manufacturing, which was to have a major impact on trend forecasting. The movement offshore of UK garment manufacturing, resulted in the rationalisation of the British apparel industry during the 1980s and again in the late 1990s, and the forecasting industry in the UK suffered as a result. Many companies went out of business, including the influential DHA and Nigel French, although the larger organisations in France survived the changes. Essentially, throughout the period, the



9.1 Factors influencing colour forecast.

format of trend forecasting publications did not alter radically from the initial Tobe Reports: trend books, which featured groups of colours to be used together, fabric suggestions and overall themes, or stories, to convey a particular message for the season.

Other colour forecasters followed with books which featured a range of perhaps four or five colour palettes, each with a group of five to ten colours, text and fabric or yarn samples. This format was to change dramatically with the advent of fast fashion, introduced initially by the Spanish fashion retailer, Zara in the 1990s. Fast fashion reduced the traditional product development process from an average of six months to just six weeks, and coincided with the development of online forecasting services, notably Worth Global Style Network (WGSN) in the UK. The online providers allowed instant updates from around the world to be distributed to their customers, who no longer had to wait six months for the next trend publication.

Today there are numerous online trend forecasters, individual consultants, and design studios offering trend services and specialist colour websites available, who all compete with the established companies to provide the most timely and accurate information possible for the coming seasons. Most operate using similar principles and formats, which will be explored further in the following sections.

9.2 Principles of colour forecasting in the fashion and textile industry

9.2.1 Timeliness of information

The product development process requires colour information at a very early stage in the cycle as it is essential to ensure all products that are to be merchandised together in store match in colour or similar hues. Forecasting has developed to assist the fashion buyer, designer or retailer, in developing their collections more accurately, by collating a variety of information either already influencing, or likely to influence fashion trends in the future, and presenting it visually, supported by text, to communicate the potential trends for specific markets up to two years in advance. It encompasses a wide range of specialist subsets, colour being one of those. Others involve fabric prints, footwear, and swimwear, with separate books dedicated to each market sector. Many commercial trend forecasting agencies today publish over twenty specialist books each season, targeted at specific fashion and retail sectors. They also offer consultancy services, and one on one services to develop colour for specific clients and their markets.

Forecasting is not an exact science; indeed, many organisations within the fashion and textiles industry do not always use commercially produced trend information, preferring instead to gather their own material and interpret it according to their own customer demographics or market sector. Most tend to gather data from a wide range of similar sources, attend the same trade shows or catwalk events, and are influenced by the same global lifestyle or technological developments.

> Buyers and fashion designers are able to predict what is likely to be 'in fashion' through a combination of influences, including reviewing important textile and style magazines, the specialist services of trend forecasting agencies, and visits to textile and garment fashion shows. (Jackson, 2001: p. 131)

Within the generic field of fashion forecasting resides colour forecasting, a specialist activity which has developed into a very individual service area, acknowledged by Brannon (2000), Diane and Cassidy (2005) and Perna (1987) as being one of the vital, early elements required within the fashion development process. The increasing sophistication of the consumer and the development of a global high-speed communications infrastructure, in the form of the Internet, has realigned the original structure of the trend forecasting industry from the 1930s, that of adhering to two seasons per year for fashion, Spring/Summer and Autumn/Winter; which continued until the early 1990s. Brannon (2000), suggests that the early 1990s saw a paradigm shift in the number of seasons used by the retailers to segment their fashion year, increasing from four to six seasons, a phenomenon which had begun to emerge in the late 1980s. Some believe the change in forecasting came even earlier, McKelvey and Munslow (2008), indicated there was a major shift from the 1960s onwards in the dominance of the single fashion trend, to today's mass market fashion industry, which adopts designer catwalk trends faster than ever before. However, an extract from a brochure published *circa* 1978 by arguably the first internationally renowned British trend forecast company, Deryck Healey International, identifies clearly that the timescales involved in the development of colour forecast predictions has not changed in over thirty years stating 'colours are forecast two years in advance, relative to specific seasons'. This timescale is still very much in evidence today, as can be seen in Fig. 9.2.

The principles of colour forecasting appear simple; as can be seen in Fig. 9.1, using information gathered from a variety of sources including fashion catwalks, fabric trade fairs, street fashion, lifestyle indicators, socio-cultural and economic trends, plus political and international events, the forecaster distils a series of influential colour concepts for a particular season, usually between two years to eighteen months ahead of the actual season. There will also be an element of consideration

Colour development timescale

2 years	**18 months**	**12 months**	**6 months**	**3 months**	**Cycle end**
Colour forecasts and concepts begin. Fibre industry and yarn spinners develop colours.	Colour trend books published. Fibre and yarn colours released. Textile mills and trade association, work on colours	Trade fairs show colours, Premiere Vision, etc. Designers, garment mfrs and retailers start colour palettes. Colour updates.	Some retailers start colour trend development later in season. International catwalk shows.	Fast fashion influences. Retailers still open to buy. Designer catwalk colours used. Most products in manufacture.	Products in stores. Consumer purchases may influence seasonal colour.

9.2 Colour development timescale.

of previously predicted colours, in particular those colours which proved particularly commercially successful in the market. In practice, forecasting anything two years in advance could be viewed as being difficult to achieve accurately, and subject to change based on any or all of the sources of information initially gathered. Others include design intuition in the mix, or inspirational finds. In the fast moving world of fashion, some would suggest that it is an outmoded system when fast fashion demands products be developed and delivered in store within six weeks.

9.2.2 Accurate colour predictions

The importance of colour in fashion and textile design cannot be underestimated, and as such, there are many who still subscribe to the notion of gathering information as early as possible, even if it is not required in the critical path until far later in the product development process. Such early indicators provide a guide by which designers can start to form their ideas, and indeed, may have much synergy with the directions being developed by fashion and textile designers.

Kate Bostock, Director of Marks & Spencer, in 2008 revealed her approach to colour and trend development, one which she had brought to bear within the company, in an interview with the author.

> We use a lot of colour information for developing the colours in the design teams, plus we travel to shows, attend colour seminars, visit fabric mills and use their information, as well as buying some of the trend books. Developing colours and trends is very much instinctive. We change our information regularly and don't stick to one constant formula. Fabric and colour are certainly put first on the design agenda. (Bostock, 2008)

Such comparative analysis of a range of forecasting information clearly allows users to distil a multifarious range of information in order to develop trends which are suitable for each specific market, thus ensuring the resultant information is almost infallible. Intuition and colourist experience will also contribute to the final colour decisions. What has sold well in store previously, which colours can be merchandised well together, what colours the brands' customer profile suggest may be successful; each of these elements can be considered in the colour development process to ensure the final colour ranges selected are as successful as possible when translated into actual products. The evidence to date suggests that the colour forecasters offer the client the ability to cut out the processing of analysing trends and translating them initially into colour use (Lambert, 2004), saving time and being able to react to change more rapidly. Bruce and Daly (2006) found organisations allowed a degree of flexibility to change some colours much closer to the actual season, adding or removing, or simply altering their existing colour palettes. As Guerin (2005) indicated, it tends to be a matter of personal preference, led by the design director, buying teams and other senior staff within the organisation who are actively making seasonal colour decisions. It is common to find that certain forecasters work with particular clients year after year; they usually find their 'signature' and trend design approach complement one another well, and so continue the association as long as it is commercially successful. 'Subscribers may purchase more than one service to cross reference and confirm commonalities in colour, fabric and trend information. It depends on budget limitations only.' (Guerin, 2005: p. 19)

However, if many do distil their own trends from a variety of publications, there is some indication that the forecaster's clients do not believe any one firm is 100% accurate in its predictions. Unfortunately, there are limited publications in this field to examine, resulting in much of the evidence being anecdotal. There is also little substantive evidence to support or question a statement by Perna (1987) indicating 80% of trend forecasts are believed to be accurate. Brannon (2000) also argues that no single forecasting discipline is accurate, but each serves a complementary function, and that the only method to assess the accuracy of forecasting is to include milestones, 'points where the forecast can be evaluated and adjustments made' (Brannon, 2000). Many of the larger forecasters themselves do indeed employ this method; Peclers Paris, one of the largest and best known fashion forecasting companies, send out updates on their main colour book closer to the season and have a publication entitled 'Trend Update', described in their 12th edition of *Who is Peclers Paris?* (2001) as 'the signs of the times illustrated by mini-stories for the upcoming season or for last-minute deliveries'. This allows them to change their original predictions if necessary, even adding new themes, modifying colour palettes and removing some trends completely.

> Most would agree that predicting anything is 50–50 at best or more accurate by chance alone. The important thing to remember about forecasting is not accuracy but outcome. Fashion forecasting, like anything else, is an art and a science that depends a lot on the touch rather than the science. (Rickman and Cosenza, 2007: p. 611)

If the information cannot be verified as accurate, why does the industry still use it as a key component of its development phase? How do the forecasters manage such diverse information? When predictions are compiled over two years in advance, how can they account for sudden changes in society or economics, such as war or terrorist attacks which may affect world markets and a downturn in world markets? Can they possibly consider consumer colour preferences in specific niche market segments? Such questions have been asked in the past, and in an attempt to answer them, forecasters have found numerous methods of identifying their successes retrospectively. At a presentation in October 2002 at Interstoff Asia, Hong Kong, made by the author on behalf of Global Colour Research, publishers of The Mix colour forecasts, the comparison was made in the script between The Mix colours for Autumn/Winter 2003/04 and the colours presented at the Italian Moda In trade fair. The three colour stories presented at the Italian fair were almost identical to published The Mix colours, but as the presenter noted 'there is only one major difference between our colour proposals and those presented at Moda In, and that is, our colours were available to you nine months ahead of theirs.' (GCR, 2002)

Other forecasters provide 'colour updates', usually published six to nine months after the initial seasonal forecasting books are released. Often the new updated colour cards change significantly from the original colour predictions, to reflect new developments in design, technology, economics or even politics.

There is evidence that it may be possible to predict specific consumer colour preferences according to the cultural context or location in which they develop, and their gender, age and ethnic background (Paul, 2002), accounting for the myriad influences of a demanding global consumer. Providing accurate, largely homogenised colour forecasts two years in advance would seemingly be impossible, a case of one size will never fit all. Consumers also express preferences for particular colours year on year, such as blue, or their preferences reflect the culture in which generations come of age. In the US men traditionally preferred dark, rich, neutral colours in comparison with their European counterparts, who chose brighter, more complex colours (Paul, 2002).

Consequently, forecasters can only respond to key sociological, cultural, technological or socio-economic events retrospectively, perhaps modifying their colour predictions when producing updates much closer to the season, as many do. This practice helps to add to the semblance of accuracy in colour trend predictions.

9.2.3 Colour longevity

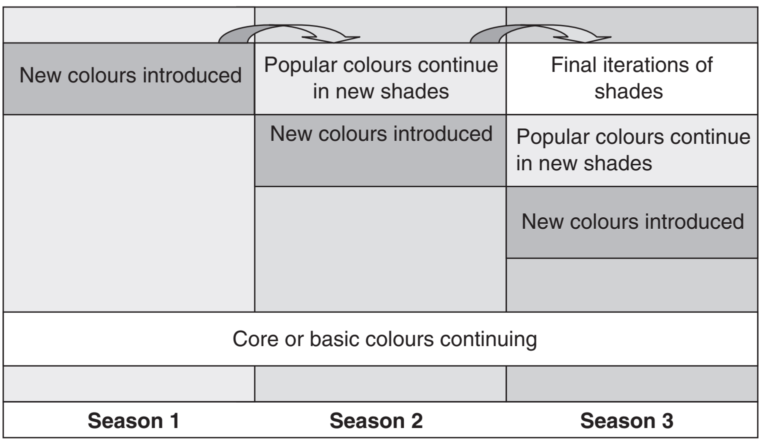
In order to account for consumer colour preferences, many retailers and brands have developed a more incremental approach to colour, as can be seen in Fig. 9.3. Such an approach ensures a slower transition of colour throughout the various phases of a season, allowing colours to evolve in tone or hue, to be merchandised alongside new colours, and finally to be phased out over time when they are deemed no longer either sufficiently fashionable or appealing to the brand's customer base.

In Fig. 9.3, colour cycles and colour trends have been divided into three basic areas.

- long-term, sustainable core or basic colours
- long-term fashion colours
- transient, short-term high fashion colours.

Core or basic colours

As Fig. 9.3 illustrates, designers and retailers work with basic, or core colours each season, which rarely change. Basic, or core colours are the staples of any forecaster or retailer colour palettes, they are the colours guaranteed to sell whatever the weather, season or style. Such basics have become known as classic colours often



9.3 Seasonal changes to individual colour trends.

referred to in conjunction with classic styles, such as the 'little black dress', the 'perfect white shirt', 'classic camel coat' or 'navy blazer'. Core colours are the staples, the building blocks upon which the more fashion-led colours often rest. They comprise black, white, cream, navy, camel, greys, and a range of other neutrals in beige and grey shades (Linton, 1994). Core colours are then supplemented by new colours throughout the seasons. Some of these new colours will develop into slightly different shades if they prove popular with consumers.

Long-term fashion colours

Long-term fashion colours may be defined as those colours which transcend several seasons in one form or another. They could be a particular group of colours, deep reds, for example, or individual colours which are specifically repeated each season, which are not a member of the core colour family. It would be wrong to say that any one colour remains the same season after season, other than the basic core colours. Undoubtedly colour groups do develop momentum, purple phases, as identified by Brannon (2000), is one clear example.

Short-term fashion colours

Every season has its own high fashion colours which can define the look and feel of the season. Such colours may only be available for a very short space of time within one season, or indeed within one phase in a season, and thus are relatively transient. They are sometimes referred to as iconic or high fashion colours.

9.3 Applications of colour and trend forecasting in the fashion and textile industry

In order to make colour concepts simple to review and relate to individual market sectors, the major forecasting companies publish large trendbooks, replete with beautiful photographs and carefully colour referenced fabric swatches, yarn or paper chips. Some also present their ideas online, again with the internationally recognised colour reference systems such as Pantone, or Scotdic; Such universal colour reference systems are arguably even more essential to online forecasters, as colour can be difficult to communicate electronically, depending on the individual user's screen configuration, or even the light within an office, which can change the nature of the colour displayed on a computer monitor.

The seasonal concepts are usually presented in several themes or stories, perhaps four or five each season, which each have a different title, look and feel, and in the case of colour forecasters, each have a different range of colours presented. This diversity allows customers to develop a range of products, either by using all the different stories presented, or by selecting just one theme, or group of colours, relevant to the client's market sector.

Successfully getting a product to market and subsequently sold to the consumer at the right time in the seasonal fashion calendar is vital to the designer, supplier and retailer profit margin. Today, more than ever, the timely arrival of products in store can make a tremendous impact on the overall volumes sold and the profit generated. Many retailers work on an approximate six-month cycle from initial concepts, sampling and final samples to delivery, warehousing and distribution to stores, and have several seasons running in parallel at any given time, featuring a number of 'phases' within each season. There may be as many as six phases within one season, each slightly different from the last in terms of design, colour and fabric selection.

9.3.1 Colour across product ranges

It is not only the development of garment collections which are influenced by the seasonal colour predictions, but a wide range of associated products which may be merchandised alongside the garments. Moreover, the number of garments within a range is often vast, especially with many of the larger high street retailers, national and international chains. 'The colour story will be combined into prints, yarn-dyed fabrics, and solids and coordinated across jackets, tops, skirts, pants and dresses into a collection with perhaps 200 separate pieces.' (Brannon, 2000: p. 116)

Further products not mentioned by Brannon include footwear, leather goods and accessories, further expanding the overall number of separate pieces possibly influenced by early colour development decisions. Additional items would also be required in accurate colours for garment components, such as zips, thread, buttons, other fastenings and closures, all of which would require dyeing to match the entire product range. Consequently, ensuring colour is ratified at the earliest possible opportunity in the product development cycle significantly reduces the risks associated with poor colour-matched trims, accessories and related products. Dutch forecaster Li Edelkoort, who is perhaps the best known of all colour trend specialists, noted a strong relationship between fashion and interior colours, 'In many cases, all the colours in interiors and fashion go hand in hand. Today we see that colour-stories often take flight within the world of design and home textiles.' (Edelkoort, 2002: p. 1). Brands which offer lifestyle and interior products alongside their fashion offering may also, as Edelkoort suggests, use their fashion colour information to develop their interior product ranges, hence requiring further colour synergy between an extended product range.

9.3.2 Fashion trends and lifecycles

Today's consumers have become increasingly exposed to, and aware of, fashion trends as a result of 'fashion magazine' websites devoted to disseminating the latest fashion trends to consumers as quickly as possible, and weekly fashion magazines such as Grazia in the UK. Consequently, brands have had to establish more responsive design teams, rapid manufacturing bases and stronger marketing strategies to maintain and increase sales, and the key to successful products today is in the accurate market and trend analyses carried out during the early stages of the fashion development cycle (Bruce and Daly, 2006, Le Pechoux *et al.*, 2001).

The lifespan of a specific fashion trend also appears to be moving much more rapidly than ever before, seemingly in response to the increase in consumer fashion awareness and their demand to see new merchandise on every visit to a store. In the late 1990s the average lifespan of a fashion trend was around one year; by 2000 that had reduced to just five months on average (D'Innocenzio, 2000). Designers such as British duo Clements Riberio have often been left with just two weeks to design their collections after factoring in the entire critical path, and yearn for the less frenetic days of the 1980s when designers were able to evolve their looks slowly over a period of years (Armstrong, 2000). In response, retailers have developed a retail mix today to manage the pace of change in fashion trends and the entire product development cycle behind it. It encompasses a combination of merchandise, price, advertising and promotion, customer services and selling and store layout and design cited by the retailers to meet target customers needs (Dunne *et al.*, 2002). Such short cycles put a tremendous amount of pressure on designers and forecasters to get the concepts right first time with substantial emphasis placed on accurate colour prediction within the initial planning stages (Easey, 2009). Is this model sustainable when fast fashion is being adopted by retailers across the globe? Rickman and Cosenza (2007) believe current methods of fashion trend forecasting are unsustainable.

> The current methods of forecasting cannot keep pace with the changing dynamics of the marketplace – The company that can tap the continual flow of data/information, contrast it with a stored set of information from the past, and adjust based on repeated cycles, will have the best insight into the lingering trend, changing trend or dynamic trend. (Rickman and Cosenza, 2007: p. 608)

However, Janet Holbrook, the UK agent for Peclers Paris, one of the largest forecasting companies, believes that fast fashion and the shorter cycles it has spawned should not be viewed negatively, and that there are still many synergies in developing trends for the newer, shorter cycles, as there were for the longer traditional fashion cycles.

> You have to have starting points . . . the yarns and the fabrics – the fabric manufacturers and spinners right at the beginning of the process, they need to be informed . . . start quite early. Then there are the trends we can see coming in quite early, the real trick is knowing what to look for and when to know what is coming in. What people want is creativity and that's what we are giving them. The Peclers books give you enough room for manoeuvre so you're not told just to do this or that. We say these are the ideas and you take it on. (Holbrook, 2006)

Other forecasters have adopted a slightly different response to the increasing pace of product development in fashion and textiles, and something which they hope will complement the demands of fast fashion. French forecasters Carlin work differently to Peclers. Their UK agent Alison Hughes outlined how Carlin was responding to the changes in 2007.

> WGSN changed the landscape with online daily trends, and books are seen as being of secondary importance now. Carlin now have some web-based add-ons mid season, such as the women's update in three parts; from the catwalk, a last minute guide, key colours and fabrics. The online service costs clients an additional £1000 for the season and has not proved as popular as initially hoped. (Hughes, 2007)

Joanna Bowring used to be the womenswear fabric coordinator at British retailer Marks & Spencer, and experienced some dramatic changes in the traditional critical path timescales in the early part of 2001.

> In 2001 the new womenswear creative director wanted to use the colours from the catwalks, not develop our own trends. As a result, things began to blur, and as the catwalks were only 6 months ahead of the season, the timings were too tight and it just did not work. Pitti Filati had previously been 18 months ahead of the seasons in July, but now they were looking at taking the colours and getting merchandise in store within 6 weeks! (Bowring, 2008)

Not every retailer has adopted fast fashion, some use it for only a fraction of their entire range, but it has obviously impacted upon the forecasters and how they present their trend information, in particular their colour palettes, using in season updates, online strategies and focusing on their creativity, developing new colour combinations and finishes.

Clearly, fast fashion's impact on colour forecasting cannot be underestimated, but there is evidence that the colour forecasters, and those involved early in the colour development stages of clothing manufacture, such as the yarn spinners and fabric mills, are being as responsive as the forecasters, but are responding not necessarily by holding considerable stocks of greige yarn and fabrics, ready to be dyed quickly, but again by being creative in what they are offering clients. New colours, new treatments which affect how a colour is perceived, perhaps fabrics with a more lustrous or reflective finish, or a softer, blurred edge, or other new applications of colour are being seen. Counterbalancing the fast fashion movement is something. which the trend forecasters are working on with the fashion supply chain in earnest.

9.4 Future trends

If Rickman and Cosenza are to be believed, the future for colour forecasting could be interpreted as being rather bleak. Jackie Nash, Publisher of the UK-based colour forecaster *The Mix* also argues that fashion colours are no longer seasonal:

> Fast fashion has taken over and producing colour every six months is not working . . . The consumer demands more and trends are driving what is happening. There are very few people who innovate and more followers than leaders today. (Nash, 2007)

So what could be the answer for today's colour forecasters? Digital and online solutions are increasingly available, featuring a broad range of information from street style to live catwalk report, and will undoubtedly continue to be used despite the inherent problems of viewing colour on screen from a light emitting device. A physical yarn or fabric swatch is always preferable when deciding on which colours work best together. Traditional forecasters have begun to adopt some of the new technologies on offer to work in synergy with their traditional trend books, thus providing something for everyone.

Undoubtedly online trend information providers are changing the nature and use of forecasting, providing a far different range of services than previously. It is not simply the immediacy of the online formats, but also the rapid interpretation of global trends, distilled for customers from agents across the globe, and the inherent economies of scale associated with the information gathering process. Instead of sending numerous teams or individuals to scout information and comparative shopping around the world, the more cost effective approach is to use someone else to do this for you. There are many providers of online information today – perhaps the best known, and certainly one of the inceptors, was the British based Worth Global Style Network (WGSN). Others such as the American Stylesight have been established more recently, adopting similar principles to WGSN; they report from international catwalk and trade shows, influential cities, exhibitions and key influential events.

Online blogs, such as those featured on the In:color and Colour Lovers websites also bring immediate reaction and daily views on colour related to fashion, interiors and product design, and can be an interesting addition to the colour forecasters range of information gathering.

Other newer sources include applications for mobile phones such as those provided by Trendstop, which users can download to their phones, gain updates, photos and trends direct from the provider as they happen. This is seen as potentially the big way forward, mobile communications providing immediate access to information away from the constraints of the keyboard, using wifi technology. There will always be a place for the physical elements of colour forecasting though. Humans by nature are attracted to the tactile, and will no doubt continue to want to touch, feel and bring together swatches of fabric, pieces of yarn, paper and other materials for colour inspiration.

9.5 Sources of further information and advice

9.5.1 Trade fairs promote colour and are a valuable source of information.

Here are a few of the best known:

- Premiere Vision, Paris, France; Held twice a year featuring predominantly European fabric mills.
  www.premierevision.fr
  e-mail: info@premierevision.fr
- Expofil, Paris, France. Held in parallel with Premiere Vision. Specifically for yarns and spinners.
  www.expofil.com
  e-mail: expofil@expofil.com
- Pitti Filati, Florence, Italy. Similar to Expofil in that it features yarns and spinners twice a year.
  Moda In, Milan,Italy.

9.5.2 Trend forecasters who publish colour trend forecasts

- Nelly Rodi
  www.nellyrodi.com
  e-mail: infos@nellyrodi.com

- Peclers Paris
  www.peclersparis.com
- Promostyl
  www.promostyl.com
- Carlin International
  www.carlin-groupe.com
  e-mail: style@carlin-international.com
- Trend Union
  www.trendunion.fr
  e-mail: corrine@trendunion.com
- Studio Edelkoort (Li Edelkoort)
  e-mail@ studio@edelkoort.com
- Global Colour Research
  www.globalcolour.co.uk
  e-mail: marketing@globalcolour.co.uk
- The International Colour Authority
  www.internationalcolourauthority.org
  e-mail: info@internationalcolourauthority.org

9.5.3 Online resources

www.wgsn.com
www.trendstop.com
www.stylesight.com
www.fashioninformation.com
www.incolourconsultancy.com
www.colourlovers.com

9.5.4 Trade associations

- Cotton Incorporated
  www.cottoninc.com
- Colour Association of the US (CAUS)
  www.colourassociation.com

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10
Sustainable textile design

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Abstract: This chapter is based on research to establish what constitutes an environmentally friendly textile, from the perspective of a practising designer. It identifies the environmental issues, the new goals and objectives, and the role of the designer in manifesting the necessary changes across the whole industry. The chapter identifies key environmental design strategies, and gives practical advice in the form of questions and exercises so that designers may engage their creativity to develop interpretations and alternatives based on their own methods of life cycle analyses. Because designers are in such key positions, the chapter also endeavours to explain the unique qualities that comprise the nature of design practice to others working within the field. There are also websites and suggestions for further enquiry.

Key words: textile and fashion design, environmental design, life cycle analysis, eco-design, biomimetics, biomimicry, renewable, recycling and reuse, sustainability.

10.1 Introduction: key issues affecting textile and fashion design

Designers have privileged access to the production process since they are responsible for specifying up to 70% of the subsequent material and production processes in any given project (McAlpine, undated). However, they do not have the power to implement environmental changes in the production of products because much of their work is confined by a brief that is set by the employer. (Unless of course they run their own business, where arguably they may have the freedom and flexibility to make changes.)

A brief is the means by which an employer purchases the appearance and often the practical instructions for production from a designer. The overall objective of all manufacturing businesses is to profit by fulfilling the demands of the marketplace. The price point for the product is the single most important aspect. The product has to sell, it has to be affordable, fit for purpose and desirable, or else the company cannot survive. The number of colours in a print, the quality of cloth, finishes, accessories such as buttons and zips, ease and speed of production, hand finishes and embellishments – all are crucial to the bottom line. Is it possible to change these priorities? This is a challenge, not only for the eco-designer, but for everyone from producer to consumer. How can we convert the destructive consequences of the way the profit imperative is systematically allowed to undervalue material and human resources, into a constructive and new method of use and recognition of the true values that conserve these resources?

The whole field of environmental design is very alive, constantly changing and evolving, and is as much about changing systems and mind sets as with immediate problem solving. It has to be lively, because putting these ideas into practice is challenging. Resources and materials, processes, supply chains, new ways to sell, use and return goods, reuse and recycle, along with the underlying understanding about whys and wherefores, all are being defined and refined as we go along. On a personal level it is also about having enough courage to choose what we do with our time, this might mean making less money, but needing less, doing more for ourselves and our immediate locale, inventing systems of change, and being aware of how we are enjoying all our activities of living. Enjoyment is one of many examples of a greater value. How much have we tried to buy enjoyment that is mediated through products, but devalued by having to work too hard doing something we disliked? Ghandi said, 'Be the change you want to see in the world'.

However, a thriving economy does not demand that we have to make less money. The success of the service industries has proved this. Because environmental design is still in this state of flux, it cannot be implemented without a self-conscious and informed effort. It soon becomes clear that whole new chains of production, relationships, dependence and interdependence need to be invented and developed. This author believes that informed and regular referral to every actual activity as well as the requirement to make profit in new ways, will enable us to rebalance the product lifecycles with the true environmental and human values. If we are courageous enough to accept what elements constitute a future environmentally friendly series of ideals, and are honest enough not to lie to ourselves when we do things that are still cleaving to the old, environmentally abusive patterns, we can align our steps. We may not get there, but having a courageous and ambitious aim, helps us decide what to do, and how to do it. This is a creative process.

10.1.1 Starting where we are

Most businesses are already locked in economically competitive chains of supply and demand, and are not easily able to make unilateral changes to their methods or products. In current practice, a designer might be given a cost–benefit analysis between the available resources on the one hand and on the other, the required product and the price point where it enters the marketplace. There are many scenarios: cheaper materials; cutting costs and processes; abandoning whole factories, manufacturing capacity and workforces in search of cheaper options in order to avoid legislation that protects the environment and workforce. All this can be accomplished by moving production to countries where the abuse is tolerated. These factors all lead to an ability to undercut competitors in the marketplace, and although there might be a low profit margin on each item, high sales volumes yield a larger overall profit. This system does nothing to ensure that the skills, the machinery and the ability to manufacture are conserved, if the profits tumble, everything can be lost. The baby gets thrown out with the bath water. Again, we need to realign our values.

Such practices have made clothes and textiles available to the masses, but these products are not of good quality, and there are knock-on effects. Loss of employment, loss of the ability of a given local population to provide for its own basic needs, loss of skills, the creation of monopolies and general destabilisation. For example, when the world bank wrote off Zambia's debt in the 1980s, it demanded the implementation of a free market, which destroyed the country's small indigenous manufacturing capacity because of cheap Chinese imports (Woolridge, 2006).

In the UK these cheap Chinese imports are also adversely affecting the charity trade in clothes. People buy them instead of quality items, do not wear them often and throw them away. The Salvation Army finds that the poor quality of these items placed in the recycling system, cannot be reused or sold on so easily, and there are no longer enough good-quality clothes for its charity shops. The second-hand cheap Chinese imports are also sent in mixed batches to Zambia where the Saluala industry, which means 'to select from a pile in the manner of rummaging' (Tranberg Hansen, 2000), employs two million workers in re-selection and reuse. White collar workers in Lusaka choose the designer labels, then wholesale lots work their way down through the social and economic orders and clothe the whole country. In the villages it is possible for a family to survive by specialising in one particular type of garment. Care is taken to clean and present the items beautifully. Nothing is wasted. However, when the quality of those clothes diminishes, their potential for reuse becomes increasingly compromised. No country is immune. The UK has lost much of its textile manufacturing capacity in this way, and India is currently concerned about losing out to China.

10.1.2 What is wrong? – the facts

Theodore Roszak in his book *The Voice of the Earth* (Roszak, 1992), thinks that if psychosis is an attempt to live a lie, then our psychosis is believing we have no ethical obligation to our planetary home. Are designers, architects and engineers responsible personally, and legally liable, for creating tools, objects, appliances and buildings that bring about environmental deterioration? Probably not, unless one is looking for a scapegoat rather than a solution. Designers should be able to understand the environmental issues within their own practice, even if they are not required to do so by their employers. This could make them indispensable and key to the survival of a company, not least because of increasingly stringent environmental legislation. The following five headings describe the issues that make the life cycles of textiles and clothing unsustainable. If we include issues of fair-trade and ethical treatment of workers the list is even longer.

1 *Water.* Misappropriation and inappropriate use. Excessive use. Contamination.
2 *Chemicals.* Profligate use of pesticides and herbicides in agriculture and of toxic chemicals in production.
3 *Asset stripping* of non-renewable resources, including energy sources. Undervaluation and non-regulation.
4 *Waste.* Too much is destroyed. Systems need to be developed to recycle all non-renewables or compost renewables.
5 *Transport.* Unnecessary demand caused by capitalist exploitation of cheap labour makes this also unethical as well as increasing the profligate use of non-renewable resources such as oil, and the attendant pollution.

Production

Many aspects of textiles and fashion get grouped together under the banner of unsustainability. The environmental issues are pollution, poisoning, excessive use of pesticides and insecticides, de-oxygenation of water supplies with subsequent loss of animal life, salination of water and reduction in soil fertility, and loss of natural biodiversity.

Ethics

Environmental abuse combines with ethical issues when there is excessive use of water and when land is misappropriated away from food production. Further ethical issues involve atrocious treatment of workers, abuses of human rights, forced labour and deaths from poisoning, all of which are unacceptable sacrifices to commerce. There are now issues surrounding the appropriation of agricultural land for biofuel production, too. How can we enable carbon reduction without compromising the even more basic need for water and food?

Market forces

The toxins are not just confined to pesticides and insecticides, but are also present in fabric treatments, dyes and printing, and are used in the creation of synthetic fibres derived from petroleum-based feedstocks. Fossil fuels are used to run agricultural machinery and to transport fibres, fabrics and finished goods backwards and forwards across the globe to find the cheapest processors and to get the cheapest deals in unregulated, developing countries. There appears to be no moral obligation where commerce is concerned. In an interview on Radio 4 (12 January 2006) John Snow, the US treasury secretary, acknowledged that the internal economy in the United States, was growing because of the consumer boom fired by cheap imports from China. This is at a terrible environmental cost to China, where there are also no core labour rights such as collective bargaining (*Ethical Consumer*, 2002) These imports also threaten the economic viability of manufacturing within the United States, creating unemployment, which has contributed to the recent credit crunch, repossessions of homes and the repercussions across the international money markets.

The paradox is that the workforce relies for its survival on a system that appears to be destroying the ability of the globe to support that workforce. But any new solution has to build on the existing system to make changes. This is because money is the best internationally recognised method with which to share resources (Porritt, 2007). To destroy the economic balance could also lead to anarchy and war.

Use

The largest environmental impact of textiles occurs when they are being used by the consumer (estimated at 75–95% of the total environmental impact) and is accounted for mainly in the use of electricity to heat water and run laundry and drying processes (www.informationinspiration.org.uk and sevenethgen.com). This contributes to greenhouse gases and global warming.

Disposal

Much of this painfully achieved produce then gets thrown away, to be buried, or burned, releasing ozone-depleting methane gases from landfill sites because the fibres cannot decompose properly. Airborne particulates which are released when textiles are burned can also aggravate respiratory conditions such as asthma.

It is therefore sensible to look honestly at where and why the systems and processes are destructive, and find ways to change production, use and disposal.

10.1.3 Where can designers start to make a difference?

To start with, designers should not stop expressing the creativity that makes them tick! Genuinely sustainable textile and fashion design should prioritise the creative thought processes (even though so many practical issues still have to be solved). Creative thought processes include the vision that is more like reverie, and is more intuitive, i.e. knowing just what is right. Designers also need to be informed, so that they can choose the right production systems and materials, and in many cases be proactive innovators of those systems themselves. To become informed, designers have to become familiar with making life cycle assessments (LCAs) of the constituent parts of the textiles they are using and the garments they are designing. This will be explored later in the chapter.

In many cases the production system gives birth to the creative potential too. Starting with an environmentally friendly system and set of criteria with which to work can enable the development of its own desirable aesthetic. For example, the London-based company Junky Styling restyles discarded clothes (Fig. 10.1). Their outstanding and innovative designs add value. They went on to invent ‘the wardrobe surgery’, restyling other people’s clothes to order. Why this is such an important innovation in environmental design will be explained later. Junky did not start out to be eco-friendly, yet they have become a model for financially and aesthetically successful design that utilises a local waste stream. In fact, they had no money and needed cutting edge clothes to get into clubs. Necessity was the mother of invention.

We cannot go back to the dark ages, forget space age technology or uninvent the wheel, and no-one wants to wear sackcloth. Every technology has to be recognised and incorporated in acceptable ways, and in combination with the necessity of sustainability. Many elements are not mutually exclusive. It seems counterintuitive, and even though it is derived from oil, polyester is currently more environmentally friendly than organic cotton, because it uses less energy during laundering. Everyone on the planet needs to align to environmental and sustainable ways of living. Textiles need joined up thinking and action from scientists, farmers, factories, shops, the public and governments. Designers have a unique knack of interpreting the *Zeitgeist*, they are often inspirational, and crucially they are the ones who will be responsible for what environmental design looks like and how it is made. Can designers also be the key people who, by understanding the specific environmental issues of their specialism, are able to advise everyone else in the production chain to change?

Given the obvious complexity of the issues, and that we are all in bondage to the system, it is essential to unpick points where interventions can be effective enough to make real changes.

- Individual governments, if given accurate information, can legislate, but diplomacy, trade agreements, international alliances and global economics keep whole

10.1 Junky Styling, Cuffs Dress (published with kind permission from Junky Styling).

countries in bondage too. Governments can put standards in place and help to establish certification systems.

- Consumer demand is one of the most powerful points for change, but this can not happen without educating the consumer and then providing actual alternatives. Coherent labelling is essential. Things also have to be affordable and fit for purpose.
- Designers divine and define what we want and need. This vision is the unique definitive talent of designers; it is the key, because it is actually what makes something saleable or not.

10.1.4 How to understand how designers understand

Something can be certified, labelled, affordable and fit for purpose, but designers add the seen and unseen beauty. Although LCA is the best and most accurate way to solve issues one by one, it is the way in which a designer is able to think out of the box that is powerful and revolutionary. The industry needs to understand that designers work and think differently, and must learn to support them in this key role, and feed them with new ideas, technology, access to materials and processes, and information in a way that they can understand and work with. This means making designer-friendly interfaces that are free at the point of access, regularly updated and easy to navigate. These should be written in the simplest ways, avoiding jargonese, and where possible give access to samples, opportunities for hands-on experience of new processes and technologies, and effective contact details. Information given to students should be quick, basic, concise, precise, up to date and *free*.

Designers are inspired by everything and everyone in the world around them. We can tell this by looking at the international fashion shows which are often an instant barometer of the most pressing global issues, reflected in a seemingly fickle mirror, which, like laughter, is often the only way to face unpalatable truths (starving models in the abundant West, blackened eyes, bleached white cotton that pretends purity, bright and polluting chemical colours that reflect the 'natural' feathers of exotic rain forest birds, etc.). The heart of the problem is in the life games in which we are all players; of power, wealth, belief and imagination.

As an artist, maker, designer and craftsperson, the current author has always used imagination to understand, engage with and transform personal experiences of the big three (power, wealth and belief). Artists, designers and craftspeople have always made these elements at first tangible and then palatable, by interpreting them, and making them real, useful and attractive. Great artists like Michelangelo made The Divine visible, Leonardo Da Vinci dreamt of machines to control and navigate the physical world, medieval stonemasons who had understanding of mathematics designed the great cathedrals, and craftsmen built them. Similarly, John Galliano's imagination might alight on Chinese hill tribes, and mix the visual evidence of their culture with romantic French revolutionary heroes, to refresh our own notions of who we could be. But why are these two groups of people so inspirational? The hill tribes live outside a money-based economy. This in itself does not mean that great visual expression would necessarily emerge in such an economy, but the existence of these very beautiful, individual, complex and fine masterful textiles and costumes could only emanate from communities of such a high order of peaceful cohabitation and harmony with their environment, as to enable this high form of self-actualisation. We also love the French revolutionary hero because at the height of his own personal power he is ready to sacrifice everything to create a fairer society for others.

Do we believe we are powerless to do anything more than look like our heroes? Galliano is certainly a visionary, who can show the best of ourselves to ourselves. Both sources of inspiration look great, and both come from two recognisably important wellsprings of the human psyche. Do we recognise what we would really like to be, can we dare to change, rather than use clothes to disguise, hide, protect or forget? It is to do with choices. Can new designers give us the other options, not just in how we look, but in new systems with which to use our textiles and clothes; how we purchase, share, swop, collect, change, sell, exchange, use, reuse our clothes and textiles. Can we be the revolutionaries who then live in the sustainable societies and lands of our own creation?

Imagination fires all the creative industries, and also reflects the destructive and frightening by-products of power, wealth and belief. Do we believe that we have no influence over these realities, and how far do the cultural reinterpretations that bring us hoodies, combat prints and the like, also perpetuate and encourage violent and negative imagery, behaviour and role models? How far are we really in bondage to the system and how much are we inadvertently supporting and perpetuating it? How much do we recognise our own differing levels of debt bondage? How far can designers intervene, and can they inspire new alternatives? Do we have to compromise our environmental wisdom just to afford the rent? Can we afford to live slowly? What does the highest, most creative ecological manifestation of our imaginations actually look like? Can we make beauty that we deserve?

Designers can have a major role in changing manufacturing systems, but this ignores the particular (and bankable) talent of the designer; namely the power of alchemy, of transformation by imagination. Can we pay our own way and still be able to change the ways that money buys goods and services? Can we balance the real environmental value of a garment, which takes into account the real embedded energy and the real raw materials, with the amount of money that it cost? The Factor 10 Institute (www.factor10_institute.org) says that we have to get ten times more out of every product than we currently do, just to maintain the planet in its current unsustainable state. We also need two earth-planets to keep producing at the current rate.

Can we find a way to relate money to the real value of the resources we use? Can we find a way to use money to prevent the abuse of resources? Can we think freely outside the destructive box that gives us our daily bread and shelter? Can we stop the invisible power of money from overriding and undervaluing the real cost of materials and processes? Can we accept and live with the answers to these questions, particularly if it means new limitations? Can the new designers make us choose the new options because that is what we really really want.

There are very real practical strategies that will enable designers to specify new environmentally friendly life cycles. There are inspiring new business opportunities that will evolve where the design of systems of use can be realised by new entrepreneurs. But the greatest contribution that any new designer can make is to manifest the subconscious desire of the whole of humanity for health and to live freely and harmoniously. What will these textiles look like? Will they be restrictive and dictatorial, or will they fulfil the promise of individuality, diversity, personal choice, abundance and freedom that could be offered by globalisation, universal access to millions of differing and specific needs and desires, made possible by the unifying power of the World Wide Web? Will it be enjoyable: envisioning, making, selling, using and reusing these textiles?

Apart from the limitations placed on them by their terms of employment, other immediate problems facing the proactive and aspiring designer of sustainable textiles are associated with the intransigence of the existing system. Most businesses are already locked in economically competitive chains of supply and demand, and are not easily able to make unilateral changes to their methods or products. Changes in supply chains or production methods could also affect diplomatic and trade agreements with other sovereign states, or reduce exports, create unemployment in some industries, or affect the national well-being in other ways. Intervening in some businesses is even dangerous. There are power structures, personal interests, hidden agendas and many cultural and social interrelationships that are simply not visible, particularly when we start working with third-world countries. This is why my own particular focus is on clarifying the environmental issues where designers could make a contribution. Sometimes these interventions can actually save money because they are more efficient and less wasteful. The issues need to be solved because they make sense on many levels. Many businesses, charities, agencies and government initiatives are already aware of and engaged with ethics and fair-trade, such as 'Labour behind the label', 'Fashioning an ethical industry', PAN UK (Pesticide Actor Network UK), Katherine Hamnett, RED at Gap, Oxfam, etc. However, it is important to note that environmentally friendly, ecological design goes *even deeper*, because without it human beings might not survive at all.

Most of the current discussion is likely to have less immediate use for designers who are already in employment (at least until more legislation comes into force), and will be of more benefit for their personal development, freelance activities, for self-employed designers, proactive eco-design companies, and of course teachers and students. Creating change will rely on building new arrangements. The word 'arrangements' is preferred to the word 'business', because until new patterns emerge, it is difficult to formalise and describe the many alternative relationships that can begin to exist between the exchanges of products, services, ideas and money. Many of the new ideas for the ways in which environmental design can be used will not be instantly recognised, and need to be explored for what they are: the relationships between people that occur when a major cultural shift is taking place.

Here we come to the heart of humanity, and the truths that drive us all. Great designers undeniably manifest these elements. They bring form to aspirations, as well as actually making things fit for purpose. How would we know that a Hollywood star was divine if the gowns she wears did not reveal such a truth? Today, the designer is no longer an alchemist who is required to make sackcloth look like the golden fleece, it really must *be* the golden fleece, because we have to appreciate the true (non-financial) value of the constituent materials. The great designer is one who can dream and make that dream into reality. Anyone who says that this alchemy can be dispensed with really does not understand the unique nature that inspires the abilities of the textile and fashion designer: the one who really does make the dreams real.

10.2 Strategies for fashion and textile design

10.2.1 What do we need? How can we get it sustainably?

Our primary needs are air, water, food, shelter, warmth, safety, companionship, sex, procreation and, hopefully, happiness and contentment. To provide these necessities, we rely on identities that are upheld by those around us. Those identities are immediately apparent in what we wear. We have little time to perceive anything other than what we can apprehend in a momentary glance. Our costumes dictate our roles, and because we are all in competition for a share of resources, the way we present ourselves can help or hinder our passage through life. The expectations of our roles, social status and behaviour are hard to override. Imagine the hoodies helping old ladies across the road, ladies in suits pole dancing, clergymen picking fights, or facially tattooed police officers: this could only be an art piece to point out the power of daily costumes.

Textiles are used to make our chameleon skins. Textiles and clothes are psychologically important: uniforms of our particular tribe of hunter-gatherers, armour for our warrior nature, camouflage to hide behind, colourful, tactile, inventive, defensive, protective, decorative, socially and 'tribally' definitive, theatrical, smart, seductive, playful, as well as practical. Taken for granted, textiles are present everywhere in our daily lives. Even if they are eco-friendly, textiles still have to beautiful, fit for purpose and affordable. Or can we possibly allow these commonly held conventions to visibly change, if it means we can survive? How necessary are the uniforms? Can they be made differently?

Fast fashion has brought a democratising element to options and choices that we have never had before. Not only can we have the fashionable clothes we want, now, but we can have enough of them to be able, financially, to afford to throw them away rather than even to bother washing them! For example, at a government-backed conference on sustainable clothing Tom Fisher from Nottingham Trent University and Tim Cooper from Sheffield Hallam University described how cheap clothing often leads to short life spans: 'During recent research we met one woman who each year bought fourteen tee-shirts for £2 each for her holiday, wore one each day and then discarded them. She liked the idea of wearing something clean and fresh each day, and discarding them meant she had space for duty-free purchases on the way home.' We mix fast fashion with a few expensive designer items, a few cleverly bought fake designer items, and some vintage or second-hand collectable finds. The one we buy to dispose of, the other we have 'invested' in. If we continue to need 'fast' or at least inexpensive fashion, we have to ask how it can be made in an entirely environmentally acceptable way, throughout the whole life cycle.

10.2.2 Designer-initiated life cycle assessment

In order to understand the specific environmental implications of any given design project, and then begin to change any textile or fashion process for the better, companies conduct an LCA. This means looking at every possible material, process, use and finally the potential for reuse or recycling when the item in question is no longer wanted or needed. In itself it is also an experimental process that throws up as many questions as answers. Everyone is on the first steps of a long and changing path.

Designers and students certainly need to know what to look at in order to conduct LCAs to a greater or lesser extent, because this is a way of developing an understanding of, and confidence to change or advise on alternative and beneficial changes that can be made. (An alternative way for a designer to engage with environmentally friendly practice would be by choosing to use and develop environmentally friendly materials and processes that have already been identified, and start with these.)

Tracy Bhamra and Chris Sherwin comment (jdr.tudelft.nl):

> design . . . is not an exact science . . . it is a spontaneous and intuitive process . . . designers work largely with visual imagery and stimulus, using creative and non-prescriptive design processes . . . having little use for 'hard data' . . . eco-design is ever strengthening its scientific and technical roots in striving for more precise and accurate environmental data, which may directly contradict the requirements of designers themselves.

This does not mean that designers cannot make their own independent enquiry, in fact it was these very comments that spurred me, as a designer myself, to try to bridge the gap. There are indeed many variables, and at the time of writing very few design websites and tools available that make information clearly accessible and comprehensible from a designer's perspective. But there are inspirational new ideas and sources that, if presented in the right way, will fit into the process of design and become an additional source of inspiration rather than a problem. Existing sources of help will be detailed at the end of this chapter, but designers should feel emboldened to invent their own methods to understand the environmental implications of the materials and processes that they are working with. This is what is meant here by individual designer-initiated LCA systems. Use the best information and processes that you have access to in order to do what you can, and keep questioning, improving and strengthening your own practice.

Governments may have legal requirements for accurate LCAs in certain circumstances. These are strict, time-consuming and expensive. Companies like Marks and Spencer have developed their own methods of assessment too, they are able to 'encourage' their suppliers to comply because they have economic leverage. In the fast-moving world of fashion, assessments can currently be too time-consuming in practice to be conducted for every garment in a collection. This is one reason why there has not been a sudden increase in alternative 'ecological' choices, and why the real pioneering retailers such as Howies are few and far between. Ideally, working to build a framework of acceptable materials and practices, and reaping rewards by building brand loyalty based on integrity and transparency of supply chains, is sensible. There are many opportunities to be the very first designer to present product lines or new ideas enabling consumers to engage with eco-textiles and fashion design.

The results of every assessment can also be variable. A designer has to be prepared to weigh the pros and cons themselves, but this is par for the course because it is a way of testing the validity of ideas, and also of making decisions that can incorporate mitigation. An example of mitigation might be that although the use of oil and lots of energy to make polyester seems bad, in the phase of use, polyester uses less energy than natural materials. If that polyester is then recycled efficiently, it could end up using less carbon in its whole life cycle than organic cotton. Sportwear manufacturer Patagonia, systematically recycles its polyester garments by 'taking them back' from their customers when they are worn out, sending them to the Japanese polyester recycling textile company Teijin.

Of course there are other issues, too, there is rarely a single right answer, but there are many better alternatives. It is the very consideration of alternatives that is life blood for a designer. Alternatives can inspire unexpected new ways of doing things, some of which might involve exciting and unanticipated design elements, or an easier way of making something. Designers who do conduct these assessments are pioneers, and it would be useful to create more resources such as those in specialised university departments like TED (Textile Environmental Design) at Chelsea College of Art and Design, London, where results and decisions made as a result of designer-initiated LCAs can be made available to others, since this is also a subject that is itself still evolving.

10.2.3 Designer life cycle assessment interpretation: underlying philosophies and strategies of eco-design

Many of the following eco-textile and fashion design strategies have been developed by looking at environmentally friendly architecture and product design which are more advanced, often because of the need to conform to legislation. Analysis tools are available, but these need to be interpreted to find appropriate parallels that may be of use for fashion and textile designers. There can seem to be an overwhelming amount of complexity, but there are founding principles that all products conform to, and because of this, the strategies and philosophies that are developing do offer alternatives. The core concepts that seems to underpin and support many solutions are 'cradle to cradle' and 'biomimicry'.

Cradle to cradle and biomimicry (or biominetics)

There are only two basic materials in nature:

(1) materials that grow, these are biodegradable and they re-grow;
(2) materials that are finite, these do not grow.

The materials that grow are 'renewable' and those that do not are 'non-renewable'. The core concept is that: in nature there is no waste. One process leads to another in a dynamic balance that is the result of cause and effect. William McDonough and Michael Braungart, the co-authors of the seminal book *Cradle to Cradle* say that 'waste is food' because every part of nature feeds on the remains of a previous form (McDonough and Braungart, 2002).

All materials will remain true to their basic nature. In manufacturing, we intervene and temporarily harness the natural order, but there are repercussions, mainly caused by our untrue belief that waste can be just thrown away. Out of sight may be out of mind, but when something is buried, for example, all the constituent parts will continue to work according to their own inherent nature, in combination with the new conditions that surround them. Natural materials biodegrade, can release methane and create nutrients for new growth and soil matter. Manmade non-renewable materials do not biodegrade or break down, and some are poisonous. Their inherent value is difficult and sometimes dangerous to retrieve if it is buried in mixed landfill.

For years the idea of getting rid of poisonous by-products from manufacturing just required their dilution into the wide world. Paracelsus, the father of toxicology, noted that benign substances can be poisonous in excessive quantities, but that toxic substances can be rendered safe in dilution. Textiles utilise many chemicals in the form of pesticides, fertilisers, mordents, chemicals, dyes, etc., that have accumulative effects. There is now a tipping point, where bioaccumulation threatens us and means we have to be far less messy, profligate and wanton. Now we have to understand and take control of the inherent nature of every chemical we use, understand its impact, then value and respect its unique qualities and apply them accordingly. This is a revolutionary call to grow up, and to reinvent the industrial revolution, by mimicking nature in a way that maintains a benign balance, not mixing it up in a way that disturbs global eco-systems and poisons us.

Biomimicry and the appropriate recycling of renewable and non-renewable resources

Cradle to cradle describes a system that calls for the appropriate redesign of all systems to enable all materials to be used in continual cycles of use and reuse. This system is inspired by mimicking the processes of nature. To complete the cycles, the end of the product life must rejoin the beginning of a new product life. This is the point at which the circle closes. In practice this means that renewable materials must be composted appropriately. If methane is produced as a by-product of decomposition, then it can be captured and used as a form of sustainable energy. Fabric treatments, dyes and pigments on natural materials should also be able to biodegrade harmlessly so that the resulting compost can be used to nourish renewable crops. This revolutionary environmental design strategy is known as a 'closed-loop system'. If the materials are renewable, the loop is closed when they are composted, because the old nourishes the growth of the new.

An industrial example of this is Climatex® fabric, from the Swiss company Rohner Textil AG. This is the world's first fully compostable industrially produced textile range. Developed in 1995 by Michael Braungart, co-author of *Cradle to Cradle* (McDonough and Braungart, 2002), the blend of ramie, wool and polyester is a substitute for cotton, and the new yarn dyeing plant reduces water use by 30%. Climatex® is biodegradable, and all processing waste is used for felt or garden mulch. Using closed production processes, the water entering the mill is less clean than when it exits the mill. (Michael Braungart has been asked for a clarification on the use of polyester in this otherwise compostable fabric. It obviously has important wear properties, but would not decompose and would remain as fibrous filler in compost. This seems to contradict the requirement of pure cradle-to-cradle systems to use materials singly in order to reclaim the non-renewable resource. A personal belief is that in small quantities this mixing is currently seen as allowable, particularly if the mitigation is that the fabric is fit for purpose only because of the durable qualities of the polyester.)

The environmental data for the production of Climatex® are extensive, and could be used as a model to inspire other manufacturers.

- It meets the criteria for use required by the upholstery industry, for wear, aesthetics and full colour availability.
- It meets the criteria of the environmental legislation in Germany with regard to dye, chemicals, heavy metals, poison, recovery of chemicals and production risks.
- The raw materials are renewable, grown ecologically by closely monitored suppliers.
- Constant research and updating of production systems occurs, with monitoring of chemicals where they have to be used, inside and outside the company itself.
- Ecological accounting and constant upgrading, including regular recertification and independent inspections towards the objective of elimination of all waste and wastewater, noise reduction and the addition of alternative energy systems (www.climatex.com, environmental data, 2007).

Many fashionable products are currently designed for limited use. This is known as 'design for obsolescence'. It encourages people to throw things away so that they have to buy more things from the manufacturer. Taken to its extreme form this has become 'fast fashion', where people buy a cheap garment to wear only once before throwing it away. The global economic success and growth that this encourages is an ecological disaster.

In order to 'close the loop', the constituent parts of the product have to move through a new system into a new beginning or a new 'cradle'. It is this 'new system' that offers the new world of possibilities for a creative designer. After all, 'new design' can be as much about systems as it is about objects. In a service-driven economy, a key area for designers is to creatively develop ways for us all to keep money moving without necessarily relating it to repetitive sales of more and more new clothes. There may be a way in which this fast disposable fashion could enter easily back into the production loop for reuse or recycling. This could rely on the availability of very efficient take back systems, close to where the textiles and garments are processed and reprocessed. The fibres made from non-renewable materials such as oil would be valued for their irreplaceable and myriad performance values. To create an ideal environmental scenario, the energy source for this should be carbon neutral. Currently, energy is environmentally expensive because electricity is overridingly created from burning gas and oil.

Honouring the embedded energy

At present, even if the fast fashion garment is put into the recycling system, the 'embedded energy' within that garment has been entirely lost. Embedded energy means all the resources and energy used in the production of the garment. This includes that used in growing and harvesting and other synthetic fibre production, then spinning, weaving, knitting, sewing and finishing, including the production chains of zips, buttons, threads, beads and decorative embellishments. There are also air-miles used to transport the garment between countries and continents to find the cheapest factories for every part of the process, transport to the retailer, and then costs of disposal. (Importantly, all these aspects of production identify crucial aspects that need to be addressed within an LCA.)

The only way to change this system is to make it possible to retrieve all the materials, and in some way also justify, retrieve and honour the embedded energy. This means changing the way that particularly energy-and resource-rich products, particularly non-renewable products like oil, are made, so that they can be disassembled to reclaim and reuse those resources.

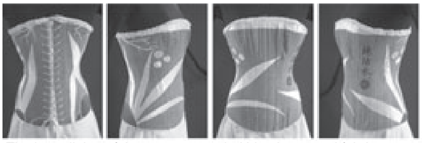
Design for disassembly

This is a new and important core strategy where the designer ensures that the constituent materials can be reclaimed for reuse at the end of the product's life. Fundamentally, this is easiest when all constituent materials to be used are in the simplest forms possible, because as soon as non-renewable materials are mixed, they become impossible to separate economically or ecologically, because they are contaminated and degraded. A textile example of this would be poly-cotton, where the polyester can only be retrieved by burning away the cotton, using excessive energy and wasting the cotton. An example of one design interpretation of design for disassembly is seen incorporated into Kathleen Dombek's wedding dress (Fig. 10.2), Eco-Friendly Apparel Design: 'The Dowry Dress'

Design goals: to redesign the life path of a garment in order to better fit its purpose and increase usefulness

Design results: a wedding dress that reflects the bride and reforms into keepsakes marking the life of the marriage

Phase 1: Design embodies the bride



The inner lining of the corset: recycled blue jeans and fabric scraps

- **The bride's sense of style:** bride can codesign her dress
- **The bride's memories:** recycling her favourite old pair of jeans for corset lining *(see above - also counts as her something blue)*
- **The bride's personality and name:** scraps from the corset fashion fabric used to create appliquéed design on the lining that reflects her personality; Chinese characters symbolise her name
- **The bride's life:** reversible corset that she can wear again and silk veil becomes a scarf to wear on anniversaries
- **The bride's gift:** adjustable fit and easily removable decorations allow the bride to pass on her wedding corset to a loved one

Phase 2: Bride sanctifies the cloth

Skirt trained, veil lying down along the train

Skirt bustled, veil tied to hands

Phase 3: Cloth reformed as life of the marriage grows

Dress on Exhibit at Cornell University

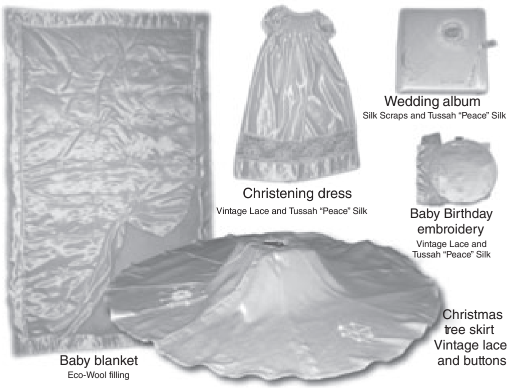
Skirt formed from a cleverly draped, unfashioned length of cloth that becomes keepsakes marking the milestones in the marriage

Step 1: Deconstruct the skirt
- Remove centre back seam and hems
- Detach from the waistband section

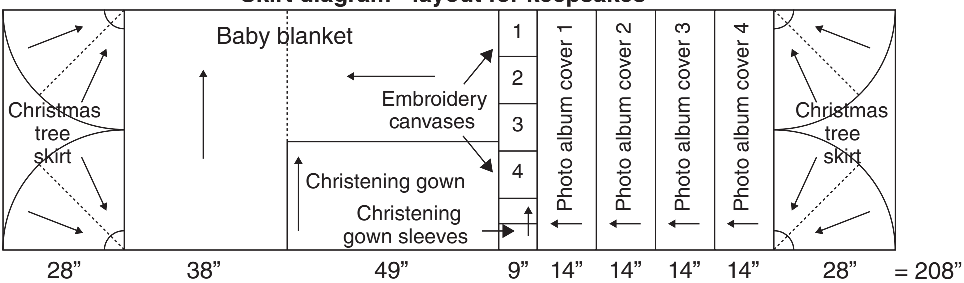
Step 2: Cut-out patterns
- Pattern shapes designed for little waste
- Pattern layout to maximise cloth use for this cloth is sacred and must be conserved (*see diagram at the bottom*)

Step 3: Construct keepsakes

Embellishments utilise other eco-friendly materials (*see captions below*)



Skirt diagram - layout for keepsakes



10.2 Kathleen Dombek, wedding dress (published with kind permission from Kathleen Dombek).

which can be changed again and again into new items that can change to meet the changing lives of the bride and groom. She also engages ideas of durability and emotional value in this work.

Factor 10 Institute

This principle of not mixing non-renewable materials and of being able to reclaim them should be the basis of a redesign of the way we manufacture things. If it is accomplished without disturbing the global economy, or even by enhancing profitability, it will have the desired effect of slowing environmental degradation. For those designers and students who need to know what will happen if we do not change our manufacturing systems: the Factor 10 Institute has calculated that we currently use 30 tonnes of non-renewable resources for every tonne of products, and that the trend is increasing; so much so that we would need the resources of over two more earth-like planets to maintain the current trend. This means that we have to get ten times more use out of every product. The system 'requires the simultaneous and even handed consideration of economic, social and ecological consequences of every impending decision' (www.factor10-institute.org).

Dematerialisation and design for durability

One of the ideas that is evolving to respond to the findings of the Factor 10 Institute is called 'dematerialisation', which essentially means getting more out of less. There are a number of design strategies that deal with how to put this into practice. Durable design looks not only at what the product looks like, feels like and how it functions, but then develops whole new systems of interaction with the customer that will add value and enjoyment, and create satisfaction and longer cycles of use. A number of companies exist that have begun to develop new systems as well as products. These systems include purchase, collaboration, use, hire, sharing, swopping, repair, reuse and eventually appropriate forms of recycling. Many of these activities can become economically viable businesses, where customers are often far more actively involved in developments of shopping experiences. Not least of these is a recognition of the value of shopping as entertainment. My own shop is already interactive, we offer to teach people specific textile skills, using our eco-friendly yarns, our varied expertise, eco-haberdashery and vintage hand tools. How and where the designer functions is also flexible. The methods for design and the materials and processes – as well as challenges to current relationships between time, motion and costing – offer many opportunities for creative lateral thinking.

10.3 Strategies for textile and fashion designers: recycling and reuse – beginning to close the loop

Recycling and reuse are particularly important and need to be the first problems that are solved within the whole environmental design puzzle. This is where the loop can close and where the wanton loss of our valuable materials and resources can be prevented. Currently, there is an abundance of materials available for creative recycling, the problem is that the systems to support the addition of value to discarded textiles and clothes are not abundantly advanced. Adding value to waste textiles by restyling them, or even simply sorting them is time and labour intensive and is the most expensive element. Accurate sorting should be a priority, and consideration needs to be given to where and why sorting facilities are sited. Sorting needs to happen where waste is created and where people need jobs, namely in large conurbations. Governments could decide to support the increased costs of employing and training staff, rather than relying on market forces which are preventing growth in this sector because it is impossible to pay even the minimum wage for such a time-consuming process. Market forces cannot be relied on to make the best environmental choice, but only to obtain the largest immediate cash reward.

Governments also needs to subsidise the buildings in which the sorting and subsequent storage and addition of value can take place. This needs to be accomplished with coherent, non-party-political forward planning, so that sorting systems can easily harmonise to take in new, more highly evolved waste streams that are working towards closed-loop harmonisation on a wide scale. The beginning will therefore be a period of transition where only some of the embedded energy and resources within the 'recyclate' can be utilised. (In other words, to kick start the future economic viability, let creative designers get their hands on the materials easily and affordably.) Success and the first profitable returns crucially depend on design companies. It therefore makes sense to also encourage the growth of new small design companies who can 'feed' from this source, while developing the sector. This could occur in much the same way as the encouragement of new enterprises in the 1980s. Again government could play an essential role in setting the system in motion.

There are two main categories for contemporary and future recycling:

1 Eventually, the largest, most-advanced companies will utilise and develop systems that will give them strategic control of material non-renewable resources. Some strategies would give future companies even more of this power, including custodianship. Large-scale management of natural, renewable materials that biodegrade could also be controlled by the larger companies, mainly because of the economies of scale.
2 Until that time, the renewal of the sector will begin with companies who utilise the discarded value inherent in the global system as it currently exists.

The first category aims to maintain and control value; the second benefits from the lack of control of material resources as evidenced by profligate waste (in this case value means economic value, but also the ecological value, even if this is inadvertent).

Three successful design strategies have been identified that have been evolving naturally using a small fraction of the abundance of materials within the waste stream. There is plenty of room for all the potential to develop, and for new relationships of supply, demand, support and collaboration. The emerging aesthetic of environmentally friendly textiles and fashion is fascinating. There are web-links throughout the next section with examples from existing design companies.

10.3.1 Design-centricity

Design-centric recycling is where the designer is selective in choosing items or materials from a waste stream for reuse, remodelling and adaptation. It requires designers with a good eye, individuality, creativity, perhaps slight eccentricity, quirkiness, and the power for reinvention and reinterpretation. Its success is aspirational, intelligent, to do with recognising quality and enduring value. It can also be slightly exclusive, stylish, 'with it', but is not necessarily fickle, because it is also at the cutting edge of creativity, where trends start.

Vintage in all its guises and uses plays a major part in the success of design-centric reuse and remaking strategies. A very important element is inherent in the received aesthetic, but also in the uniquely chosen physical properties of more unusual waste; for example, bicycle inner tubes, which are used to very different effect by designers Barley Massey and Nani Marquina. The key is that the materials are specifically selected. This selection occurs by cherry picking from sources such as waste textile merchants, online auctions, jumble sales, antique and second-hand dealers, or by eureka moments where an available material inspires a creative mind to make a particularly innovative and relevant product. These constantly re-evolving interpretations of 'vintage' also go on to influence the mainstream contemporary design trends.

Textile and design students and professionals often create their own original looks based on past styles, while design training and professional practice has always included knowing how to conduct research into historic movements. Designers are familiar with the development of new ranges through sketchbooks, story boards, colour and pattern development, essays and fabric searches. Contemporary designers already revisit retro styles in their collections, and also analyse the actual cut of vintage pieces. These methods are little changed from the way that dressmakers have worked with their clients throughout the ages. Originally fashions changed, and were embodied in the same valuable fabric year after year. Oblongs were carefully cut and pleated into the new styles, then unpicked and put away every year to be remade again later. Fabric was in and of itself, far more valuable than we believe it to be today.

Beverley Lemire points out in *The Business of Everyday Life: Gender, Practice and Social Politics in England c. 1600–1900*, that until the middle of the nineteenth century, everyone in society, rich or poor, was able to evaluate the worth of textiles, which were used as currency, and used, reused and bartered even when they became rags (Lemire, 2006). Our current systematic inability to husband our resources is a relatively recent phenomenon which has its causes in the power of the world financial markets to override our respect and proper husbandry of goods and services. Lemire tells us that before 1850, there was very little money in circulation in the form of bank notes or actual coins. A good pair of shoes or some dress fabric really was an 'investment', and was commonly used as currency as well as clothing. There would be little desire to put a Primark T-shirt into the bin if you could use it to pay your fuel bills! What are the modern equivalents and possibilities? This is where the challenge to designers begins, and this is where many new business models can stimulate new economic growth.

Designers learn how to manipulate and master their materials in order to express practical and creative ideas which are then made by manufacturers.

Designer-makers apply hands-on experimentation, dexterity, creativity, vision, imagination and flexibility to their fields of 'craftsmanship'. Technically proficient designers and designer-makers collaborate with good technicians, too. Some materials are inspiring in themselves, others are transformed by creative intervention. Artists such as Tracy Emin involve varying levels of textile-based hand skills in their artwork to express more conceptual observations.

Within my concept of 'design-centricity' this is pretty much where the reuse and recycling stops: with concentrated forms of creative brilliance. This brilliance does not dissipate into manufacturing processes, but recognises and retains, enhances, preserves and plays with materials that it simultaneously confers value upon. Counterintuitively, these are not all exclusive and expensive products. This work is available at local levels whenever makers and artists are able to afford access, through galleries, shows, market stalls, exhibitions and fairs, as well as online sites.

10.3.2 Product-centricity

Product-centric recycling allows manufacturing systems to engage with textile waste streams. It can occur because materials and processes are affordable, available, sustainable, repeatable, in quantity, allowing the addition of value and profit. At the moment there is enough waste to enable some companies to recycle existing waste streams of textiles so efficiently that even variability can be integrated without compromising the requirements of larger-scale production methods. Worn Again (www.wornagain.co.uk) utilises huge quantities of repeating fabrics to make its shoes, and Ecoganic uses faux sheepskin made from 100% recycled polyethylene terephthalate (PET) (www.hipandzen.com), which means that there is no remaining vestige of an original aesthetic to affect or influence the new design. Patagonia used PET for its fleeces and has now developed an extremely advanced system of take back where it fully recycles its polyester garments into new garments, the Common Threads Recycling Program utilises the ECOCIRCLE™ recycling system from Teijin in Japan (www.patagonia.com and www.teijinmonofil.com).

Currently the way that the waste stream can be utilised as a source of materials is different from the way that it should evolve. In future, the production systems need to evolve so that manufacturers will have more control over the life cycles of their textiles, clothes and other products. Eventually, it will be easier for textiles to go back more efficiently into the production stream. The systems that will make this change possible include 'design for disassembly', 'take back' and systems of use that would include 'products of service' where items are hired, returned and reused, and which can be upgraded.

Typically, materials in the product-centric group are very abundant and aestheticly random. Currently, the variation in materials requires that all companies using large quantities of waste have production methods that have been developed specifically to include sorting, cleaning and cutting. Small- and large-scale businesses use different methods, and the products themselves differ according to the economies of scale. For example, Worn Again can make thousands of shoes from 99% recycled materials, while smaller companies can use repetitive components and/or make multiples of small saleable items such as fashion accessories. Examples include handbags made from ring pulls (www.escama.com) and handbags made from silk selvedge embedded in polyurethane (www.riedizioni.com). Traditional quilting and appliqué are even smaller scale, labour-intensive methods of making treasure from the smallest scraps (www.auburn.edu/academic/other/geesbend), while rug making (progging, hooking, pegging and plaiting) is a thrifty way to use more shabby and worn textiles.

The industrial side of the textile waste stream makes fibre that is used for wadding for furniture, underlay and fibreboard. It could be invigorated as evidenced by my own project to spin recycled yarn on a commercial scale once more, so that new basic materials, fabrics and yarns become available. This part of contemporary recycling is closest to the models that need to evolve if we are to be able to husband all our resources efficiently in closed-loop systems.

The keys to success in product-centric systems are that the materials are inexpensive, easily available (often at a local level) and that businesses are sustainable because they can exhibit healthy trading models that allow for wholesale, retail and also, most importantly, enough profit to be vertical units that can compete against globalisation and cheap imports. The very existence of such healthy product-centric systems could be the salvation of a lot of manufacturing capacity within the UK. This is absolutely essential in ecological terms because ultimately, every country needs to be able to accomplish appropriate self-sufficiency at local levels to deal with the soaring costs of energy and ensuing limitations on transport.

10.3.3 People-centricity

The first aspect of design within people-centricity is respect for what people need and how those needs are met, both in products that last, and in systems that support proper husbandry of materials and resources. By replacing the systems of debt bondage in order to make AND enjoy the choices we are able to make as responsible adults, it is not solely about profitability, but quality of life, products and systems that work harmoniously. All these things are defined as much by the way things are done as by what they are when they are complete. Relationships that are not mediated solely through objects, but that are enjoyed as part of daily life.

People-centric design is durable, loveable, valued and used. Things can be repaired, hired, swopped, shared, remanufactured, adapted, customised, upgraded, restyled, embellished and accessorised. In her thesis of 1999, where she identified that the largest environmental impact of textiles occurs in laundering, Dr Kate Fletcher (2008) suggests that garments could even be modular, so that bits can be taken off to be cleaned or replaced. Historically cuffs and collars on men's shirts were detachable for cleaning.

People-centric design involves creative thinking about how to service existing textiles. People-centric design processes creatively find ways to preserve textiles. It makes sense to work with and encourage good quality, workmanship and classic, lasting designs. Jonathan Chapman (2005) writes in his book *Emotionally Durable Design*, that we will cherish what we love. Often the items we care about most are very personal, individual, about ourselves and not necessarily designed to impress others. People-centric design can be achieved by noticing the quality of every activity of living, so that everything we do and create is not compromised or sacrificed on the altar of market forces. There are movements that already work in this way: slow design; permaculture farming methods; respect for local knowledge, skills and resources; and a respect for all talents within the community's own human resources. These skills get marginalised and lost whenever systems refuse to recognise and embrace the possibility for compatible diversity in all things. The greatest example for this is homogeneity of the high street. Now that those shops are empty, we can fill them with the products and services of our new sustainable revolution.

Interactivity can be manifested by co-designing, by wardrobe surgeries to remake your clothes, by commissioning new designers, artists and craftspeople, and by hiring, swopping, mending, and sharing. Sharing includes freeshare, and skill swopping, and is a modern form of barter, which works best in relatively small communities and flourishes when people are able to get to know each other personally.

10.4 The designer empowered

A referencing eco-textile glossary has been written (in wiki form so that it can continue to grow: http://ecotextileglossary.wetpaint.com/) because, although the issues may seem complex, everything is interrelated, so even a small action will have an effect. Use it to begin to answer specific questions:

- Start by asking simple questions in order to identify which eco-options are possible.
- Let a multi-dimensional awareness develop naturally with time and experience.
- Allow your subconscious mind to process and include new 'sustainable' information within the mix of your design inspiration, market trends and your technical expertise.
- It is better to get one thing right at a time than to fail or become dispirited by trying to change too much in one go. Remember, this is a whole system that has been evolving for centuries.

Bear in mind the following questions:

- When you specify the production path for your design, can you factor out any big impacts such as excess use of resources, energy or transport?
- When you design, will your product be a beloved classic that people want to treasure forever?
- Will it preserve traditional skills? Will it use existing facilities? Will it provide or destroy employment?
- How can you work more closely with your customers to give them exactly what they want?
- Can you make sure that when your textiles are worn out they will have honoured the embedded energy and resources that made them, and will be able to be reused or recycled easily and appropriately?
- How can all these ideas, and more, be accomplished in a way that maintains a healthy, growing economy as well as a healthy planet?

10.4.1 Use the following strategies to examine your particular production route

Can they help you to understand and alter anything along the way?

- *Efficiency and resource conservation*: ensures that the textile production is not taking out more than can be replaced, is not wasteful, and may even be contributing a replenishment of resources.
- *Design for disassembly*: asks you to be concerned with how a textile is going to be reused or recycled at the end of its useful life. It is essential not to mix or contaminate materials, particularly non-renewable ones, which you need to reclaim in order for them to be recycled.
- *Closed loop*: ensures that the end of the product's life leads to appropriate reuse or recycling. Non-renewables can be reclaimed and reused, renewables can be reused and eventually recycled by composting.
- *Design for durability*: asks you to value your materials, and make a textile or garment that will last at least long enough to honour the embedded energy and resources that have been used to make it. You could develop business plans that keep you in touch with your textiles and the customers who acquired them. Charge a little more for ongoing maintenance, spare parts, mending, swopping, collecting, sharing, altering, embellishing.
- *Emotionally durable design*: when you love something you have produced and so does your customer, it lasts longer, is cherished and treasured. It doesn't need to be replaced, but it might need to be maintained. It might be collected, traded, or mended, but probably not thrown away.
- *Product of service*: a modern-day twist on hiring rather than buying. A way of extending the way that needs and desires can be satisfied without the requirement for ownership; ensuring that everyone has access according to their need and desire when there are very limited resources. Sharing, hiring, borrowing, swopping, upgrading; everyone can have their day with a Prada bag!
- *Take back*: goods are returned to the manufacturers at the end of their cycle of use, either to recycle or to dispose of appropriately. If the materials are valuable or non-renewable, this is a way of maintaining access to raw materials with which to make new products.
- *Reuse and recycling*: this is the key to all fully functioning cradle-to-cradle systems of production; this is where the loop closes. Working hard at this point will reap rewards, because it is a major source of raw materials. Reuse is where a product is used again as is, or slightly changed and adapted. Recycling is where the materials transform into a new form either by composting and feeding the next renewable cycle of a natural fibre, or, in the case of non-renewables such as polyester, by being returned to feedstock for repolymerisation.
- *Local sourcing*: maintains and honours natural geographic and cultural diversity, enables specialism and is low on carbon emissions. An ideal is local self-sufficiency where possible and appropriate on a global scale. It does not exclude the possibility of global, specialist, individual trade if shop windows on the Internet can use carbon neutral or more energy-efficient transport systems.
- *Slow design*: an antidote to fast fashion, this is less stressful, and allows us to value materials and processes for their own sake. There are fewer 'deadlines' and more life. There is enough time for solutions and designs to evolve, for skills to develop and mature.
- *Tribal, ethnographic, regional, traditional design*: the industrial revolution sped up and relentlessly reproduced original technologies that had evolved slowly

from generation to generation to meet needs and desires. The making of Harris Tweed or tartan involved problem-solving skills in harmony with the use of local resources, efficiency, aesthetic expression and sophistication. These are the very images and allusions that fashion often emulates, but that market forces make uneconomic in their original form, while the workforce becomes redundant and the expertise is lost. But the originals are cultural treasures, whose creation gave dignity, identity and livelihoods. Not everyone wants to stack shelves or tweak computers. Can a new ecological economy revive and define traditional, tribal, regional and ethnic in a contemporary context?

- *Custodianship of skills and specialism*: needs to be maintained within local populations in order to be resourceful and resilient to change, but also to preserve the potential for self-sufficiency and the potential for future diversity at local levels. A high degree of accomplishment is fulfilling and satisfying. Schemes to recognise and encourage individuals and businesses arising from specialist skill bases are psychologically beneficial. This fosters a capable population.
- *Vintage, collecting, heirlooms*: husbanding resources, recognising and preserving value, enjoyment and entertainment. Economic vitality is enabled by passing things around, without expenditure of resources, allowing the culture to be reflected upon, maintained and vitalised. This is a way of sharing while maintaining economic movement.
- *Education, skills, training*: some of the most fulfilling activities of life, which should continue throughout life, refresh, contextualise, enliven, preserve, pass on, share and generally activate any community no matter how diverse, in challenging, yet non-combative ways. In the creative arts, this is the springboard of imagination and, for me, the zest of life. How we make things, how we meet, all the possible encounters, mediated through all the objects in our lives, these are activities of living a sustainable and fulfilling life; it is the quality of the encounter that holds the real value, not the speed of accumulation on a balance sheet.

10.4.2 Exercise: combine the previous strategies with issues in the life cycle stages below

Can they help you to understand and alter anything along the way? (The resulting ecologically friendly textiles and clothes need to be useful and beautiful. They need to be fit for purpose and affordable.)

- *What category of raw material?*
  Synthetic. Polymerised natural (cellulosic). Natural.
- *Raw material processing/harvesting methods?*
  Melt spun. Polymerised. Manufactured/farmed. Water use. Energy. Toxicity. Emissions. Land degradation. Waste. Appropriate locality. Appropriate regulated source (oil and non-renewables). Colouration. Biodiversity protected. Incorporation of recycled materials. Use of pesticides and fertilisers. Health and Safety for workers. Greenhouse gas emissions.
- *Yarn and cloth production?*
  Water use. Energy. Toxicity. Emissions. Waste. Appropriate locality. Infrastructure investment (machinery, factory, offices, transport fleet). Indigenous skills and expertise honoured. Transportation between processes/division of processes

between localities and/or continents. Chemical usage: preparations, colour, finishing, dyes, printing inks. Airborne or waterborne pollution. Industrial waste created by rejected dye lots and production mistakes. Contained/closed production systems. Filtering and reclamation of chemicals, dyes and finishes. Greenhouse gas emissions.

- *Garment construction, finishing, embellishment?*
  Energy, toxicity, contamination between renewable and non-renewable raw materials, including finishing and embellishment. Informative labelling. Offcut waste and processing waste. Appropriate land use. Airborne or waterborne pollution. Transportation between processes/division of processes between localities and/or continents. Greenhouse gas emissions.
- *Packaging, presentation?*
  Origin of packaging, renewable or non-renewable, local or transported. Type of printing inks. Biodegradability. Use of machinery/energy in packing production methods of packaging. Toxicity, pollution. Excessive. Protective. Recycled. Recyclable. Reused. Reusable. Labelling. Greenhouse gas emissions.
- *Dispatching?*
  Transport. Energy. Packaging/protecting. Local or global distances. Toxicity/pollution. Greenhouse gas emissions.
- *Service/sales, industry infrastructure?*
  Where customer and textile meet. Local or global. Transport. Energy. Infrastructure investment (machinery/computers, shops, warehouses, offices). Trade and retail shows. Advertising. Public relations. Magazines. TV and film. Photography. Forecasting. Transport fleet. Greenhouse gas emissions.
- *Use?*
  Laundering and drying. Energy. Toxicity. Greenhouse gas emissions. Practicality/identity/aesthetic. Added value. Extending use.
- *Reuse/recycling?*
  Embedded energy. Consumption of resources. Reclamation of resources. Return of products. Sorting. Storage. Adding value to the recyclate. Reprocessing. Transport. Toxicity. Repolymerisation. Remanufacture. Water use. Energy. Emissions. Land degradation. Waste. Appropriate locality. Appropriate conditions for aerobic and non-aerobic biodegradability. Energy production. Production of compost. Conservation of finite resources.
- *Disposal?*
  Collection. Transport. Energy. Greenhouse gas emissions (methane). Appropriate or inappropriate conditions for aerobic and non-aerobic biodegradability. Energy production. Pollution. Water contamination. Toxicity. Chemical leakage. Land use. Burning. Waste of resources. Loss of access to non-renewable resources. Airborne particulates. Sorting. Added value.

10.5 Sources of further information and advice

10.5.1 Books

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Dombek-Keith, K. (2009), *Re-Fashioning the Future: Eco-Friendly Apparel Design.* VDM Verlag Dr. Müller, Saarbrücken.

Faud-Luke, A. (2005), *The Eco Design Handbook: A Complete Sourcebook for the Home and Office.* Thames and Hudson, London.

10.5.2 Websites

www.anniesherburne.co.uk
www.ethicalfashionforum.com
www.katefletcher.com
www.kingston.ac.uk/design/SDRC (dept: sustainable design)
www.productlife.designinquiry.wikispaces.net; also www.extra.shu.ac.uk/productlife
www.redesigndesign.org
www.tedresearch.net (Textile Environmental Design)
www.tfrg.org.uk (Textiles Future Research Group)
www.ecotextileglossarywetpaint.com/?t=anon

10.5.3 Articles and papers

Well Dressed? The present and future sustainability of textiles in the UK (www.ifm.eng.cam.ac.uk)

10.5.4 Certification, labelling

www.oeko-tex.com/OekoTex100
www.pan-uk.org (pesticides action network)
www.skal.com
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11
Fashion design: the dynamics of textiles in advancing cultural memes

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Abstract: This chapter describes the role of fashion design in the dynamics between the global textile industry and the growing power of retail. The effect and importance of textiles, expressively promoted by designers as carriers of cultural memes, is explored. How and why choices for fabrics are made, how this scenario was established and has changed over the last century through technological progress, education and is further challenged by the progress of communications and CAD/CAM is discussed. Opportunities for closer co-design ventures between suppliers and consumers are predicted. At the same time movements towards sustainability and consumer and corporate conscience provokes implications and repercussions for future perspectives and changes in longstanding cultural habits and education are envisaged.

Key words: fashion design, future perspectives, design education literacies, co-design, cultural memes, CAD/CAM.

11.1 Introduction

This chapter aims to highlight the relationships between the once separate but codependent industries of textiles, apparel and retail and how the fashion designers' role in the choice and use of textiles is defined therein. Extraordinary changes in the industry are apparently leading to greater convergence of these fields. The expertise and flexibility required by the contemporary fashion designer to ride these transformations and promote cultural trends is described. The irrepressible drive to adorn our bodies and imitate the best of these embellishments by the manipulation of available materials and the creation of glorious decorative fabrics has inspired, over the passage of centuries, not only the great mechanical Industrial Revolution, but also spawned the moveable type of the Gütenberg Press.[1] These early technologies facilitated a protracted revolution in the dissemination of technical, scientific, intellectual and aesthetic ideas and 'memes'. The chapter describes how vocational skills and fashion education developed in line with growing industrialisation and communications, creating new vehicles for product marketing. The job of the designer has matured with the parallel development of materials and processes and the inspiration of individuals to arouse market forces. The start of this century has seen another, even faster catalyst for commerce, social change and ideas in the incursion of the media and the use of the computer for communications into all aspects of 'fashionable' 21st-century living. CAD/CAM driven and monitored

[1] Gutenberg, Johannes zum b .1400 Mainz, Germany is credited with inventing moveable type. In 1455 he published the Gutenberg Bible.

electronic machinery, the Internet, integrated business and design software, trade deregulation and wireless communications have become inherent aspects of industry business methodologies which are necessarily to be addressed by higher education. As new styles of communication have levelled the international playing field, businesses have closed and traditional skills are being depleted. At the same time, new literacies are required of the designer to fulfil the demand for visualisation, virtual prototyping and supply of competitive fashionable products. In conclusion, new technologies imply opportunities for innovative and collaborative methods of working; allowing the fashion designer and resellers a broader geographic scope and concerted opportunities in diverse fields. The chapter concludes by considering future perspectives and questioning how fashion design education may permit responsive and responsible global relationships with the end users of textile products and summarises the priorities in the light of a volatile textile supply.

11.1.1 Employability and skills

Human skills are at the foundation of value creation and innovation and fashion design adds distinctive added value to the textile product and clothing. Euratex, the European Apparel and Textile Confederation, suggests that 'non-technological' innovation in the textile and clothing sector could represent up to twenty per cent of the turnover invested in product development per annum. The Leitch Review of Skills[2] pointed to the significance of this sector to the gross national product as amongst the highest in the cultural industries and the need to attract new generations of skilled and creative workers. Over the last fifty years, British and European arts education has enjoyed a supremacy that has seen the creative industries dominate in export achievement and countless graduates rise to the top of the design-driven sector. When Angela McRobbie published her independent investigative study *'British Fashion Design: Rag Trade or Image industry?'* in 1998, she revealed that in spite of the high visibility and revitalisation of flagging couture houses and luxury fashion tipped by the raw creative input of stellar designers such as John Galliano and Alexander McQueen, the submerged iceberg was a massive middle market retail sector of chain stores who 'dominate and exert enormous control over product' (McRobbie 1998). In the decade since, that drift has grown, internationalised and asserted ruthless power while the underpinning manufacturing base has devastatingly melted or slipped eastward. According to Textile Intelligence (2010), there is a rapidly declining demand for EU-made goods and falling domestic sales. In 2009 sales of textile exports were down 17.9 per cent and clothing by 14.9 per cent. In The UK over 95 per cent of clothing was imported. The number of unemployed benefit claimants whose usual occupation relates to the fashion and textiles sector increased by 47 per cent between September 2008 and April 2009. Although there is less demand for blue-collar industry operatives today, the

[2] Leitch (2006). UK HM TREASURY: The Leitch Review of Skills, London. The Review prioritised the use of Sector Skills Councils, employer-led bodies, established to enable employers to exert influence on the UK's education and skills systems to ensure they meet their needs and instigate institutional change to deliver better integrated employment and skills services.

European industry is already seeing a critical shortfall of clothing and textile technologists and capable upper management recruits (Euratex), which justifies concern and possible intervention (Keep 2006). At the same time as many of the practices, chemicals and processes have been restrained by REACH regulations and employment legislation, the cultural and ethical side effects of the textile and fashion industries have been called into question. Approaches to teaching and learning for tomorrow's generation will have not only to integrate changes that have occurred in the supply chain, energy resources and technology of clothing but also more widespread issues concerning business ethics, sustainability and global marketing.

11.2 Key issues: the relationships between fashion houses and textile merchants

Anthroplogists and sociologists have long since brought to our attention that innate to humanity is the wish to cover and decorate ourselves not only for protection but thereby displaying tribal origins, individual status, personal creativity and enhancement for sexual allure (Flügel 1930, Cordwell and Schwartz, 1979). Richard Dawkins, in his seminal text *'The Selfish Gene'* (1976) concerning genetic inheritance, also coined a new term, that of the 'meme': the imitation of others, by means of expression, gesture, ideas and clothing, for social and cultural alliance and advancement. We imitate in order to survive, and like genes, memes mutate. This concept has since been expanded by social scientists (Plotkin 1997, Blackmore 1999, Pech 2003) to describe how beliefs and behaviours from foolish fads to serious religions become handed-on as important and infectious social movements. Here I would like to present the case that fashion, as a primary signifier of social status and adherence to tribal alliances, promotes social memes carried through selected use of materials and styles that signal and facilitate fast recognition of 'friend or foe'. The ability to read, decode and manipulate the signs and make fresh associations is now the chief work of the fashion designer. As we no longer inhabit the tightly defined communities of previous times, but a world that has expanded globally and virtually through the reach of air travel, television and the Internet; those memes and choices and the inherent value are of great significance for social cohesion.

11.2.1 Fabric availability and status

Since the Silk Route brought silks and carpets from China and the East, desirable fibres and fabrics have been transported, at great cost, around the globe. Cottons from the Americas and India and cashmeres from the Himalayas and wool and mohair from Australia and New Zealand are still traded in commodity exchanges. Because natural fibres are subject to the consequences of weather conditions, pests and seasonal harvests, their quality and price fluctuates. Many, for reasons of scarcity or performance, are considered luxury or 'noble' fibres and can be made into numerous textile qualities according to the dictats of fashion. Textiles were widely understood to have inherent hierarchies of status (Taylor 2002). The observations of sociologist Thorstein Veblen still resonate today:

> The requirement of expensiveness is so ingrained into our habits of thought in matters of dress that any other than expensive apparel is instinctively odious to us. Without

reflection or analysis, we feel that what is inexpensive is unworthy. A cheap coat makes a cheap man. (Thorstein Veblen 1899)

Aside from ranking fabrics (subjectively) by fibre content, Taylor (2002) suggests a checklist of twelve 'marks of distinction' for scoring the hierarchy of materials:

1. Rarity of fibre or cloth type
2. Novelty
3. Use at an elitist social-ritual function
4. Elitist status of wearers
5. Country of origin
6. Known elitist designer or manufacturer name and known elitist manufacturing name
7. High level of aesthetic quality
8. Unusual or costly manufacturing technique
9. High price
10. Newness of pattern or colour
11. Tactile qualities, delicacy, exceptional softness, etc.
12. Elitist-orientated marketing.

Taylor asserts that the hierarchy of a fabric shifts and depends on the presence or absence of these factors. Manufacturers and buyers would certainly recognise these values as generally valid today, although never formalised, they are a basis for questions and evaluation between merchant and buyer. However, they are not an exhaustive list and value to the buyer may in fact lie more in need or the protective and functional aspects of cloth or of a *message* a phenomenon described by social anthropologist and sociologist Pierre Bourdieu as 'cultural capital' (Bourdieu, 1984). The value of materials is also socially constructed through the imitation of other people's desire. As society changes, these positions shift. This list, whilst largely holding true throughout the past century, is subject to the lens that judges fashion as a linear meme, transmitted from the elite to the proletariat. Fashion can no longer be said to 'trickle down' from elite sources to the masses, it is everywhere, pluralistic and effective in all social strata. As evidence, the American socio-economist Pesendorfer (1995) claims that since the spread of the middle classes and the ubiquity of blue jeans took hold in the 1950s, imitation has switched to an egalitarian lateral diffusion. While fundamental fabric advantages such as rarity, novelty and performance characteristics would be promoted by the drapers guilds and haberdashers then to be found in every city centre, the tacit manipulation of materials as 'fashion' went largely unrecorded (or merely passed on verbally between tailors and from mother to daughter or by friends as helpful hints) and was uncelebrated or schematised as valued knowledge.

11.2.2 Craft and dressmaking skills

We know that the cult of needlecraft was an important aspect of home economics, for those who could not afford a tailor or seamstress and an expression of female caring (Burman 1999). The emphasis was on crafting and repair of everyday clothing within narrow parameters as demanded by seasonal and social occasions and according to fairly fixed expectations of class-based income levels. Until the 1960s apprenticeships and education that touched on what we might today call 'dressmaking', coalesced around the practical appreciation of different fabric characteristics, quotidian styling and how to measure and fit the body. Post-school education in the first half of the previous century was therefore primarily concerned with the teaching, (to girls of middle- and working-class families) of skills considered to be a practical necessity in preparation for homemaking or employment in service; it was not commercially orientated. Additionally, those who were unable to provide for themselves otherwise, and showed particular flair in needle arts could have their skills refined by trade schools and accredited City and Guilds courses and earn a useful wage in factory mass-production as seamstresses or dressmakers. The photographic archive of the Barrett Street and Shoreditch Trade Schools at the London College of Fashion is witness to busy classrooms of tidy rows of girls practising their stitches (Fig. 11.1). Safe handling of tools, shears, electric irons and sewing machinery was prioritised and technical accuracy, neatness and speed were rewarded, while artistry was approved in incremental adjustments to the knowledge and imaginative expression of others. The fabric quality was the first consideration and the number of hours to make an outfit were the rule of thumb for calculating the eventual cost, in a direct ratio to conspicuous consumption, not style. Value could be added to basic materials by decorative stitching and embroidery but only rarely were evening wear or speculative designs made by students, other than for trousseau and weddings.

With growing social democracy post World War II, the agenda shifted from making for a domestic or local demand to training for commerce and export and, particularly within working women's wear; education pushed the needle-arts to interpretive new ideologies of femininity and class (Fig. 11.2). If some people enjoyed the pleasures in crafting and personal fabric choices that home dressmaking afforded, many others still made their own clothes out of hardship. Homespun clothes implied poverty and the band-box quality of store bought clothes became more culturally valued. Mass-produced garments that were previously barely

11.1 Sewing class at the London College of Fashion, c. 1900.

11.2 1950s dress designs.

differentiated gained worth through neat production, minor style changes and trends in colour and print. Textile choices could make all the difference and added attraction and identity to emergent brands. Women were particularly adept at reading and estimating these details.

The distinction between the occasional dressmaker and the professional designer often rested in the approach to and availability of fabric selections. Fashion students rarely realise that the professional designer customarily makes or is given fabric choices *before* doing sketches. Not only does the professional need to work many months ahead of the season with a well-tuned intelligence for what will appeal to others as popular colours and materials but also to ensure a reliable source, quality and to budget carefully for overall price as garments produced *en masse* can amplify any mistakes in costing, fit and appearance that are negligible in 'one-off' cases. Whilst a fashion student can buy a few metres of idiosyncratic choice fabric, the fashion professional is restricted by the need to order in hundreds of metres with the reassurance that the fabric is fit for purpose. Where contracts with merchants could be made and protected, there were competitive advantages; relationships with suppliers, exclusivity deals and trade agreements, which often needed to be maintained over decades. Clothing companies therefore tended to specialise in a class of products, such as coats, or shirts, tied in closely with fabric providers, rather than in creating coordinated fashion ranges. Store buyers picked and made up their selections.

11.2.3 Marketing textile innovations

Making and transporting unwanted fabric types or redundant shades is immensely wasteful so the tendency, in fashion fabrics and knitwear, has been to predict demand and dye fibre and weave or print greige cloth as late as viable or as close to the market as is cost efficient for quick response and novelty value. Additionally, attempts to imitate the properties and appearance of luxury goods have proliferated. For instance, silk is highly prized but difficult to farm and its supply was tightly regulated by Chinese quotas. The expense, deep colours and lustrous quality of silk led to its identification with dress codes for mourning, evening wear, weddings, religious ceremony and also the single item worn by businessmen, that declares sartorial flamboyance or allegiance, the necktie. For mass-producers of clothing, bringing down the cost of fabric, or improving textile performance is a route to profitability. Spinning innovations that took the weight and odour out of woollen fabrics or improved the lustre or longevity, washcare and colour fastness of materials instantly found favour. Experiments made by the megalithic UK company Courtaulds Fibres in the 1890s with cellulosic viscose and acetate rayon extrusions led to the first artificial silks commercialised as suitable for clothing in 1905. Imitations of natural fibres have since become highly effective and attractive in their own right and some are difficult to distinguish from 'natural' textiles. Methods of adding value through innovative engineering techniques and colouring have led to great competitive rivalry. Clothing manufacturers were quickly entreated to test and promote new fabrics, and fashion designers were needed to make the best of them and to gain public confidence.

Throughout the decades of the 20th century the supply chain ran as a direct line from fabric supplier, to fashion wholesaler, through promotion and retail buyer to the consumer. The onus was on the fibre and textile mills to market their ranges *to*, not to work *with* the fashion designers. Designing new textiles and prints is intrinsically risky; they must be made in sufficient quantities and popularised in order to recoup the high costs of development. Most fabrics were created speculatively, at high cost. Throughout the 20th century textile mills conducted their own researches into colour and prints, sometimes relying on the tastes of a single creative employee or the managing director's wife. The work of the textile designer was largely anonymous (Taylor 2002), although patterns could be copyrighted and design registers were set up as early as 1839. In the US fabric designs were safeguarded by copyright but the cut of the garment pattern was not considered worthy of such protection.

Fabric salesmen with heavy suitcases of swatches travelled from city to city by appointment; it was a slow round. Although textile mills led the sequence, initiating the colours and qualities, they were sold indiscriminately and vendors were not often aware of the pivotal role of the fashion designer in marketing. Many designers did not source the fabrics themselves; the accounting department buyers made choices on price and availability. Consequently fabric manufacturers and merchants enjoyed little formal association with the designers. For the most part, there was a disconnect; small textile businesses barely sought feedback as to whether the colours or fabrics satisfied, beyond scrutinising the sales ledger. Some merchants and importers of exotic qualities, such as Libertys, opened as emporiums and department stores and continued to offer commercial businesses special rates. In order to distinguish their offers the fashion designers had to add difference and flair through cut and styling.

Towards the end of the 1960s national and international fairs, such as *Interstoff*, held in Frankfurt, *Première Vision*, in Paris, *the Bobbin Show* in the US and *Fabrex* in the UK, were established, which helped, together with European Community export tariffs, to smooth the shipment of fabric qualities across borders without attracting duties. Until the appearance of the commercial Internet, biannual trade fairs were the essential sources for fabrics and information for future seasons.The competitive nature of tradeshow exposure often forces textile companies to improve their product offers and introduce innovations. Forecast companies evolved and proposed trends that helped fabricators to eliminated unpopular qualities and harmonise their colour ranges with dye suppliers and consumer interests. Textiles samples and innovations are taken to trade fairs approximately twice a year, at least six months ahead of seasonal requirement and orders for swatches, samples, bulk quantities and delivery dates negotiated. Tight margins and squeezing by large conglomerates and wide competition have kept textile prices low but choice high. In response, clothing wholesalers, differentiated their wares, in competitive choice in fabrication, and through strategic market positioning, broader ranges, window presentations and speed to market. In turn, clothing and footwear manufacturers also began to show their ranges at 'market weeks' and trade fairs, such as the Paris Collections, Prêt-à-porter, Milanovademoda, Italy, London and New York fashion week (Majima 2007). Such fashion runway events have gradually built into complex and grandiose seasonal spectacles, which today may be less focused on selling than on asserting power relations through performative displays. (Entwhistle and Rocamora 2006).

11.2.4 Valuing creativity

A turning point in the relationship between textiles suppliers and the fashion designer, was instigated between the wars, by Coco Chanel, in Paris, who not only caused sensation when she broke the taboo against using fabrics for culturally specific uses by repurposing low grade matelot jersey as dress fabric; but exemplified the exhilarating concept of the independent, successful female designer, designing for the independent successful woman. Ontological rules could only be constructed on the back of a rigid and stable tradition. Once established, the rules could be challenged to create new fabric variations and continuously provocative fashions. Chanel claimed to be able to interpret the needs of the woman of her time and revelled in doing the opposite of what was expected of an Haute Couture stylist. She set the scene for a number of rebellious and artistic followers, such as Schiaparelli, and raised the bar on the celebrity profile of the designer as an outsider who consorted with stars and royalty.

War and wartime rationing caused a hiatus in fashion. That the authority of the fashion designer already carried sway, in the UK at this time, can be deduced from the fact that the British government used political intervention to bring them to heel by creating an industry body: the Incorporated Society of London Fashion Designers, launched in 1942, whose aim was to control domestic consumption by encouraging the design of utility dresses. Immediately post World War II, designs retreated through the misnomer of Christian Dior's 'New Look' to a conventional cinched and full skirted silhouette with traditional use of materials. For a while Dior's silhouette thrilled the fabric merchants, his full, long-skirted designs demanded quantity as well as quality. Nevertheless, Chanel's bid for more liberating outfits was later reinforced by her triumphant return in 1953, at the age of 70, to her workshops (Morand 1976). It is said that she was motivated and incensed by the lack of acknowledgement or importance that textile and perfume industry tycoons had accorded her taste and role in their success and that of the Chanel brand over which she no longer had financial control.

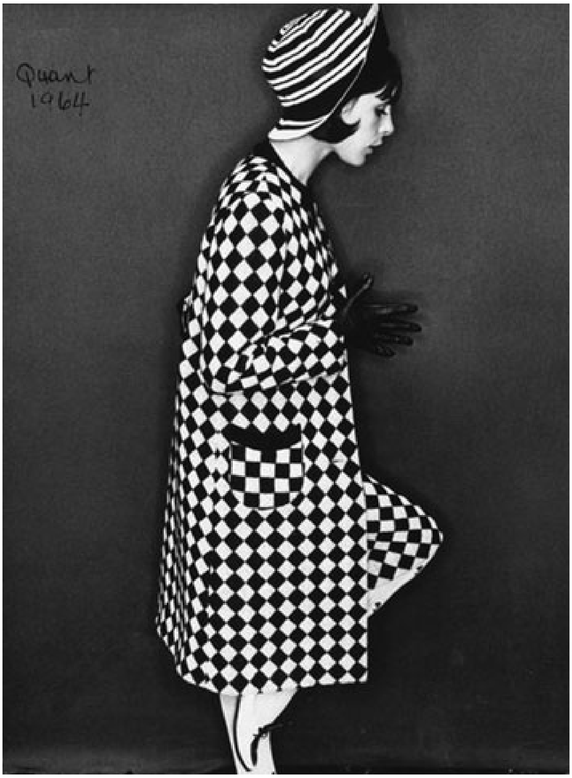
11.2.5 The designer's position

The cult of the named label 'createur' is a prize that belongs largely to the rarified atmosphere of the Parisian salon. This aspiration and mark of distinction has grown thanks to Chanel's fight for the recognition of the designer in the profit machine, and blossomed in parallel with celebrity culture and now extends to New York, Milan and Tokyo. The *griffe*, or sign of the salon has also led to the burgeoning imitative meme of fashion brands and logos. The work of a designer could be described, in academic terms, as an iterative and creative research methodology; building on known practice. However, the designer's role in a commercial fashion company was (and largely remains) to follow and interpret the existing trends and keep the seasonal fashion cycle operating in high gear. He or she is a democratic actor in the creative team, accorded respect but not autonomy and subservient to the brand values. The social ranking in the average industry design room resembles the hierarchical star system once prevalent in Hollywood studios, where lower ranking starlets were contracted but uncredited until they polished and shone at their métier. Commercial designers are employees, team leaders with executive powers, but rarely business partners. Most are aware that they are 'only as good as their last collection', and easily replaced, so the pressure to deliver profits, without the risk of identifying a personality is intense. When middle-market manufacturing chain-stores, such as Wallis and Richards Shops began to establish a brand vernacular and a presence on the British high street, during the 1960s, by coordinating fabrics and styles into flexible collections of 'separates', they rarely admitted to employing designers. Indeed the designers names were kept secret, out of fear of their being poached by competitors.

The effective importance of the work and visibility of the designer, if only for business and public relations, intensified during the affluent 1960s. Frustrated with the status quo and desiring more control, *ingenués* such as Mary Quant and Barbara Hulanicki (Biba) in the UK, set up their own name businesses and bravely pioneered new experiments between the body and materials (Fig. 11.3); investing unusual mixtures of traditional and new-fangled textiles with unrestricted silhouettes and miniskirts. Universities and colleges expanded and accredited courses for fashion and textile design and a wave of art school educated, independent freelance designers and youth orientated brands followed and challenged the hegemony of the elite couture system and stranglehold of dull high street stores (McRobbie, 1998). Their styles fizzed with added value, that spoke of modernity, democracy, sexual freedom facilitated by the contraceptive pill and clarity of allegiance to youthful social values and incomes through cheap commodities and savvy branding.

11.2.6 Growing independence

Fabrics allow fashion designers to resonate and mirror the prevalent visual and cultural themes by articulating the body covering with synergy of material and cut.



11.3 Mary Quant dress, 1964.

Released from the tyranny of 'luxury' as a fashion statement, and unable to find the bright colours, prints and textiles they wanted from the conventional suppliers, this generation silk-screen printed, appliquéed and knitted their own. Designers Ossie Clark and his wife, Celia Birtwell, Bill Gibb, Zandra Rhodes, and Thea Porter were as much admired for their charming textiles as the cut of the garments. Fashion aligned itself powerfully with art and pop music rather than Hollywood and was marketed in boutiques, analogous to galleries and clubs rather than department stores. Anti-materialistic and counter-cultural memes expressed by a return to tie-dye, batik and non traditional and ethnic looks held sway for a decade. European mills and printers such as Marimekko, Pucci, Bianchini and Boussac who were receptive to the changing look and patronage of the fashion designers flourished. In Paris, the rising designers, Pierre Cardin, Paco Rabanne and Yves Saint Laurent were also investigating new materials and artistic allegiances, technological methods of making and marketing through diffusion ranges, boutiques and licences. The designer no longer created mere dresses but offered a lifestyle vision, often extending products into cosmetics and home furnishings.

Throughout the 1970s and 80s a healthy middle market of small independent, moderate price street-style labels, expressive of an era of youthful refusal of high street homogeneity, were established, but were unable to sustain economic viability without a more rapid turnover of styles and stock. Fashion cycles speeded up, break seasonal barriers and changing gear with *inter* and *pre-seasonal*, *party* and *cruise* ranges until they went into freewheeling through the 1990s with lean production and quick response manufacturing. Through subsequent recessions and cash crises, the innovative independent design-led business has not often fared well; most have had to seek business support and funding by financial 'angels' to bankroll them. Such covenants are not necessarily appreciative of the golden goose; Barbara Hulanicki, who had built Biba up from a successful mail order business offering sumptuously coloured fabrics and jerseys, into a central London department store was an early casualty of the archetypal misunderstanding between designer and management. She described her fraught relationship with financial backers to a fashion school audience in January 2010, at Central Saint Martins, as 'sufficiently depressing' for her to decide to close the business altogether; as, for example, the accountants could not see the advantage of offering styles in a broad range of colours, when black was the bestseller. Fashion designers have frequently been accused of financial irresponsibility; conversely, a number have struck a counter-capitalist pose, yet remained in play for decades.

In recent years the cost of manufacturing close to home and competition from chainstores has squeezed out the smaller enterprises and few small boutiques remain (Mintel 2009). Ironically, even the large stores now admit the need for variety and creativity to pique interest. As a measure of the value now accorded the designer, we can see fresh collaborations extend back into high street retail chains. Designers Stella McCartney for Adidas, Jean-Paul Gaultier for Target, Comme des Garçons for H&M are amongst those who have created limited edition ranges and added value to high street stores, in some cases selling out within hours of delivery. As a result, the textile producer and retailer now has a greater understanding and respect for the synergistic premium effect of the innovation and creativity of the fashion designer on the market response. This was, and largely remains a strategic success for the conversion of fabric into profit; but only too often the value is recognised in hind-sight. The high street has now imitated the design gurus for decades; as fashion accelerated, those who were not adept at spotting the trends lost their grip. Retailers, at the sharp end, have been faster than textile mills to recognise the value of design in driving sales and some have taken designers in house, cutting out the wholesalers.

11.2.7 Private label lines

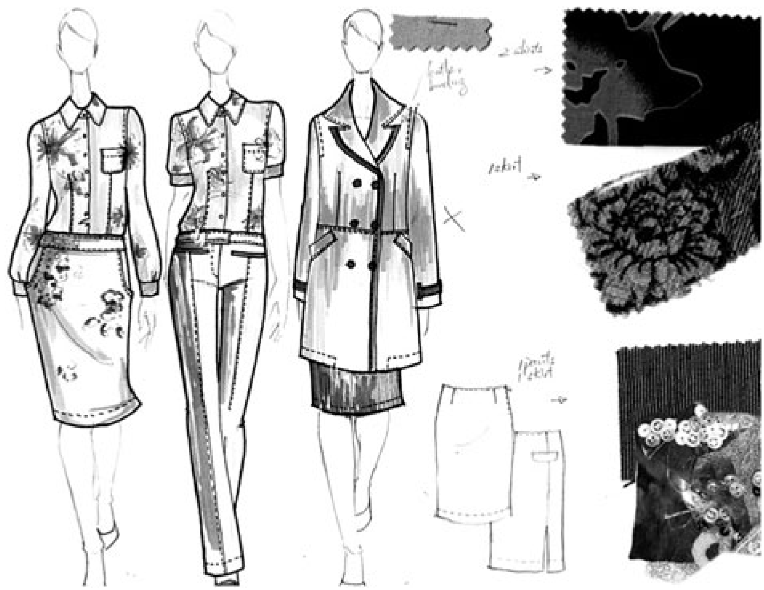
Where stores once either exclusively bought garment ranges from wholesalers or offered operating space as concessions, since the early years of this century, confident of a solid understanding of their customer base, many are bringing out their own clothing lines as 'private labels'. The private label phenomenon allows stores to cut out the costs of the middle ground suppliers and offer similar quality goods at lower market prices, It also gives them phenomenal financial advantage as the owners of the stores. The private label may sometimes be fronted by a celebrity name and the style interpreted by a 'ghost' designer. Exclusivity of fabric, colour and style is vital to differentiating the product offer to keen the competitive edge of the private label. If unique prints and weaves can be commissioned, the store avoids trampling on the sensitivities of independent brands and concessions that are imitated and stocked at higher prices. Not all are so delicate. Private label ventures are only made possible through the use of integrated CAD/CAM design systems, whereby the retailer, or specifier can be shown, and approve potential styles offered by agencies, intermediaries and fabric merchants, usually producing off-shore, and able to act quickly to capitalise on popular fashions within the season. The lone designer is becoming a rarity in fashion businesses and the need to work in cross-functional and geographically dispersed teams with shared use of CAD/CAM tools for concept, fabric choice, colour and lab dips and data management has become an essential skill set for the new hybrid retail design studio operative. The application of CAD/CAM is discussed in greater detail later in the chapter, but here it can be argued that it has brought a greater rapport between the retail fashion houses and the fabric mills and jobbers as clients confirm their fabric choices quickly. The in-house designer, as a key intermediary, must nevertheless, be able to identify and arbitrate suitable qualities and specify appropriate styles.

11.3 Suitability of different textiles for fashion design

For a fashion designer materials are akin to flavours and ingredients for the chef of haute-cuisine. Both objective measurements and subjective assessments are needed to balance, record and create novel sensations. As the chef needs to weigh and savour ingredients to manipulate the taste, the designer requires not only practical information about fabric behaviour, suitability for purpose and season and overall visual stimulus, but *tactile* experience as inspiration and as a means of expressing personal creativity. The emphasis is important, because today so much fashion is consumed vicariously through vision, flat on the page or through the screen and computer monitor; that touch, one of the most important senses, is routinely denied. Yet it is the tactile skill, or 'haptic knowledge', that subjectively evaluates the 'fabric hand' or 'handle' of materials; that is the more enduring sense and the hardest to record and replicate. In spite of concerted research to standardise descriptors in sensory analysis (Kawabata 1980) there is an insufficient and inexact terminology to describe tactile fabric attributes and nuances for the enormous number of textile types. Moreover, although there is general consensus as to terms such as fluffy, supple, smooth or grainy (Civille and Dus, 1990) they do not necessarily translate into different languages or without personal idiosyncrasies and cultural discrepancies. Computer-aided laboratories, such as the Touch Lab at MIT and the HapTex project at the MIRALab in Geneva are endeavouring to capture and replicate such distinctions, yet even with sophisticated metrics and pressure measurements the threshold values have not been standardised and determined.

11.3.1 Hands-on practice

An inherently stimulating aspect of the fashion designer's task is to find ways to use, manage and finish new materials. By hand, the fashion designer must assess the desirable weight, drape, torque, stretch and the crispness of a cloth to sculpt fabric as a protean material around the body; to be alert to, and memorise, the sensory differences and the corporeal sensations evoked by fabrics against flesh. Some textures and fibres will be cool or rough to the touch and so suitable for certain circumstances or seasons. Fabrics that have a napped pile surface may feel and look different brushed in one direction or another. The diverse structures of weaves and



11.4 Page from a designer's swatchbook.

knits also cause materials to fold and behave in various ways and simply by cutting fabric, tighter, looser or on the bias to create different effects of volume the sensations and tactile-pressure responses are controlled. In spite of, and perhaps because of inevitable subjectivity, haptic knowledge is an essential starting point and key to understanding which techniques to apply to coax the material to the style or silhouette, whether cutting into strictly protective heavy leathers and felted wools, or delicate materials such as silk chiffon, slippery acetate satins and decorative lingerie laces. Keeping a swatchbook (Fig. 11.4) or a photographic CAD library helps a designer to build up haptic and technical knowledge and build a design vocabulary to order the right weight and density of fabric by their specifications, particularly over the phone, sight unseen, or from online sources. It is valuable to be able to recognise the names of the different fibre types, proprietary brand materials, weaves and finishes; shop and market bought fabrics without labels may not be suitable for printing or other purposes. Many textiles are plain cloth staples that permit constant reinterpretation: denim, gabardine, poplin and cotton jersey. Their use underlines a sensibility of the honest, and denim is even semi-destroyed in order to evoke comfortable threadbare workwear and everyday uniformity. International legislation requires coherent labelling of proportions of fibre content and origin in garments. Mercantile fabric swatches are usually labelled with the weight, width and various other parameters such as finishes and prices.

11.3.2 Identifying fabrics

Materials cannot be identified by sight or touch alone. While this volume goes some way to expanding on the differences between textile types, it is the fashion designer's job to deploy them effectively and efficiently. Not only do designers need to appreciate immediate sensory responses to fabric but also to be aware of the uses of combinations, blends and layers as a technical balancing act for comfort, performance and maintenance. (The Woodhead series of Textile Technology books are of particular use in the detailed identification, handling and design uses of textiles.) There are numerous objective tests for identifying fibres and fabrics, from the use of lenses and microscopes and the characteristic odours of silk and wool, to burn tests and solvents (conducted in safe conditions) on swatches and scraps. Minute differences in material properties can now be measured and calibrated by textile technologists using the Fabric Assurance by Simple Testing (FAST) and Kawabata Evaluation System (KES) instrumental methods. This data is useful for mapping and comparing flexibility, stretch and handle particularly for active sportswear and lingerie. However, objective metrics are insufficient for evaluating how fabrics will respond to sewing and finishing, or look and behave once made into garments, used and laundered. Today an intermediate stage of virtual prototyping through CAD/CAM can be used to satisfy curiosity as to how a fabric might look and drape, before investing in actual material or machinists. While fashion samples are usually made up for eventual aesthetic evaluation and production timing, both subjective hand tests and wear tests of garments are essential for critical comfort of underwear, protective garments, military wear and performance sportswear; this is even more essential with unfamiliar synthetic materials.

11.3.3 Branding assurances

By the late 1950s the supremacy of natural fibres was over. As man-made fabrics became more useful and desirable, they not only required protection from imitation abroad but needed memorable names to market them. Early cellulosic and synthetic fibres were not branded, even nylon 6, first synthesised for military use as a replacement for silk parachutes in 1938, by DuPont was not patented. To safeguard the recipes of the chemists, patents and proprietary branding were needed to market the bold assurances associated with synthetic products. An armoury of icons, trademarks and store liveries were brandished as a competitive assault on the consciousness of consumers and became the new mammon. The 1960s space race saw a myriad of new-fangled petrochemical, acrylics, aramides and molecular formulations to create a domestically spun class of fibres and branded materials such as Tencel® (viscose), Supplex® and Meryl®, Tactel® (nylon66), polyamides and nylons for hosiery. In response, natural fibre growers and producers, fearful of the encroaching synthetic materials, developed trademarks as guarantors of quality. Trade associations such as the Cotton Incorporated, the Irish Linen Board and International Wool Secretariat (IWS, now the Woolmark Company) courted both independent textile and fashion designers to advocate their interests (Fig. 11.5). Yves Saint Laurent first came to public notice at the age of 17, by winning first prize in an IWS contest. (The second prize was won by Karl Lagerfeld.) The producers of man-made fibres fought back. DuPont's stretch Lycra®, an elastomeric rubber substitute that withstands frequent washing, led not only to a reengineering of underwear and hosiery but also to elasticated leisure clothing in the form of leggings and stretch jeans that gave the look to an era of aerobics and 'body-con' dressing. The example of DuPont in the US (O'Connor 2008) and Courtaulds in the UK, in promoting chemical 'secret

11.5 Advert for Lycra® leisure clothing.

ingredient' factors in fabrics for comfort, resilience and aftercare was persuasive (Fig. 11.5). By the mid 1970s, Courtaulds was the world's largest textile manufacturer. Fashion designers became increasingly important as spokespersons and vehicles for promotion of new textile properties and some designers, such as Pierre Cardin and ICI became inextricably linked with the synergistic identification of materials with a futurist vision.

11.3.4 High-tech textiles

During the 1980s the term 'technical textiles' was coined to describe a new strand of products, finishes and manufacturing techniques developed primarily for their 'smart' technical properties and performance characteristics rather than their appearance or other aesthetic qualities. The technical textiles area contributes £1.2 billion to the UK's economy annually. The majority of these invisible advantages, such as anti-microbial, anti-static and anti-ballistic fabrics have been engineered for medical and military purposes rather than fashion; however, some of these, for example stain-resistance, water-repellent and anti-flammable finishes, are inherently useful for fashion and domestic use and many have been applied to 'improve' natural fibres. Countless unanticipated materials and finishes have found a way, through the enthusiastic experimentation of designers, into fashion. For example, polyethylene packaging products that are recycled into polar fleece have become a staple of men's sportswear and youth clothing.

Today scientific breakthroughs and advances in electron microscopy and mathematical modelling and prototyping through computer programs enable us to explore ever deeper into the technological construction of materials to engineer their properties at truly atomic (nano) level. Billion dollar investment in nanotechnology is now yielding some extraordinary properties that will be used to create a truly advanced generation of fabrics incorporating anti-microbial, biological, biomimetic and electronics enhancements and their applications through clothing. Fabrics and wireless garments that can monitor the sportsperson's heart rate and control perspiration levels during performance are already available for military and sports purposes. Although such new fabrications are generally extremely expensive to develop, in time, they become desirable, popular and even cheap. The latest range of novelties are fabrics recycled and resourced from biodegradeable materials, such as bamboo and corn, low in environmental impact. One interesting difference between these fabrics and previous generations is that in spite of special performance factors, the fabrics will not be overtly 'futuristic' or plastic looking. Finishing techniques such as fulling, enzyme washing and relaxing or coating of fabrics can add another range of interactive and tactile possibilities, even before the options for printing, embroidering and other decorative applications expand the potential for attractive surface effects. As previously, fashion designers are being asked to collaborate and find uses for the materials in promotional exercises.

11.3.5 Sustainability of textile and fashion processes

Today natural materials represent a small proportion of textile goods, and the public has become more aware and concerned about the environmental costs associated with their growth and usage, to the degree that, with the exception of cotton, still popular for casual t-shirts and jeans, many have fallen out of favour for everyday wear. It is not necessarily the case that natural products are cleaner or less fuel hungry. Natural fibres are subject to seasonal fluctuations and inconsistencies caused by infections that are usually managed by pesticides; washing and bleaching are costly procedures, using high volumes of water and consequent environmental damage (Allwood *et al.* 2006). Manufacturing, chemical and energy use and effluent was barely regulated until the late 1970s. Cotton denim, the most popular of fabrics, involves unsustainable quantities of water in processing. A considerable number of dye colours and solvents have already been withdrawn or are being phased out. Neutral and natural colours now have a cultural cachet as they imply 'purity' and a clean lifestyle to keep them unsullied. Once purchased, the cost and chemicals of dry cleaning also deters consumers.

Conversely, although there is justifiable environmental concern over the use of petrochemical processes, synthetic fibres and blends have become ubiquitous; to the extent that polyester materials now dominate world production and yet yield very little profit on price. Peak oil consumption and depletion has led to forecasts that oil prices will soar within the near future, provoking resource wars. The availability of fabrics and yarns for the drapery stores and marketplace were often the results of production overruns. Many textiles are now efficiently dyed and made to exact demand leaving little for retail. What is most cogent today is that the dye recipes, weave plans, knitting instructions, print data and other technical data can be kept in a database and fabrics processed and designs replicated by quick response manufacture. Expensive procedures and sometimes potent finishes need not be applied until a demand for the fabric, and even a buyer, is established, thus eliminating unnecessary effluent and many wasteful making and storage costs in speculative production. The fashion designer in the past made choices that were directed at selling *more* and *faster*, to feed a fast fashion demand. Now what has become appropriate is to consider the bigger picture and design items that will last, require less laundering and safeguard the planet and resources.

11.3.6 Endangered skills and materials

A myriad of responses, both physiological and psychological, can be orchestrated through the intelligent use of fibres and materials by a skilled practitioner. However, not all materials stay in the designer's repertoire and techniques used by the seamstress and couturier are sometimes threatened or lost through changing social customs and business pressures. Once serviceable materials have fallen out of favour. Silk crêpe bombazine, the fabric of choice for mourning, that brought the Courtaulds textile company to glory in the 19th century, has all but disappeared, as has Courtaulds Plc itself. In spite of the lucrative switch to synthetics the company failed to survive the transfer of production to the Far East under new ownership of Sarah Lee and was sold in 2006. Even hand knitting, a popular pastime and craft deployed for centuries for the protection of babies and loved ones, and particularly expressive of family identity through heritage patterns handed down from mother to daughter, has diminished due to the cheap imports of machine-made alternatives. Many attractive techniques such as smocking and lace making are too expensive or slow to produce for the wider market and the skills of fine needlework are disappearing. This is also true of haberdashery, ribbons, and millinery trimmings for which fripperies there is little current demand. Specialist industrial machinery has been exported or broken up and the instructions lost to time and museum archives. The use of furs, skins and feathers are very often protected by CITES legislation and are widely socially disparaged. Some fabrics are no longer suitable due to the ubiquity of central heating in homes and the work place; and global warming has also played its part in diminishing demand for leather and heavier woollen styles. As a consequence, together with the rapid closure of many textile businesses; rather than a constantly enriched palette, and wide availability of fabrics, sources of materials for the fledgling designer and dressmaking enthusiast are increasingly reduced and once valued craft skills will fade away unless they are cherished and promoted by vigilant communities of interest and by education. We can see from our museum collections that the downside of innovation is that many pleasing traditional materials are lost. It is to be hoped that a growing interest in sustainability and resurgence of crafts as fostered by online communities such as www.etsy.com, might keep the flame alive.

11.4 The 'apparel-body construct' (ABC) theory of fashion design

The contemporary fashion designer does not, as was once the case with the didactic *grande couturiers*, assume an instructive role and overlay his or her own tastes on the product offer. The student of design is taught to interrogate the materials and research the consumer. A number of attempts to demystify, code and decode the semiotics of dress have been made, most notably if impenetrably by Roland Barthes, the French philosopher and critic in '*The Fashion System*' (1967). If fashion has a system, it shifts and resists categorisation. Nevertheless, the theory of the 'apparel-body construct' (ABC) introduced by DeLong in 1987 to American merchandisers, sought to build on this concept and more practically, systematise the description of the gamut of fabric qualities, colours, body and clothing proportions in harmonies in a way that could also be used by designers, journalists and consumers. The theory aimed to satisfy both viewers and wearers, by creating instruments for analysis of aesthetic response to the myriad potential variations of fabric, apparel and body types. While students in Europe may not be taught the ABC theory *per se* all will be familiar with the need to combine an analysis of these components and to engage the senses in making aesthetic and 'fit for purpose' judgments. An important aspect of the apparel-body construct is the acknowledgement of the desirability of some proportion of this codifying being 'newness' as fashion (Benjamin 2003). The refreshing of a tired silhouette, the surprise of new materials, the breaking of sartorial rules, can all contribute to 'newness' until they become familiar or overexposed.

11.4.1 Taste and context

While it has been seen that fashion design is frequently driven by innovation in fabric design; however fantastic the materials, the suitability and longevity of fabrics for fashion design do not reside in the fabrics alone. Above all it would be a mistake to confuse the novelty of new or synthetic fabrics with the appeal of fashions. Design involves evocation of mood through nuanced alliances and coordination of fabrics to various experiences and purposes. By the transformation of materials into new styles, not only as technical constructions but as 'marks of distinction', fashion becomes a construct of symbolic cultural capital (Bourdieu 1984). Furthermore, the intended effects of fabrics and clothing go beyond the garment rail, and the skills of the designer and are also interpreted (and misconstrued) by others, including the wearers, sometimes segmented by taste, age and the snobberies of lifestyles to evoke powerful messages of prestige, sexuality, social power and identity. Writers and poets have celebrated many subtle sensory signals evoked, for example, by the rustle of silk taffeta or the touch of velvet. Here, Marcel Proust describing Mme Swann in *'Remembrance of Things Past',* (published from 1913 to 1927) evokes a character through clothing:

> . . . I would find her dressed in one of her lovely gowns, some of which were of taffeta, others of grosgrain, or of velvet, or of crêpe-de-Chine, or satin, or silk, gowns which, not being loose like those she generally wore in the house but buttoned up tight as though she were just going out in them, gave to her a stay-at-home laziness on those afternoons something alert and energetic. . . . One felt that she did not dress simply for the comfort and adornment of her body; she was surrounded by her garments as by the delicate and spiritualised machinery of a whole form of civilisation. (Marcel Proust 1871–1922)

In choosing fabrics the designer synthesises experiential, tacit and objective knowledge from our stored memories and also arouses fresh evocations in response to shared tactile responses. These sensory prompts are as important and evocative as colour and visual characteristics. To this extent, there is always a tension and overlap between traditional and even historic styles, with which people are comfortable and familiar, and new trends. Vivienne Westwood, who has repurposed traditional textiles with startling effect has claimed: 'nearly every fabric that is produced in England has a kind of emotional charge'. Indeed fashion often reverts, or backpedals to past silhouette, as the case of Dior's 'New Look', or in fabric choices, for example, to the rustic calico 'ditsy print' styles of Laura Ashley and the prim Edwardian lace blouses sold recently under the Kate Moss for Top Shop label. A significant difference wrought by the high watermark of the 1960s advertising era and now incorporated into the education of a fashion designer, is the study of marketing techniques and the application consumer segmentation to the fashion mix. Certain fabrics, such as tweed and country oilskins, are inherently related to a market segment defined by upper class activities and price range, material characteristics are sensorially associated yet are no longer necessarily the most effective protective wear for hunting, shooting and fishing. Organic cotton, for instance, is now being used to reinforce a message of ecologically friendly goods and sustainable ethics that has little foundation in cotton industry history. Harnessing such knowledge to evoke emotional stimulation, identity and brand personality within the promotion and advertising is a designer's stock-in-trade; although not without ethical pitfalls and being open to misinterpretation. When Burberry's iconic plaid was hijacked by counterfeiters and worn by 'chavs' it almost brought the company to its knees, as the luxury market could not stomach or protect the intrusion on its status. The contemporary to 'slow fashion' movement also finds political expression in former styles and fabrics to comfort us in the face of perceived threats by cocooning in traditional materials. So, for example and paradoxically, the use and mixing of vintage pieces together with new clothing can be creatively fashionable for one sector or generation whilst simultaneously an anathema to another.

11.4.2 Market intelligence and media

Opinion changes fashion more than the mere availability of goods. Researchers have asserted that women can be classified into different levels of leading and following in fashion innovativeness and market orientation according to their consumption of fashion media (Summers 1970). Students brought up in an era of electronic communications often fail to appreciate that fashion intelligence was once hard to come by. Outside of the capital cities styles changed relatively slowly compared with today. Superior quality and styling in clothing was almost exclusively admired via the movies, and until television came along, was inherently costume oriented and somewhat dated. Until the development of the colour-offset lithographic press in the 1950s, the majority of magazines were printed in black and white and showed a small selection of middle market clothes, knitting patterns and pictures of society outings. Although there were weekly women's magazines, the glossy monthlies took three months to produce. Fashion adhered to seasonal weather patterns and changed slowly.

Fashion editors were once powerful arbiters of female taste and opinion. Mavens from glossy magazines and national newspapers went to Paris to make biannual show reports, but were prohibited from taking photographs; so were usually accompanied by a staff illustrator who made quick sketches. The elitist *Chambre Syndicale* shows has been described as a 'closed institution' (Majima, 2007), deliberately so, since the organisation was convened not only to promote but to protect the intellectual property of its adherents. This is not the place to amplify or moralise on issues of copyright but Fashion is highly relational and terms for a number of shades of imitation, from legal usage to downright theft, exist in the design vocabulary; e.g. 'homage to', 'inspired by', 'referencing' and 'knock-off'; clothing brands sometimes bought the rights to simplified patterns, or employed an astute fashion designer to interpret the look for the masses. Acute scrutiny of silhouette, fabric and samples were brought back as collectively screened prizes available to the elite companies and dressmakers. Store buyers also screened and selected choices for public consumption. One of the pleasures of the 'fashionista' or insider, is the effectively fast interpretation and wearing 'in the spirit', or the *Zeitgeist*, of such semiotic memes, and to track them through the collections and lifetimes of a particular designer. Indeed the study of fashion economics has made claim as 'the piracy paradox' that weak intellectual property laws actually provoke strong innovation and have not damaged the sales of originals (Raustiala and Sprigman, 2006). While the glossy fashion press have been highly influential, magazines fulfilled a need for aspirational fantasies and novelty rather than practical needs; there to seductively imply that the model, improved by wearing various brands and cosmetics could be *you*: professional or sexy, elegant or sporty for a given season or occasion and to keep fulfilment tantalisingly just out of reach. The clothes depicted were unlikely to be available in local stockists; and middle market manufacturers rarely advertised, relying heavily on editorial exposure and word of mouth.

11.4.3 Culture, preference and choice

Fashion magazines are now produced and syndicated in multiple languages and as online organs for broad consumption. Today, the fashion editor is a less didactic taste-maker and the trade press is stronger than the commercial magazine market. The Internet has democratised opinion and e-zines, blogs, trade journals, international prediction companies and exhibitions spot colours and trends for future seasons and instant reports on import and export metrics and sales to help the professional trader track and focus on upcoming fabrics and innovations. The fashion world has flattened and the hegemony of Paris/New York/London is rapidly losing authority. There are now over 85 global 'fashion weeks' in global fashion cities, per season (Ling 2007) and while there is jostling for tickets and position, the online dissemination of these events is instant and openly accessible. It is entirely likely that in future, trends will be initiated by the powerful BRIC countries[3], Brazil, Russia, India and China with new aesthetics that will coexist without a clear hierarchy. Very few clothing companies do not have a commercial website for advertising and contact purposes and the majority also use it as either a business-to-business

[3] Goldman Sachs. In '*Dreaming with BRICs: The Path to 2050*' a paper published in 2005, by the Goldman Sachs banking group argued that, since the BRIC countries are developing rapidly, by 2050 their combined economies could eclipse the combined economies of the current richest countries of the world creating a potentially stable but highly populated force. On 16 June, 2009, the leaders of the BRIC countries held their first summit in Yekaterinburg and issued a declaration calling for the establishment of a multipolar world order.

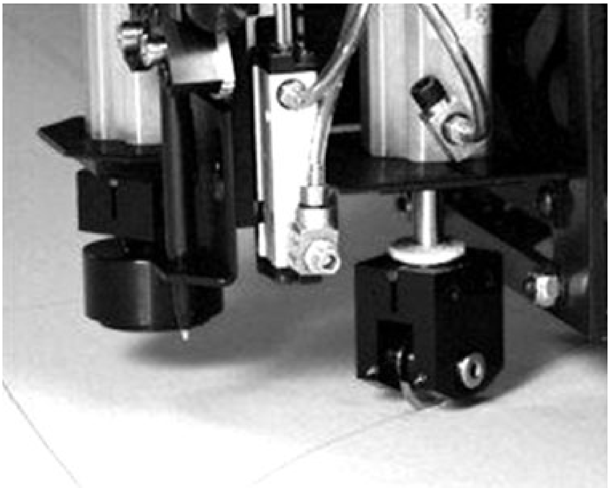
or business-to-consumer sales conduit. It could be said that there is so much available information that filtering the media for relevant viewpoints and meaning is now a central activity of the contemporary designer.

In a multicultural society it has become increasingly important for the designer to understand issues of market segmentation and demographic and geodemographic differences, not only because the market for consumption has globalised, but because sources, consumption patterns and attitudes, loyalties and preferences, lifestyles and habits are no longer dominated by a Eurocentric view of fashion and middle class values. While age and gender are reliable points of reference, the broadening social mix, preferences, occupations and disposable incomes are now unreliable as yardsticks of fashion choice and spending in a fragmented market.

For the student and designer it takes valuable time to cultivate the additional subtle experiential understanding of the semiotics of fabrics. A comprehension of fabrics is, like a music collection or a recipe book, a pleasure to build on through life and even to pass on to others. Most individuals, designers and merchandisers will in time find their own preferences, a focused range of fabrics that it suits them to manipulate and explore to a satisfying degree, and this proficiency then becomes a hallmark by which the style, skill, social target or a market brand is recognised. Sadly, workshop time is being carved from the academic timetable to make space for other demands, and at the same time the range of fabrics that was once available to the student and the hands-on opportunities to embellish, knit, print and weave are diminishing. In other words, it is not merely the compliance with a set of rules for visual and tactile aesthetics that make fashion and fabrics work together in harmony, but the fit with cultural and contextual values and the conveyance of ideas, or memes. The extended responsibility of the designer is to research and identify with personal aspirations and self-concepts, political or religious attitudes and the leisure activities of the target consumer for the brand they serve. Fortunately, there are now a broad range of electronic tools that have opened new doors and which may allow new alliances and constellations to flourish.

11.5 Applications of CAD/CAM (computer-aided design/computer-aided manufacturing) in fashion design

Since the 1990s software for fashion design and production has become increasingly sophisticated and at the same time more accessible and user-friendly for those who are not necessarily expert. CAD/CAM (computer-aided design/computer-aided manufacturing) systems have come down in price and those interoperable within the Windows environment, have seen widespread installation in even the smallest of apparel companies. CAD has impacted enormously on the way that products are planned and designed and files sent to external outsource production units fully documented. In larger companies there is a significant gearing up towards the logistical and organisational aspects of machine booking and monitoring and automation of moving conveyors and parts. Most of the larger software companies offer suites of tools that are now compatible with or form the larger part of industry enterprise resource planning systems. In the design room, one solution that has revolutionised and speeded up the communications and confidence in product development responsibilities between different parties in the supply chain is the application of



11.6 Automated pattern cutting.

2D to 3D visualisation. Virtual prototyping, when applied to various patterns, can help stakeholders make informed choices as to the suitability of styles and silhouettes and fabric behaviour and accelerate an understanding of technical issues between designers and garment technologists. Manufacturers will also aim to validate new designs by building and testing *physical* prototypes, so CAD/CAM systems are usually fully integrated with pattern libraries, grading tables and can output to pattern marker plotters or single ply cutting equipment for sampling (Fig. 11.6). Roboticisation of plant is a growing feature of the garment factory and all aspects in the timing of incoming and outgoing goods working to lean principles must be tightly coordinated and integrated, so the costs can be calculated and applied on the fly. Barcode and RFID tracking of parts and deliveries is also integrated to aid distribution to retailers. Many software suppliers have agreements that are suitable for academic environments and some offer special rates or versions for students and recent graduates to encourage practice and skills.

11.5.1 Use of CAD/CAM in teaching environments

CAD/ CAM systems are developed around the needs of fast commercial productivity and not primarily orientated to the learning environment, where speed and efficiency are not the chief objectives. While systems differ and offer various advantages, most use an icon-based graphical user interface with the familiar metaphor of the drafting table and sewing room tools, and it is easy to identify the sequence of tasks across different languages. The ability to simulate, analyse and review work all adapt well to teaching conventional 2D drafting and also to practice-based problem solving in fit and form. The results of different drafting processes such as dart suppression, slashing and opening and adding flare and godets, can be quickly demonstrat to a large class using a projector and tasks set up for students to correct or reapply until the principles are understood. The value of

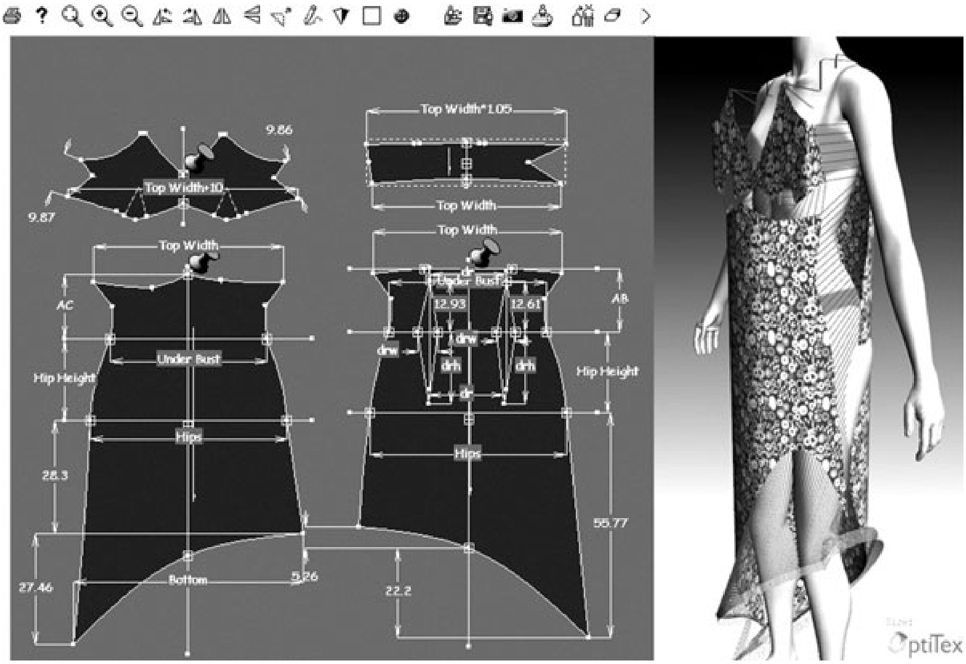
11.7 Digitising patterns.

thorough simulation of different style effects such as collar shapes, pockets and trims can be trialled and lay plans and markers used to avoid waste of either paper or fabric and to make individual and team decisions whilst also shortening the overall sampling time.

Where students need to replicate basic blocks, the time taken to produce these with the *copy* and *measure* tools optimises development productivity and an accurate starting basis. Pieces such as sleeves and legs are mirror images and ensure accuracy, where paper cutting by hand often leads to sloppy inconsistencies by novices. Over the period of their education, students can make and add to library files of their own designs and patterns. Pre-existing patterns can be digitised into the system by use of a specialised mouse, or puck (Fig. 11.7). In a networked environment these can always be accessible over a server, which is not the case with fragile paper patterns which may be left at home or end up damaged. One advantage that CAD/CAM drafting enhances, beyond speed, is an overall neatness and authoritative appearance to work, which results in higher benchmarks and expectations that work should have a professional appearance. Patterns drafted on a high-level system and saved in a generic file format such as the ubiquitous .dxf format can also be emailed to commercial premises to prepare and make up. The ability to instantly create lay plans for different fabrics widths and calculate metrage and wastage is also critical in helping to determine efficiency of fabric use and cost per garment. Costing sheets can be generated to help students gain a sense of all the interfacings and structural additions that make up a garment cost.

11.5.2 Testing fit and fabric appearance

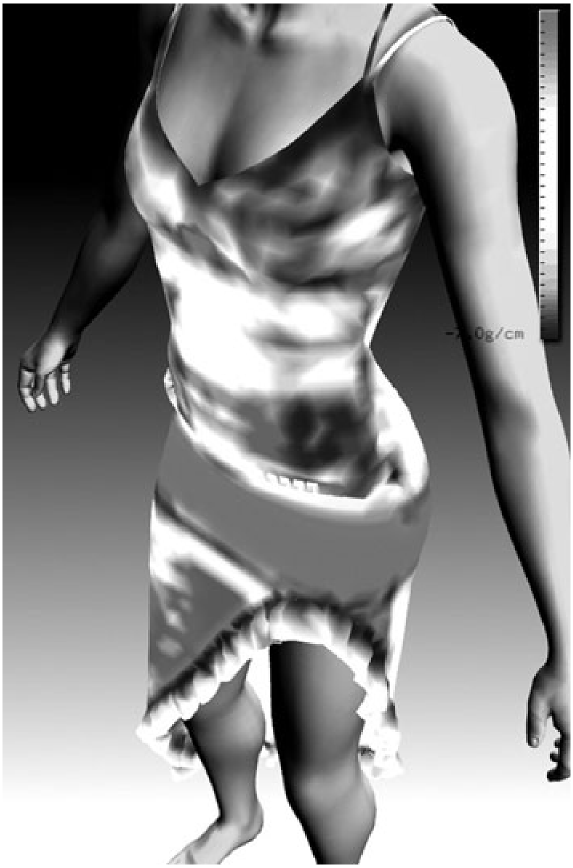
Much has been written about the application of CAD/CAM to issues of fit and grading. It is worth stating that learning how to cut to fit different body shapes is awkward without the use of mannequins or preferably real models. Sizing systems are orientated around incremental growth norms, yet in fact people are unique and body shape and mass differs. Garment simulation offered by most of the larger



11.8 Conversion of patterns using a 3D render engine to simulate look and fit.

commercial pattern drafting suites in the 3D environment gives very realistic results and the data used is actual sized, with real body and garment measurements. Parametric garment models are used to dress virtual 3D avatars for rapid prototyping and both visual and metric verification. The size and shape of the avatar can be adjusted to individual measurements and specifications of skin tone and hair colour, and in some instances, effects such as pregnancy, weight distribution and posture are adjustable. Some software, such as Optitex and Assyst Bulmer's Vidya permit the integration of 3D body scan data from particular scan systems to create an avatar, so that the student can modify styles to fit customised made-to-measure outfits for an individual customer. 2D garment drafts are 'virtually stitched' in the interface, following a few adjustment to the pattern, and then passed through a 3D render engine to cover the body and transform the flat mesh into a 3D pliable surface (Fig. 11.8). Mistakes in cut, length, positions of darts and ease can quickly be seen in three dimensions and different viewpoints; the figures can be rotated and zoomed in to detail and troubleshoot problems. Before long it is likely that CAD systems will be able to automate pattern drafts from scan data. The 3D visualisation tools can act as a practical stepping stone in learning how to adjust for diversity, and particularly for intimate lingerie garments. Reverse engineering, whereby a garment pattern is drawn onto the 3D avatar body and then flattened out as a parametric pattern is also possible.

The ability to visually and virtually simulate the appearance of fabrics cuts much of the need for making samples. The overall cost reduction in time and rejection of mistakes is significantly improved. Fabrics are most often simulated through application of 2D 'texture maps', i.e. photos or scans of real fabrics, entered as



11.9 Use of pressure maps to improve fit.

.jpeg or .tiff files. Fabrics can also be made to appear semi-transparent, shiny or lacy. Real physical parameters such as weight, fibre content and tensile properties can be read from the manufacturer's swatch information, entered and applied by the physics engine which calculates approximate fabric behaviour. This will be translated into either 2½ D simulated mesh or realistic anisotropic forces for 3D drape around the figure, dependent on the positioning of the grain lines and quantity of fabric in the pattern piece. Prints, plaids and stripe positions can be improved and appraised before cutting. Tools such as these can be useful in the planning of the scale of print designs and the positioning of motifs even *before* the fabric itself goes into production. Stretch fabrics and knits may have negative ease. Various display modes can be used and the compression of stretch materials and their effect on the body can be seen with pressure maps to adjust for the required snug fit (Fig. 11.9). Similarly, if virtual pattern pieces do not fit the body size, the designer or pattern cutter has the opportunity to correct the pattern on the fly and check it before it goes to production. Virtual sewing also enables stitch detailing such as top stitching, elastication, quilting and other effects to give verisimilitude to the outfit. Items such as buttons can be given real depth as 3D objects, or quickly added as flat images.

Some 3D programs add animation properties to the figure; arms can be raised or the body posed, or extended to more complex movements like parading and twirling down the virtual runway, or sports activities such as a tennis serve. Fabrics that are cut loose from the body such as skirts, will swish naturally around the figure according to the type of fabric specified. Students can also use game and virtual environment software to create and dress avatar personas; *Poser* and *Second Life* are two popular environments that offer detail in hair, skin and accessories and acceptable realism in fabric drape and movement. One advantage of the virtual environment is that otherwise geographically separated groups and individuals can meet within the virtual space to experience the clothes show in a shared experience. While animations and various applicable background graphics can be useful to give context to a design, and can be screen captured as evidence for the portfolio and for further discussion and presentations; for the student they also add an early sense of achievement and incentive, even before they gain the skills to make the outfit.

11.5.3 Personalisation and mass-customisation

It can be seen that the demand for variety within the broader framework of the fashionable silhouette and fabric choices is an important motivation for buying. The opportunity for CAD/CAM systems to be used for individual made-to-measure tailoring has been mentioned above. With the increased skill, pace and variety that can be engineered through such systems the opportunity for a closer participation of the consumer in a collaborative relationship with the designer can be envisaged. Haute-couture clients are an elite, who have their garments fitted and styled to their exclusive requirements at a significant cost. Not only do they pay dearly for the privilege, but they also expend considerable time in viewings, fittings and shows that are intrinsic to the process. The particular reward is not only that the garments fit properly and are unique and recognisable, but that the client has felt fully engaged in the process. Although this social investment may be desirable, it is no longer necessary, since a virtual avatar, or even an exact polystyrene replica of the client's body, can be laser cut using a body scan as a fit model. In the US, two companies, Alvanon and Shapely Shadow, specialise in creating mannequins and optimised size models for use with CAD/CAM software. Universally available VOIP applications such as Skype and video conferencing allow an individual to talk with a designer or salesperson anywhere in the world to watch progress and to collaborate on details of the design. Once a suitable pattern and silhouette is approved, any number of variations can be made for the client. The method is particularly expedient for those with a busy schedule and for perfecting clothing for elite sports people and those with atypical body shapes. Moreover, the value put on quality and the cultivation of a personal identity aided by clothes is an aspect of personal self-confidence that is worthwhile to business people, politicians and celebrities. The market for such bespoke services is growing.

11.6 Future trends

Predictions are unreliable, but we do know that there are significant social and technological paradigm changes against which we can gauge likely trends and challenges that will affect textile and fashion production, demand and supply and educational requirements. Some overarching, and already apparent differences in our material consumption patterns are seen in the effects of globalisation and free trade and concern over climate change, the water supply and its effect on agriculture and crops. Where trade barriers have lowered, media, communications and production savvy have flowed in and cultural similarities have usually homogenised, particularly with the younger generations. Conversely, some conservative religious cultures and Muslim nations, have put up moral bulwarks against the 'contamination' of Western mores and fashions in order to safeguard their regional and cultural identities. Populations are expanding, but unevenly, and the number of older consumers increasingly outweighs the most enthusiastic of fashion consumers: the youth market. Fashion may even shift from serving a trend-responsive young generation to providing for the demanding demographic of ageing baby boomers, and those described as the 'Y generation'. The greater size and disposable income of those in their 30s and 40s is a potentially lucrative and untapped market. Technological and computerised systems are proliferating. At the same time it can be seen that efficiency in high-tech production creates tensions in employment policies and consumer prosperity.

Worldwide, industry bodies and governments are to varying degrees, implementing legislative changes and future-proofing their national industries. The Forum for the Future, a non-profit organisation, is a service that helps business and public bodies to assess and manage the risks that change brings. Their project '*Fashion Futures 2025*: *Global Scenarios for a sustainable fashion industry*', partnered with Levi Strauss & Co to create a joint report on potential circumstances for consideration and action. The report offered four different, yet related settings for the forseeable future: *Slow is beautiful*, *community couture*, *techno-chic* and *patchwork planet*. The reality will probably be an amalgam of all factors. Clearly, any outcomes and implications are dependent on public awareness and political action and the education and dissemination of information to the public is a vital facet of any future state of affairs. Consumers do not necessarily connect their consumption of fashion with environmental and social consequences, yet as they become increasingly discerning and connected to market trends through the internet and digital communications, they want more product data, shared dialogues, personalised and custom products. Demand for business transparency regarding corporate ethics and a requisite 'feel-good factor' driven by a sensitivity to the scarcity, production costs, carbon footprint and labour ethics implied by the products they wear is likely to increase. New cultural memes and signals are in play. Formal higher education therefore needs to incorporate space for global thinking and diversity of viewpoints into the curriculum.

11.6.1 Perspectives on future fashion education

Students of fashion and textiles, have in the past 50 years been predominantly young, Caucasian and from white-collar and middle income backgrounds; usually they were indigenous and attended the college or university nearby. It was previously assumed that the educational and technological superiority in Western economies would limit high skills and creativity to OECD regions (Leitch 2006). There was an undisputed expectation that suitable employment within the industry would be available at the end of a degree course and that students would design products for their own generation. The same cannot be said today. In some pockets of the US, UK and in

Europe, where the local economy revolves around textiles, there have been rapid and catastrophic business collapses and widespread unemployment as outsourcing has proved more profitable. Where production has continued, it has become highly automated and many unemployed workers have returned to education, sometimes travelling great distances, to improve or update their qualifications, often with the ambition of returning home to start their own small enterprises. Design education encourages independent thinking, and this in turn often enthuses the designer with entrepreneurial intent and the willingness to combine aesthetic freedom with business ambitions as SME start-ups. In the Far East, South America and South Africa, emerging economies have moved into high skilled, high value-added activities and invested in high-tech production. Employers now 'cherry-pick' their elite workforce across national boundaries. The modern fashion designer is expected to travel, like an opera diva, from city to city each season.

The need for education in specialist textile and fashion areas has diminished in the OECD countries, but remains highly valued, especially in many of the developing economies that are now shouldering the manufacturing load for the Western nations. China now has more people in higher education than the United States. Parents are prepared to fund an expensive European education in order to warrant and improve their child's upward mobility in the new economies with computer and language literacies. This is a situation that is almost certainly untenable in the long term, since within a few years it should be feasible for newly industrialised countries to educate their middle and upper management, in their own institutions and according to more localised conditions. In addition to a broader constituency of life experience and age range in higher education, the means of education is changing, with e-learning for distance instruction and blended techniques allowing for courses that are more flexible and modularised. Learning *in situ*, in the factory, or by part-time workplace release is becoming an option.

While employers, government and academia are not necessarily in accord as to a way forward for education in textile and fashion design disciplines, it can be said that amongst the advantages afforded by increased communications is a more involving virtualised relationship and the opportunity for ongoing and inclusive debate and learning. Once fragmented and minor departments could collectively pool resources and expertise and build research and development in the field. The global reach of CAD/CAM technologies and communications has created widespread change in consumer demand and profiles. Inflexible attitudes are in flux and new markets and hybrids of the ideal and fashionable body, materials and styles developing. The potential is there for strategies for a leaner and more evenly distributed scenario, that charges the designer with taking fashionability into to a fairly traded, socially inclusive, responsible and sustainable era.

11.7 Sources of further information and advice

11.7.1 Skills and employment

AUTEX, Association of Universities for Textiles. http://autex.ugent.be

Euratex – The European Apparel and Textile Confederation http://www.euratex.org/news-and-publications/33 http://www.skillfast-uk.org/

Skillset – Sector Skills Council, employer-led body, established to enable employers to exert influence on the UK's education and skills systems to ensure they meet their needs and instigate institutional change to deliver better integrated employment and skills services.

11.7.2 CAD/CAM

http://www.lectra.com
http://www.gerbertechnology.com/default.asp?contentID=56
http://www.optitex.com/
http://www.assystbullmer.co.uk/

11.7.3 REACH legislation and chemicals

REACH is a European Union regulation concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals. It came into force on 1 June 2007.

http://www.reachready.co.uk/
http://www.bfr.bund.de/cm/230/introduction_to_the_problems_surrounding_garment_textiles.pdf
http://www.pan-uk.org/

11.7.4 Fashioning sustainability

DEFRA: Department for the Environment, Food & Rural Affairs: Sustainable Clothing Action Plan.

http://www.defra.gov.uk/news/latest/2009/clothing-0220.htm
htp://www.forumforthefuture.org/projects
http://www.sustainable-fashion.com/

11.7.5 Ethics

http://www.labourbehindthelabel.org
http://www.ethicaltrade.org/
http://fashioninganethicalindustry.org

11.7.6 Fashion councils

http://www.britishfashioncouncil.com/
http://www.modeaparis.com/vf/index.html
http://www.cfda.com/

11.7.7 CITES

http://www.cites.org/

11.7.8 MINTEL market reports

http://www.mintel.com/

11.7.9 Trade publications

Textile Intelligence
Textile Review
Textile Research Journal

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12
Interior textile design

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Abstract: This chapter describes current approaches in the design and development of both woven and printed interior textiles. It discusses both commercial and creative briefs for new products and ways of balancing performance and manufacturing requirements with innovative design. The chapter includes case studies illustrating the design process in practice.

Key words: interior textiles, design, commercial brief, creative brief.

12.1 Introduction

The aim of the chapter is to describe the current approaches involved in the design and development processes of interior textiles for specific market applications. Throughout the chapter reference is made to the design and development of both woven and printed interior textiles, and the commercial and technical considerations that affect the creative process in an effort to develop an aesthetic, practical and profitable product. From conceptual innovation of a textile through to the testing of its performance, it is important to focus on the commercial brief and the specific priorities set out that will ensure the commercial success of the interior fabric. From the evaluation of the commercial brief a creative brief can be created and the opportunity for innovation can be clearly outlined. At this point the designer is then free to manage the design and development process. The role of the designer is to ensure that the creation of the product achieves the highest standards and throughout the development the design is not compromised. This can only be achieved by a comprehensive knowledge of the manufacturing processes involved and a clear understanding of the range of end uses and applications that the textile could be used for.

The ability to innovate and create an exciting design concept, whilst meeting the commercial and practical criteria, are the greatest strengths that an interior textile designer requires. The end use and environment in which the product has to perform are demanding in different ways and can constrain some design possibilities or create challenges that need to be overcome during the manufacturing process in an effort to produce a textile that is both innovative and durable. The emphasis on performance and durability as well as commerciality are important considerations for the textile designer and end user of interior furnishings and a knowledge of the performance standards is an obvious advantage. These contributing factors will not only influence research and innovation but also the creative design process, as well as the preferred method of manufacturing and the finishing of the product. These considerations should not reduce the opportunity for creativity, in fact the textile designer requires commitment and determination to see any limitations as challenges and never lose the confidence to innovate and strive for perfection. The designer has a unique opportunity to create trends and fashion within interiors not only by influencing the textiles but also this can influence new styles and trends in the application of the fabric. Each new textile project will have unique criteria and will demand an individual commercial assessment. The key issues for the designer will depend on the commercial brief and the creative brief and it will be up to them to decide on the priorities and work with the manufacturing team to achieve the best results.

Case studies will be outlined in the chapter to demonstrate the unique criteria of any interior textile design project. These case studies will outline both the performance criteria and the commercial objectives that formulate the commercial brief.

12.2 Overview

The design and development of textiles for interiors has become more directly linked to fashion cycles as the lifespan of the textile product becomes shorter due to faster changes in trends for interior fashions and the demand for innovation. Consequently the role of the textile designer in the new product development process is far more exciting and challenging. The initial design stage often starts with a created concept on paper, referred to as a moquet, which can be a finished piece of creative artwork or an inspirational idea, with the suggestion of a repeat or layout and colour placement. Textile designers often become specialists in particular areas of design and methods of manufacture, as it is such a complex field and difficult to keep abreast of all of the technical advances from design through to manufacture considering the many different processes that are available today. A design concept can be adapted by CAD and the repeat and layout can be experimented with to achieve the most practical but also the most creative interior textile. The advances with CAD in textile design and printing techniques have enabled the designer to trial possibilities and experiment more before committing to bulk printing or the woven manufacture. CAD has also reduced the overall development time of a product and reduced costs in many ways, for example by reducing the samplings and trials produced on bulk machines and consequently reduced the costs of 'down time' on the machines, that is time not engaged with actual manufacture of bulk goods.

One of the most successful advances in CAD is the ability to visualise a design concept for a textile or interior made up and seen as a final application in a room set or superimposed onto a piece of furniture, for example, long before any manufacturing process has even begun. This advance has enabled textile designers to develop a concept through to the final interior or end application and to experience the overall impression that the product will make. This concept is becoming more popular in all areas of the market including retail, contract and domestic markets.

12.2.1 Printed interior textiles

In recent years demand has moved away from printed furnishing textiles and more towards woven products, but that trend seems to be changing as the evolution of digital design has given printed textiles a new direction. There are numerous methods of textile printing and dye systems for furnishings that can be used but the method of manufacture is selected carefully depending on the application that the product is to be used for and the desired level of performance. The selection of base cloth is a very important factor as this will determine the general performance of the product and influence the chosen print method, and relevant preparation and finishing of the fabric.

Planning and layout

The layout of the design is critical and the designer will benefit from a good knowledge and sensitivity of end use and applications.

The final application is an important factor especially for printed textiles, for instance if the design is intended for use on upholstery, it is essential that the design is sympathetic to the required layout for pattern cutting. Alternatively, the same design may also be considered for curtains, and strong directions or imbalances may become more obvious when used in this way where multiple repeats will be used. The base cloth to be printed on requires preparation and has to be suitable for the eventual cutting and sewing and making up. The joining and sewing of the fabric and the eventual wear of the furniture depends on a durable construction of base cloth.

The design process for a printed textile

The creative process often starts with an inspired creative 'moquet' or loose artwork, that is more of an inspirational creative format rather than a formulated print repeat or layout. The concept is then developed by CAD into repeat and the scale is adapted, at this point a variety of options can be considered. Once the design is scanned it can be developed creatively or simply technically, but these instructions are directed by the designer in an accompanying brief. Colour placement and separations will also be evaluated, as colour can also create focal points and imbalances in a design. The repeat can be developed in form and layout as well as in colour and the consequential repetition of colour creates rhythm and drama to the design.

Technical advances

Historically, the style of printed design was restricted to the adaptability of the print process with which it was manufactured, but now there is the opportunity for far more experimentation through CAD and digital imagery and the ability to concentrate more deeply on the innovation stage before committing to tooling costs. More experimental marks and techniques can now be accurately replicated in the printing process due to the transfer of the creative art work image digitally either to printing directly or onto separations for screens. This means that there is the opportunity to experiment with mark, scale and colour and then continue the innovation on to different structures of base cloths. Previously it was more difficult to present a concept or proof a design without the expense of making colour separations and trial screens. Not only did this involve many skilled manual hours but also expensive tooling costs such as the production of films and sample screens, and a variety of processes such as sampling or bulk trials, known as 'fents', on paper or cloth, and mini trials of colourways. With the advances of digital printing, concepts can be commercially evaluated before the tooling costs have been committed to. This is extremely important when designing and developing an interior textile product to a budget, responding to a technical commercial brief or innovating a product for an interior scheme.

As CAD is used extensively now in the design process, digital printing has also advanced the printing processes in manufacturing, and has increased in volume, replacing many original print processes such as rotary screen and flat screen printing. Commercially, one of the main advantages of digital printing is the ability to almost test market a design and colourways before committing to larger quantities of stock associated with the traditional methods of rotary screen or flat screen printing. Although digital printing is more expensive initially, once a design reaches a certain volume it can be transferred to a faster, cheaper method of print and be more profitable. It is obvious that the design has to be interpreted and set up in a way that the transfer from one process to the other, say to rotary screen printing, is undetectable and careful technical expertise is therefore required when setting up the design and final bulk production of the textiles. Advances with digital printing have also reduced lead times as changing from one design or colourway to another is simpler, with less setting up of rollers or screens and less down time on the machines.

As the demand for English print increases whether in the form of the classical design or contemporary form, we are seeing new trends emerging and the increase in demand for linen, cotton and silk base cloths. The scale of repeats of designs is growing and the loose free handwriting is giving a fresh appeal. Subject matters are becoming more adventurous, as prints once again show their true potential in interior textiles.

12.2.2 Woven interior textiles

Innovation and progress in woven interior textile design and manufacturing has increased dramatically, even in more difficult economic climates, resulting in the evolution of more trends and individual fashion styles as manufacturers become more aggressive to win business and create a strong identity.

The design process

Advances in digital imagery and computerised design packages for woven products have enabled the designer to explore ideas before incurring expenses in new product development and making expensive trials. The design concept can begin with a drawn design or a traditional weave plan depending on the experience or method of creative design by the designer. These artworks are mainly made by hand and

12.1 Weisters Jacquard production.

adapted technically by CAD or created totally by CAD. The development of the design can involve experimentation of weave effects also known as 'bindings' or 'construction' and a variety of these can be considered using different settings of warps and a variety of weft yarns. These ideas can be created or adapted by CAD and reviewed before manufacturing costs are incurred. Once approved, print outs of alternative colourways can be prepared, even to the extent of previewing a whole collection. The next stage will involve the concepts being trialled on a production loom, possibly on an existing warp in between bulk production runs (see Fig. 12.1). Samplings and trials are made on the production looms and at this point the final effects can be seen and approved. With the advances in CAD, amendments can be quickly made and the textile perfected on loom.

When making the initial sample the colours used are not always accurate as it is not essential at this point, the priority is to understand if the sample is reliable and technically sound, as well as aesthetically successful. Many changes and adjustments can be made at this stage to improve the product, these adjustments can include the settings on the loom, the structure of the weave bindings used, the selection or combination of weft yarns and the detail or clarity of the design or repeat.

Yarns

The advances in manufacture of yarn development and weaving techniques have meant that most manufacturers of interior textiles have been able to diversify and produce unique ranges of interior textiles. It is now common practice to be developing a new weave construction on a 'standard' or common warp. This is a long warp regularly used by the manufacturer to produce multiple products. The stock of weft yarns varies dramatically, but by including a variety of weft threads and constructions the manufacturer will create a distinctive and unique product range and have the ability to create new and innovative textiles from a standard range of yarns. A standard warp is often made of bleached yarn, and textiles manufactured using bleached yarns are often bulk dyed or prepared for printing on as base cloth, often referred to as 'PPP fabric'. These fabrics are then used as base cloths for printing on and can be woven in great volumes. If the warp is yarn dyed either as a solid colour or a 'planted' or striped warp, then yarn dyed weft yarns or blended yarn are used in the manufacture of fabrics. There is still an enormous number of yarn manufacturers, and this is a very complex and innovating business. Yarn manufacturers create yarns for many types of manufacturers. The variety of final products is endless and the end uses and applications will cover many market areas including apparel, interior furnishings, performance fabrics, industrial fabrics and many many more. The interior textile designer will benefit from an understanding of yarn manufacture and an awareness of the variety of international yarn suppliers. It is also necessary for them to have a sensitivity to yarn and the enormous variations and possibilities that the manufacture of yarn holds. Yarn manufacturers innovate speculatively throughout the year and work very closely with weaving manufacturers and printers in an effort to anticipate or respond to new market trends and styles and concepts created by textile designers, as a result of this they are often developing new innovations continually throughout the seasons. Yarn suppliers work towards trends and fashions two years in advance of the fashion or apparel market.

From one standard or common warp the manufacturer can manufacture hundreds of different designs all unique and sold to a wide selection of end customers, including international wholesalers, retail stores and furniture manufacturers (see Fig. 12.2). This image shows a standard solid warp with a trailing allover design repeat made in chenille yarn with a background of plain weave cotton viscose weft. The contrast of the two yarns creates a strong design effect and a raised construction.

During tougher economic times and with the increase of cheaper sourcing, all manufacturers have had to become more adaptable and consider how they can cut costs, become more flexible and competitive and develop a wider selection of products from the same warps. In many cases they can manufacture a high end luxury product on the same warp as a budget article for the lower end of the market, this is achieved by the choice of weft yarns, the constructions and the quantity that is manufactured. Consequently companies developing interior textiles at all levels as a result of these advances have been able to diversify their brand image and become more individual.

International interior textile trade fairs around the world create the opportunity for yarn manufacturers and textile manufacturers to launch new qualities and

12.2 Hartex Leaf trail Jacquard woven fabric.

present their latest ranges to editors and wholesalers from around the world. It can take a further 6–12 months for these styles and new trends to reach the high street following complete restyling and editing by the wholesaler interior textile company developing them into comprehensive collections of innovating designs and colours, often incorporating wallpapers, trimmings and fully coordinated ranges of inspiring furnishing collections for the interior designer, architect or furniture manufacturer to create with. The innovation of a concept can be initiated by an interior textile wholesaler or designer creating a commercial brief for a weave manufacturer that is creative and experimental. It may involve research into specific yarns and finishes in an effort to achieve a product that fits a specific market gap. The cooperation between this extended team can result in a successful collection that could run for years without interruption.

Technical considerations

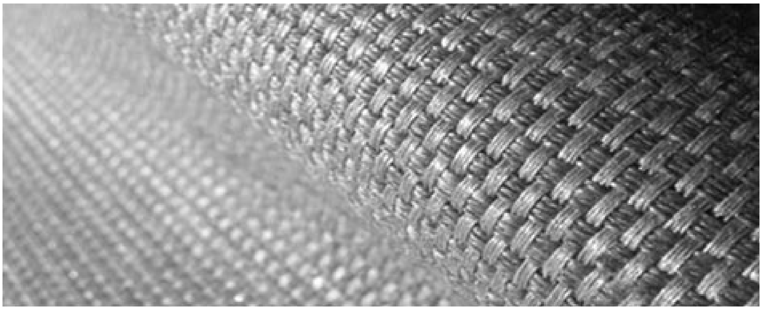
It is important to acknowledge that the international interior market is split into two distinctive areas of domestic and contract and the relevant interior textiles can often have quite different design and construction requirements depending on the intended end use and application the textile product is intended for. Furnishing textiles for contract also have different performance expectations from the textiles used in the domestic environment whether for drape, soft furnishings or upholstery; for example, a contract textile for the interior of hotel and leisure or cruise has particular minimum performance requirements, and the key issues and priorities of the designer in relation to the new product development process will depend on the application the textile will be used for. The safety standards of flame retardant textiles are quite different for contract situations in comparison to domestic safety standards and many countries have their own minimum standards and individual testing processes. This means it is quite a challenge to manufacture a product that meets all of these international safety and performance standards but emphasises the importance of knowing exactly which countries the product will be distributed in. Every time a new product is designed and developed it is essential the designer and manufacturer have a clear understanding of the criteria the product must meet and the performance tests it must pass to be a commercial success. The amount of wear that the textile will be subjected to when situated in a contract location is likely to be substantially more rigorous than the domestic textile, therefore the structure and composition or yarn content can differ quite dramatically between the finished textiles in an effort to achieve the correct level of performance.

In recent years the demand has increased for more natural looks and fibres, softer handle and less formal treatments and styles of application. This has created new challenges for the designers and manufacturers and in many cases results in the sourcing or creation of new yarns that will not only have aesthetic appeal but also will perform in the end application, whether it is, for example, used as a drape, upholstery or bedding. To take a beautiful natural product and then treat it or back coat it to make it flame retardant often destroys the finished aesthetic qualities of natural drape and handle in an effort to make the fabric flame retardant.

Trevira flame retardant products

Trevira is a manufacturer of high-tech polyester fibres and filaments yarns. Fields of application extend from home and contract textiles, automotive textiles and apparel to technical applications. The fabrics manufactured using trevira yarns are labelled trevira CS the flame retardant brand, the CS stands for comfort and safety. These fabrics are inherently flame retardant to the majority of international safety standards and have particular performance qualities that enable textiles to be developed for many specific contract interiors, such as healthcare, hotel and leisure and cruise. Trevira bioactive textiles have permanent antimicrobial properties that inhibit the growth of microbes in or on the fabric. The fabric is also easy care, comfortable to wear and breathable. The bacteria that come into contact with the textile are damaged by the silver ions preventing them from multiplying. Trevira work continually to develop innovating yarns that enable the textile manufacturer and designers to push the bounderies of textile innovation in the contract markets and produce beautiful fabrics that can also be used in the home. Consequently, many high end international textile furnishing wholesalers have been able to launch sophisticated and inspiring collections that replicate quite closely the luxurious articles introduced at the more exclusive higher end of the domestic market, whilst also meeting the performance and safety standards associated with the international contract market (see Case study 2: Harlequin Elita collection in Section 12.5.2).

Trevira manufacture a comprehensive range of yarns that not only offer an innovating selection but they also continually develop yarns that will imitate natural fibres such as linen, cotton, silk and wool and also yarns for a variety of textile manufacture including base cloths for printing (see Fig. 12.3). Some of the latest developments by Trevira and their partners introduce a clean, pure natural look in fibres. The look introduced this year has a dry luxurious non reflective quality and will enable the textile manufacturers to create fresh, pure and innovating new ranges.



12.3 Trevira CS @ 2010 collection.

Performance

The relevant performance test that an interior textile will require to pass depends on the specific end use and application that it is selected for and all areas of end use and application have guidelines and safety standards that require following. The details of levels of performance and the testing procedures are specific to the end use and application and are too numerous to cover in a single chapter. It is therefore advisable to seek professional advice from an independent accredited laboratory or the BSI (the British Standards Institution). The testing of the products to UK British safety standards is made in accredited laboratories regulated by UKAS (United Kingdom Accreditation Service). The following descriptions are offered as a brief introduction to the variety of tests that can apply to interior textiles depending on the end use and application.

There are many forms of physical testing that can be made on textile fabrics to test their performance level, such as abrasion resistance and abrasion to colour change or surface changes that affect the overall quality of the fabric. Fabrics can be tested for abrasion in a laboratory on a machine called a Martindale. This machine replicates the abrasive wear under controlled conditions and measures wear that a fabric can be subjected to in a variety of end uses and applications in situations when used, for example, as an upholstery fabric The amount of wear is measured in 'cycles' or 'rubs' until the fabric shows signs of colour change or physically starts to break down. A number of fabric pieces are taken from the same article and tested separately under laboratory conditions and an average of four samples are taken from the results of the Martindale machine. The current recommended minimum measure, at time of going to press, for of a fabric to be used in a domestic environment is 20,000 Martindale cycles whereas 40,000 is the recommended minimum level for a flat woven contract product. Testing for pilling and a change in the structure or physical reliability of the fabric is important as this can become evident after a period of time once the textile has had a period of use. These changes are noted as even the aesthetic look of a fabric can be changed and disappointingly, although it is not physically affected, can appear different. Depending on the number of revolutions by the Martindale that the fabric has reached before signs of breaking down, the fabric can be categorised to perform to the various stages from domestic to severe contract.

Seam slippage, tear strength, washing and cleaning tests include colour fastness, wash care claim and dimensional changes. All of these tests can determine if the product can be recommended or is in fact suitable for certain environments or end use and applications, such as domestic or contract.

Where resistance to flame test is required, again these tests are carried out under exact procedures and will detail how the textile reacts and if it meets the relevant standard required.The actual procedure of testing for flammability varies between certain countries, so it is important that the end use and application and market are defined clearly before manufacture.

Light fastness tests determine the level of exposure to daylight that the product will perform to before changes in colour are identified. This test is not only important in warm climates but also the average domestic interior, as some fabrics are far more susceptible to fading than others. Wet and dry rub tests and pilling tests are important for fabrics recommended for end use such as for upholstery. Pilling tests determine if the fabric will eventually create small bobbles of yarn that sit on the surface of the fabric.

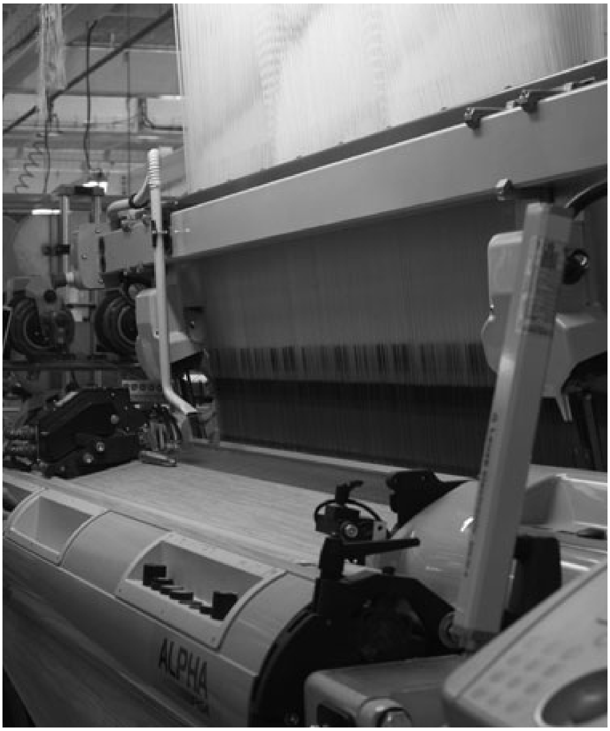
All of the above tests are carried out under controlled laboratory conditions and have exact conditioning and testing procedures. A certificate is supplied detailing the exact fabric and its content with a physical sample for identification. This certification is individual to the design, construction and any finishing for that specific product and regular batch testing throughout the life of the quality/design will ensure that the product reliably achieves the performance criteria of the original item. The recommended end use and applications for a textile are normally supplied by the wholesaler or editor of the fabric and any test results are usually readily available for any professional wishing to enquire about individual test results.

12.2.3 Selecting a manufacturer

The choice of supplier/manufacturer is critical as each one tends to use a selection and combination of yarns, dye systems, manufacturing processes and finishing methods that result in a unique finished product. It is interesting to note that many manufacturers have the same type of manufacturing equipment, but due to the basic set up their selection of stock yarns and finishing techniques they will produce a completely unique range of interior textile products and specialise in different market areas (see Fig. 12.4). It is the unique combination of manufacturing facilties and yarns that make every manufacturer unique but innovation is what really sets textile manufacturers apart from each other.

Products manufactured in China, Turkey and India have been associated with the more volume areas of the market of both printed and woven textiles and also the making up of finished products all of which are shipped in volume around the world.

Key requirements of specification will be critical deciding factors as to which textile manufacturer is selected to develop a new product. Other essential commercial and logistic considerations are taken into account including location and shipping, the reputation of quality control and experience of the manufacturer, delivery times and levels of service, the minimum quantities of manufacture per design and colourway, and of course the creative opportunity that the supplier offers.



12.4 Hartex Jacquard Somet loom type Alpha.

The manufacturer needs confidence in a designer's ability to develop and create a reliable product that will be successful and commercial, and one that over a period of time will result in volume of sales and profit. It is therefore imperative for a textile designer to have an understanding of the manufacturing processes available and have the ability to innovate and design to maximise the opportunity and produce a reliable commercial product.

Traditionally, certain countries and regions were famous for the manufacture of specific types and qualities of textiles and these companies were surrounded by specialist yarn manufacturers, dyers, finishers and printers all supporting the creation and development of a regional design and quality style. With the impact of cheaper sourcing and the diversification of many textile industries the manufacture and supply of textiles has changed dramatically and many types of textiles are now found worldwide but it is also true to say that many skills have also been lost and consequently some traditional processes and techniques have disappeared.

12.2.4 Role and responsibility of the designer

The design director or designer needs the ability and adaptability to understand the key responsibilities and contribution from a variety of experts during the development of a product, and also the capability of answering the commercial brief in an effort to create the best interior textile solution for each individual project. Interior textile design is definitely now an international practice as specialist manufacturers can be found all over the world. The market for these products is also worldwide, interior textiles are manufactured and shipped to international wholesalers and retailers, they are then selected by customers including interior designers, architects and specifiers and can often be earmarked for further international destinations. With this in mind it is essential for the textile designer to keep up to date with international emerging trends and styles in textiles and all related interior products and materials, and to have the ability to reliably evaluate and interpret each individual brief technically, commercially` and aesthetically. The textile designer is part of a development team and to achieve the desired product the process can include briefing an extended team which can include spinners or yarn suppliers, weaving technicians, dyers and finishing experts, textile technologists and laboratories, through to marketing teams (see Case study 1: DHJ Weisters Ltd in Section 12.5.1).

12.3 The key issues and considerations of the design of interior textiles

There are many key issues that are common to the design and development process of any interior textile product whether printed or woven but the priorities and order of the creative process need to be considered based on each individual project. However, all projects are likely to include: the commercial brief (Section 12.3.1), the critical path/timing (Section 12.3.2), creative and aesthetic (Section 12.3.3), scale and repeat (Section 12.3.4), commercial evaluation and budget, competitor evaluation (Section 12.3.5), end use and application (Section 12.3.6), and performance criteria (Section 12.3.7).

12.3.1 The commercial brief

A comprehensive fully researched brief is the most important part of the design process in any new product development plan. The brief is prepared primarily by the designer but with agreement from many areas which can include marketing and sales, purchasing, the inhouse technical team or independent laboratory, and the financial team. Following a commercial evaluation, a sourcing and purchasing section of the brief is created. It may be that a manufacturer has already been identified but it will be after careful evaluation that the development will begin. During discussion with client both parties should agree on the detail and a schedule should be drawn up to represent the new product development plan and a critical path, which will form the timeline from concept through to installation of the finished product. The commercial brief will define the criteria that the product has to meet in all aspects including technical and commercial and the details of the market gap and commercial opportunity related to the individual product or range of products. There could be a broad range of end users and applications, so all alternatives need to be wisely considered. The potential applications will have an influence on scale, layout and repeat, for example with a drape or curtain application, the repeat on the edges or selvedges of the fabric where the design is intended to flow across have to be carefully matched. The design must continue without interruption in an effort to disguise the joins of each width of fabric.

The marketing and technical research behind the commercial brief is a crucial part of the process to evaluate and determine the aesthetic requirements and the practical requirements that are essential to success of the project. Aesthetic requirements include the colour and design style, the physical qualities of the product i.e. the weight, type of textile, and the preferred method of manufacture. Commercial aspects such as cost price and minimum quantities are established for the textile and the following application, i.e. potential end uses and making up options. The brief will indicate launch date and marketing programme including any requirements for photographic lengths and samples in advance of launch. The technical requirements will be outlined depending on which countries the textiles will be sold into and the desired end use and applications the textile can be used for. The tests for international markets are specific and the testing methods vary, so it is essential that this information is available at the initial briefing stage from the client, as it will determine which suppliers or manufacturers can be used or if any finishing or treatments are required to enable the product to be marketed in certain markets.

12.3.2 Critical path/timing

In any design process it is necessary to have a new product development plan with a critical path. This will detail all of the key responsibilities, relevant processes and stages that take place throughout the creation of a new textile, and the relevant timeline required to meet the necessary deadlines. There will be critical times of evaluation where signing off is required, for example for costs, design, quality, or certification. This can involve experimenting by making up the textiles into soft furnishings and witnessing how they perform. Agreement can then be made to proceed to the next stage. In the contract market it is normal practice for a prototype or trial hotel bedroom to be made up complete with blinds, drapes carpets, bedding, lighting, etc. Often the commercial brief is offered to wholesalers to create a range of bespoke interior textiles that meet the specific contract specifications by a specific deadline. This whole project has to be signed off by the client before final orders can be placed and the bulk production of the interior textiles and furnishings can be made. The coordinated deliveries of all of the elements of the scheme have to be delivered to the contractor in order for the final making up of the furnishings to take place. CAD and digital printing has created the opportunity to create virtual schemes but trial rooms enable the final application and quality of the making up, and the performance and handle of the interior furnishings to be scrutinised before going into mass production.

12.3.3 Creative and aesthetic considerations

Design briefs may be quite open in relation to design concept or styling but often the brief can be extremely specific, even replacing an archive design or product authentically to match as closely as possible an historic document or part of such. In the case of developing a collection, a collection brief will indicate the total number of 'SKUs' (stock keeping units). There will be a description of how the collection should work which contains all of the components that make the collection successful. Different scales of design are important so that there are dramatic design solutions, as well as more harmonious and lighter effects of scale, repeat and colour. Semi plains and simple coordinates are essential to enable the end user to combine fabrics and create more complicated schemes. A comprehensive market leading colour palette is essential to ensure the collection reinforces the brand and works effectively with other interior textiles.

When responding to the brief of a client or developing a new textile concept, the ability to innovate and create a unique textile is always the most exciting aspect for any textile designer. Alternatively, there is as much satisfaction in replicating an exact match of an historic piece through the same or alternative methods of production. The brief may clearly determine what type of textile is required and there is usually an indication of scale and weight of the textile that will clearly define a starting point of design and development. It is normally relatively easy to establish a preference for a woven or printed fabric, which helps enormously in narrowing down the supplier options. At this point the designer has the opportunity to be creative and innovative. The technical aspects of repeat are essential boundaries for scale and by using this structure it is possible to develop rhythm and repeat with the formation of pattern within the unit.

Colour is essential to add harmony or drama but certain colour use can also have a financial implication. Printed textiles are costed partially on the amount of colour applied to the base cloth and the depth of colour and this can vary between colourways of the same design. There may be limitations to the number of colours that can be used within the design and this will form the balance and form of the design. The positioning of each colour from dark to light is essential to maintain the clarity of a design and not to interfere with the way the manufacturing is set up from dark to light colours.

12.3.4 Scale and repeat

Textile manufacturing processes have evolved around pattern making but the width of finished fabric has been standardised around the manufacturing process and capability of the machines. It is necessary for interior textiles to be joined selvedge to selvedge so that the design runs across the joined widths disguising the edges. For this reason it is essential to ensure that the design flows naturally and the repeating of the motif is accurate. By applying pattern through print processes by roller or screen the nature of the process applies the motif in a repeated way across the width and length of the textile that is normally engineered in such a way to enable the fabric to be joined edge to edge to successfully make a continuous patterned effect and disguise the joins. With a printed product it is possible to create an allowance on each edge of usually approximately 1 cm. This ensures, especially with a detailed design, that the motifs can be joined accurately especially with half drop repeats. There are various stages in which CAD is required to ensure that accuracy and technical manufacturing details are finalised accurately. Repeating and layout can be reviewed, finalised and programmed in a matter of minutes. The standard usable finished width by jacquard looms is 140 centimetres but double width looms are able to create 280-centimetres wide woven fabrics especially for contract interiors where the extra wide fabric reduces the costs of making up. The fabric is edged at each selvedge with a header at one side and the hem at the other and made into drapes. The 280-centimetre drop is suitable for the average drop of hotel windows. This is called 'width for drop' in the contract industry and is very popular especially on new architectural projects where the hotel windows are particularly wide and tall. This solution not only cuts making up costs but it also ensures that the large expanse of fabric is not interrupted by seams, and it also means that the fabric hangs well. This obviously is a critical design detail that needs to be considered when making the weave plan, as the design that flows across the width of the looms will eventually be a vertical on the curtain.

12.3.5 Commercial evaluation, budget and competition

Designing to a specific target cost price and target retail or trade price is common practice but also having a stringent development budget is also normal. It is therefore necessary for the designer to be able to evaluate and manage these costs and plan and control the design and development budget. Many factors contribute to the cost of a product which will not only include the design development and creative role, but also the manufacturing process, the minimum quantity, any finishing that the product requires. Currency fluctuations and shipping costs need to be assessed and calculated as these costs can change regularly throughout the life of a product, and will have an immediate consequence for the profit that an item can contribute to the business. It is also essential that the competitive market is identified and the market gap has been clearly defined as it is important that the product will be a success and seen as innovating, value for money as well as market leading. It should not be overlooked that marketing is critical to the success of any interior textile, and that demonstrating how a textile can be used in a variety of applications inspires the consumer to buy the product. The formation of a dynamic marketing plan and a sales team that fully support the aspirations of the design concept are extremely important to the successful launch of a new collection.

Sustainability and carbon footprint are now key responsibilities of many companies today. How a company takes responsibility for its environment and that of the world are key factors in how a manufacturer is selected.

12.3.6 End use and applications

The end use or applications of interior textiles comprise an enormous variation of soft furnishings and made up products, which include upholstery, curtains, cushions, bed covers and bed throws, accessories and many other made up items. Most of these items are designed incorporating more than one textile and a variety of other products such as fillings, trimmings and linings. Once a combination of products is combined it is necessary to consider the performance aspect of the item and the method by which is is cleaned and managed. It will be necessary for the interior designer or person making up the item to combine products that achieve the same performance criterion of flame retardancy and to consider that the cleaning of the product may require a more delicate process due to the combining of the textiles into a new constructed article.

This will determine the technical specifications required and consequently how the product will be expected to perform. For example, if the end use is curtain, the

12.5 Harlequin Elita @ collection bedroom scheme.

textile will be expected to conform to a particular flame resistant specification which will be more severe for a hotel and leisure environment. The international performance tests are different country by country both in test procedure and classification criteria. Therefore the product will normally be tested in a registered laboratory for many international tests at the same time. These will normally include fire retardancy for a specific end use, i.e. bedding, curtains, or upholstery, etc., minimum light fastness, abrasion tests, washing and minimum cleaning tests, pilling, etc. (see Fig. 12.5). The interior textiles shown in this image demonstrate how important the design layout and flow of the repeats are. The fabrics are cut and engineered into made up soft furnishing products and have been combined with linings and fillings. This collection meets international flame resistance regulations for contract environments and is suitable for numerous end uses and applications.

The destination is also important, as certain export markets prefer textiles that are more compatible. For example, heavier qualities such as velvets and chenille are less popular in Mediterranean and warmer climates where it is particularly warm in the summer months. There are also individual safety standards that each country specifies that have to be adhered to and a series of unique tests that are carried out throughout the testing process.

12.3.7 Performance criteria

Does the product require laundering/cleaning in a particular way? Is it required to be washable at a particular temperature for infection control or economies of housekeeping? Is it preferable for it to be soil resistant or should it have an infection control agent or composite?

There are many ways in which a textile can be engineered to reach particular performance criteria. Many blends of fibres are now combined to create an ever changing supply of yarns which can offer unique handle and performance qualities such as tensile strength and flame retardance. In the weaving process certain bindings or weave constructions used individually or in combination with other bindings ensure that the textile is stronger, has less seam slippage and will be more resistant to abrasion and wear.

There are many options to improve the performance of a textile through chemical finishing techniques from softening to improve the drape and handle of a fabric, anti-static, easy care, chintzing and soil resistant finishing. Antimicrobial treatments and flame retardant treatments have been developed in many forms and applications including chemical dipping and fusing a backing onto the cloth creating a protective barrier.

The aftercare of a product is a key requirement many times as the finished article may require a certain level of aftercare or laundering, for example to maintain infection control such as cubicle curtains in a hospital, or a soft furnishing article in a hotel bedroom that will require regular laundering.

12.4 New trends and fashions

12.4.1 Influences

Fashion in interior design and furnishing products has evolved throughout history with key influences and styles that have been adapted both culturally and regionally. Internationally styles and trends have probably never changed so radically and quickly in previous history as they have in recent years, resulting in a very broad range of products available from international suppliers. Interior textiles now have a unique strong fashion style that does not follow apparel or fashion trends but seems to have an individual identity. Contemporary, classic and ethnic styles continually inspire interior textile designers, and their influence seems to be present at all levels of the market. Key trends emerge as an individual design style, new interior collection, or new construction of textile quality is launched into the market, and is identified as innovating or market leading. By inspiring other designers to develop new designs the trend evolves internationally throughout the interior design market. Metallics and pearlised effects created in yarn construction or applied by printing and finishing methods have had enormous success recently and are evolving in a more natural way becoming more subtle in the treatments.

As a designer gains commercial experience in both knowledge and understanding of the various methods of the manufacturing processes, a freedom and confidence to innovate and push the boundaries increases, and with it the ability to invent and create unique textiles without jeopardising the reliability or beauty of the product, in fact, on the contrary, this confidence and knowledge allows the designer to create new dimensions of design, and experiment with the engineering process that textiles has always been.

12.4.2 Colour

In the interior textile market design and colour forecasting is not easy to predict or anticipate, new emerging key colours are introduced and inspire other designers and a colour trend emerges. Unlike the fashion or apparel market where seasonal colours are predicted or one could say prescribed and consequently they appear in many forms and many brands at one time. In interior textiles there are pioneers of style and design that emerge and become successful due to their capability to innovate and set trends. These pioneers assist in the strengthening and establishing of wholesale brands by the creation of unique handwriting, use of colour and the successful development of dynamic ranges of interior textiles. Many of these brands lead the market with strong colour direction that is interpreted across the international markets creating a wave of support and resulting in key colours emerging. When colours become 'key trend colours' they remain in the commercial colour palette for a few years, maybe not at the forefront for long but in coordinating accent combinations dropping back from mainstream leading colour palette in interior furnishings. Recent trends have included combinations of black and white, duck egg blue combined with chocolate brown, lime green presented with fuchsia pink, or deep purple. Neutral shades of creams, white, warm greys, beige, browns and taupe evolve each season but continue to be the most commercial group of colours in all areas of the market including contract and domestic markets. It is difficult, almost impossible, to describe colour with the written word but it is one of the key factors that create the impression of comfort and luxury that is such a major part of textile design.

12.4.3 Natural

The trend for luxurious natural products such as linen, wool, bamboo, cashmere, hemp, silk, and cotton are increasing in popularity in their pure form as well as in blended form, throughout the international market in all weights and constructions. The beauty of natural fabrics and the soft handle and look of these qualities never seems to diminish in appeal, on the contrary their demand is increasing, Natural fibres are now also imitated in synthetic yarns that have flame resistant properties and superior performance capacity so the trend is following through into the international contract hotel and leisure, cruise and healthcare markets, enabling these environments to have luxurious furnishings that also perform.

12.4.4 Sustainability

Sustainability and global responsibility are important factors for the whole industry and recycled and ecofriendly products are not a trend but are becoming a priority for the industry. Companies now, as a part of their corporate strategy, design and source products that are globally friendly and manufactured to avoid damage to the environment and conserve resources. How textiles are manufactured, disposed of and recycled are important factors to the whole industry as well as the consumer and the complete lifecycle of the product is now a key issue that is rising quickly to the top of the list of corporate priorities. Many international manufacturers and textiles bodies are investing in global research to ensure that the industry acts responsibly and becomes more self-regulated.

There are numerous interior textiles products available including printed and woven textiles, and wallpapers woven and printed trimmings and therefore the demands on designers to innovate and develop new and exciting products responsibly, has never been more intense. Consumer desire for fine fabrics and furnishings both in the domestic and contract markets at all levels, is still creating the opportunity for good design and innovation resulting in an exciting time for the interior textile designer.

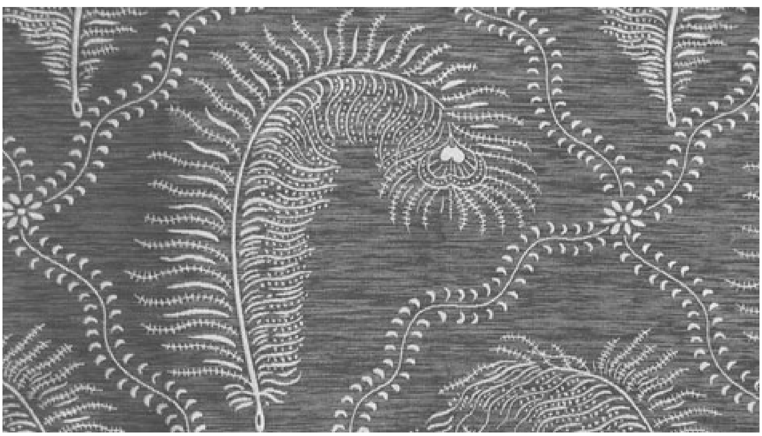
12.5 Case studies

12.5.1 Case study 1: DHJ Weisters Ltd: Designing for a manufacturer 18 months in advance of the market trends

DHJ Weisters are UK jacquard textile manufacturers of apparel bridal fabrics and Trevira interior textiles. The company manufactures high end Trevira CS products that are produced on standard coloured warps with a variety of stock weft yarns. The company innovates new woven qualities continually for its customers and experiments with new Trevira yarns to produce and exciting qualities for the international contract market through its wholesale customers. With a long history of manufacturing bespoke design Weisters

In spring 2010 a new selection of Trevira yarns were sourced from many yarn suppliers who had taken the Trevira fibres and blended yarns to construct new innovating yarns. After careful analysis of the selection a number were selected and a commercial brief and creative plan was made to develop a collection of designs that would maximise the qualities of the yarns and create a collection of designs to expand the existing customer base of the company. The designs were drawn and put into repeat. The inspiration for the collection split into two areas. The first part of the collection was based on classical research of 18th-century textiles, and drawings were made based on the classical layouts and flow of printed and woven documents. From this research, drawings were made and images inspired by block prints were created. The designs were loosely drawn and produced in a more contemporary handwriting. The paintings had a textured quality which was then captured in the weave effects for the jacquard. The designs were put into repeat and documented to indicate weave effects and motif positioning on the centre of cloth and centre of half width (see Fig. 12.6). This image shows the finished woven fabric and the repeat of the motifs. The two textured Trevira weft yarns create a matt textured effect and the strong definition to the design.

The second part of the collection had a more ethnic inspiration and was developed on quality to replicate a more silk effect. As the warp density was very close and the pick rate (number of wefts per centimetre) very high, the yarns had a

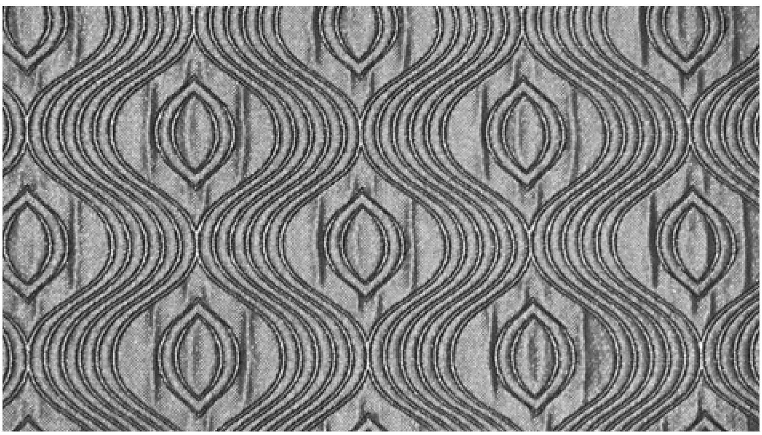


12.6 Weisters woven jacquard feather.

reflective quality and the designs started to look almost printed. In this part of the collection a more contemporary feel was desired, as this fabric was created to be used for bed throws and cushions, where simpler, cleaner, more pure designs were required. A shrink yarn was used in the weft which, when the fabric is calendared in the finishing process, shrinks to draw up the design and create a 3D effect to the design and textile (see Fig. 12.7). This jacquard textile has a raised effect to the surface of the fabric created by the use of a shrink yarn and was created for the end application of bed throws and cushions.

As a result of the design development the overall impression of the collection was very strong and offered a choice of style that could be developed into a new direction and broadened the commercial opportunity for the company.

Once the designs were approved, the artworks were scanned and developed by CAD individually. Each design was put into accurate repeat in relation to the appropriate jacquard loom. The looms are set up to specific repeat sizes of 1 across, 2 across and 4 across. Within the 4 across, divisions can be made to weave very small repeats. All looms, of course, can weave plain fabrics. During the CAD development the technical designer added the constructions or weave effects also known as bindings. It is very important to ensure that during this process the overall structure of the fabric is considered to ensure that the weave effects are balanced, and sit well next to each other, and also that floats are tied down, and the construction of the weave makes a reliable fabric. This is a very skilled role and during this process the technical designer follows the creative instructions and also the manufacturing requirements. The technical design was then transferred to a disk for the specific loom and a woven sample was trialled on the loom. During the sampling the weaver and technical manager were present to evaluate the sample and observe the jacquard loom. A few of the designs were reworked on the CAD and amended to improve the weave effects and achieve the best interpretations of the design brief. Once all of the designs were woven the collection was reviewed with the designer and Duncan Weisters, the owner, to evaluate the overall results of design, construction, weight of fabric, handle and drape, and to consider the commercial aspects of price and production.



12.7 Ogee woven jacquard.

Samples of the collection were selected and they were then dispatched to an independent laboratory for flame resistance tests for UK contract specification. The laboratory TFT (Ilkley) Ltd conditioned and tested the fabrics for IMO (International Maritime Organisation) flame retardancy testing specification for bedding and drape resistance to flame. The fabrics passed the tests and a certificate was issued to DHJ Weisters for each quality. This is often a good opportunity to discuss with the laboratory specialists how the fabrics performed and responded in the test and to identify any issues where a fabric may fail, and to take advice on how one might improve the quality.

Following the testing, colouring was prepared by the designer using the yarn colour card for the Trevira weft yarn and the colour card for the Trevira warp selection. Colour blankets were then made using a sectional warp that was divided into six sections showing six of the standard warp colours. The whole collection of colour trials were then woven using a multitude of stock weft yarns. During the trialling the designer was present at the loom to evaluate the colours and combinations and to ensure that the coordination between the designs was accurate. Following the sampling the designer made a coordinated selection of the whole collection based on the trends for 2011 and 2012.

The whole process from the establishing of the brief to the final collection presentation as samples took four months. During this time regular meetings took place to review the technical details, market evaluation, and design and colour. As the warps at DHJ Weisters are continually on the looms, trials can be prepared extremely quickly, a design can be created by CAD and samples can be manufactured on the jacquard looms efficiently and accurately.

A trial room was made and the bed throw and drapes were made up and assessed after washing tests and product analysis.

12.5.2 Case study 2: Harlequin fabrics 'Elita' Trevira CS collection

In Spring 2009 Harlequin Harris one of the UK's leading interior textile brands launched their first Trevira CS collection for architects and contract specifiers. The end use and applications for this collection would include cushions, curtains and bedspreads and the layout and scale of the designs are practical and inspiring with a variety of motifs and a botanical theme. The collection is called Elita and has proved to be internationally successful due to its performance level, satisfying a high level of safety and all of the international fire safety standards (see Fig. 12.8). This image shows the elegant and sophisticated design style that creates the luxurious interior. The interior textile designs in the Elita collection offer a comprehensive choice of dramatic or simple repeat and layout, and are suitable for many international contract applications.

The design theme of the collection was inspired by Art Nouveau and Art Deco motifs and features four designs ranging from 'Voluptuous florals and sinuous flowing curves to striking stripe combinations and all over leaf motifs, in a fashionable palette of colours. Elitas flame retardancy ensures the whole collection can boast a high level of safety, since Trevira CS materials meet all international safety standards'. (From the Harlequin press release March 2009.)

12.8 Harlequin Elita @ collection Trevira CS hotel scheme.

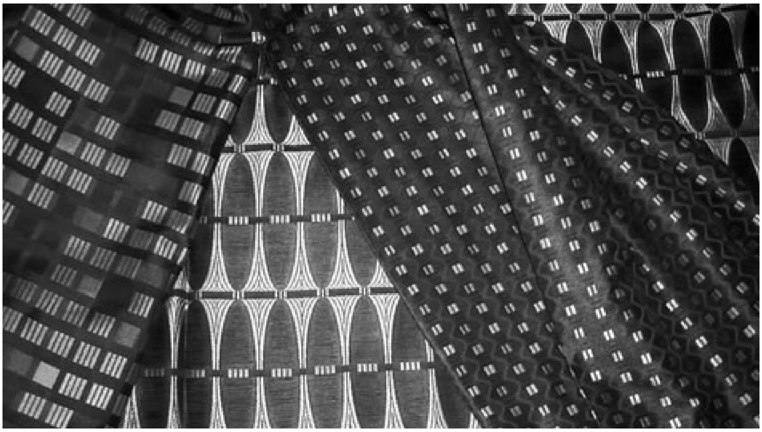
The Elita collection is successful in the international market for many reasons, firstly the combination of elegant designs offering choice and variation in the overall impact of the collection where there are many options of style and colour. The designs are distinctive but also easy on the eye with a flowing rhythm. The woven textures and quality of the textiles are luxurious and vibrant and the Trevira CS yarns enable Harlequin to develop the already extremely successful brand into the international contract market

'The many different flame retardant Trevira yarns enable us now to produce designs in flame retardant qualities that are versatile and full of ideas and we can thus meet the growing demands for safety in the contract market on a high aesthetic level' says Carolyn Mitchell. Group Contracts Sales Director of Walker Greenbank.

Harlequin also have considered the environmentally friendly qualities of the Elita collection, as the maintenance of the fabrics through the washing requires less drying time and uses low consumption of water and detergents, which combined with short drying times, results in an undisputed reduction in subsequent costs, especially when compared with other textiles and are therefore kinder to the environment.

12.5.3 Case study 3: new cruise ship interior textiles scheme of coordinating fabrics for new cabin design: applications, cabin drapes, bed throw, upholstery fabric (contract cruise ship)

Designing for the contract market is extremely varied and also much more specific in relation to application. For example, when designing textiles for cruise ships and



12.9 Hartex AVA collection @2010.

interiors such as cabins, the main considerations are the end application and performance of the made up product. The majority of the interior textiles are manufactured into bedding, drapes and throws. It is essential to have an understanding of the environment you are creating and the influence that the furnishings have on the space. Cruise ship cabins are normally designed to maximise the amount of available space, and although innovation in design and a specific colour palette is required, it is necessary to ensure the repeat and scale of the design, complexity of the textile design and use of colour is not overwhelming or too dramatic. Certain colours are avoided in cabins, such as particular greens and colours that may be less calming, especially if the occupant is unwell at sea. The environment is required to be relaxing and comfortable at all times and yet luxurious (see Fig. 12.9). The design style of this collection is rich and textured with an abstract theme. The variety of colour palette throughout the collection is neutral and styled to work with timber effects and natural materials that are often used in cruise cabin schemes and in hotel and leisure environments.

Natural light is sometimes not available, especially in internal cabins, so the lighting is critical and the furnishings should not overpower or reduce the feeling of space. The design style of a vessel, its cabins and public areas are determined by the fleet design director or architect and the interior brief and can be very specific for all areas. There may be a particular classic or contemporary style to the whole vessel. The colour palette will relate to other materials used in the interior. When a new cruise ship is introduced into the fleet it is usually to capture or increase market share. The ship has its own profile and identity, which the whole interior design scheme is focused on in an effort to attract a certain customer profile and to win market. There may be an historic aspect to the concept that literally aims to build on a nostalgic aspect of the cruise company. Details of construction and interior environments will, however, loosely refer back to this era by the selection and use of certain materials that were originally used, the design detail in carpets and textiles and the sensitive use of furniture and fittings. There is always a balance between the contemporary, new and classic that is fresh, functional and luxurious without creating an historic period piece. The reference to the original historic period is usually referred to more strongly in certain areas of a ship like theatres, lounges, libraries and suites than other areas depending on the setting and function of the area. It is imperative, when designing interior textiles, for these areas to ensure that the repeat and layout of the textile designs are practical in size and scale for the end application. It is necessary to start with the quality of textile that has been identified for its aesthetic handle, weight and construction. Housekeeping management and cleaning not only have performance criteria but also economic targets so the final made up articles will have to perform well under stringent controls of washing and drying methods. As is often the case, the finished soft furnishing item like a bed throw or curtains will be fully tested and scrutinised for weakness in design or possible improvements in the making up.

The commercial brief for the interior textiles initial design concept is created by the interior designer commissioned to design the area. An essential critical path is created to identify when the finished bulk product is required by the contractor for fitting. As one would expect, the timing is synchronised with other furnishings and contractors, and the process of fitting the cabins may be restricted to a limited number of days as other areas are then developed. There will be many teams of designers working on different areas of the same ship simultaneously and all to critical lead times. The new product development is then limited to an actual number of days and the design and technical management has to completed within this time. The concepts will be presented on mood boards with an artist's visual or a CAD virtual interior presentation which depict the room plan and adjoining rooms, i.e. bathroom or living room. A collection of interior textiles that indicate a mood or quality, handle or even a design style that offers a sympathetic solution are discussed at this stage. This will enable the manufacturing process to be considered and a selection of possible suppliers to be considered. The colour palette will be specific and other furnishings such as bespoke carpets and rugs will be available, styles of furniture, the lighting plan, artwork and as always the technical requirements must meet IMO (International Maritime Organisation) performance and safety standards.

In the first stage the interior textile products are reviewed by the interior designer responsible for the project scheme in the form of digital printed artwork, made to scale in repeat and showing a full width layout. This prototype is then assessed for its suitability for the end application and for the economical assessment of how it will be cut and sewn to create the bedding, drapes or cushions. The contractor who is responsible for making up the finished soft furnishings will approve the layout as will the interior designer. The design will be amended by colour, repeat or layout to remove any directional effect or to create any improvements in layout that will make the manufacture of end product more economical. Once approved the design will be manufactured as a fully finished trial that will be made up and laundered and tested for its durability and aesthetic success. The contractor will make prototype finished soft furnishings that will be presented in a trial room or cabin. They will also be fully tested for durability and will be taken through a rigorous range of tests. If any improvements have to be made then they will be made at this stage. Sometimes it can be just the application and engineering of the finished article that is amended or the combination of fabrics that are used to make the final article.

12.6 Sources of further information and advice

12.6.1 Key furnishings exhibitions

Maison object. Paris. France. www.maisonobjet.fr
Decorex. London www.decorex.com Trade fair for interior designers
The Sleep event. London. www.thesleepevent.com Trade fair exhibition for contract hotel and leisure industry
Chelsea harbour design showrooms. www.dcch.co.uk
Heimtextil. Frankfurt Germany. www.Heimtextil.messefrankfurt.com Trade fair for manufacturers
Mood and Expofil.deco yarn exhibition. Brussels Belgium. www.moodbrussels.com

12.6.2 Trade fair for manufacturers

Evteks exhibition Istanbul Turkey www.itf-evteks.com Trade fair for manufacturers

12.6.3 Manufacturers

Harlequin Fabrics Ltd. www.harlequinharris.com
DHJ Weisters Ltd www.weisters.co uk
Hartex www.hartex.be
Trevira Inherent flame retardant contract yarn supplier. www.trevira.com

12.6.4 Laboratory and standards associations

TFT (Ilkley) laboratory, www.ukas.org (The Sidings Business Park, Skipton, North Yorkshire BD23 1TB)
International Maritime organisation. www.imo.org
International Standards Association. www.iso.org
The British Standards Institution. www.bsigroup.com
BCFA British contracts furnishings association. www.thebcfa.com

13
The interaction of two and three dimensional design in textiles and fashion

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Abstract: This chapter will focus on the relationships between 2D and 3D design issues through discussion of three core elements: the body, textiles and fashion. Garments and the textiles from which they are formed have a unique interrelationship; they are both interdependent and yet have individual characteristics before they are integrated. Designers working within the two disciplines of fashion and textile design may practise independently, collaboratively or simultaneously. A textile design may be printed, embroidered, knitted or woven by a designer working with or without prior knowledge of a final garment shape, cut or fit. A fashioned garment may be sculptural, architectural or hybrid in shape, depending upon the characteristics of the textile it is constructed from and the way it is designed to work with the body form.

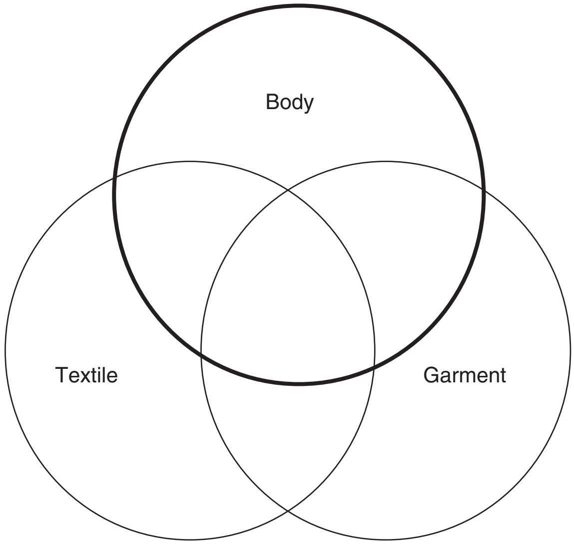
Key words: sculptural, architectural, hybrid, digital print, digital craft, digital embroidery, simultaneous design, deconstructed, minimum waste, textile-led, garment-led, garment as canvas.

13.1 Introduction

2D textile surfaces and 3D garment shapes have a unique physical and aesthetic relationship with the form of the human body. The body's contours have been shaped, constrained and distorted through different silhouettes which visually define fashion history. In this chapter the body will be analysed as a shape, structure and form which ultimately acts as an armature for different garment concepts that transform it into a 'fashioned body'. The 2D and 3D material and illusionistic qualities of textile fabrics will be explored in relation to their construction as different garment forms. In dialogue with each other, the dominant voice may be the textile, the garment or the body. The chapter presents different ways of categorising and thinking about this design dialogue and how it is influenced by many factors including: contrasting design approaches, fabric quality, garment silhouette, volume, 'minimum waste' and technological advances.

13.2 Triangulation: the body, textile and garment form

The relationships between the body, the textile and the fashion garment are complex and have a synergy when brought together, presenting a matrix of considerations for designers (Fig. 13.1). The textile and fashion design disciplines have a mutual dependency and in many ways are inseparable: 'when considering one it is difficult to ignore the other' (Gale and Kaur 2004). Textiles and fashion encompass design journeys which embrace specific expertise, skills and knowledge. Sometimes this



13.1 Diagram of body, textile and fashion (© Goulding 2010).

journey is undertaken separately, but some aspects are shared or have common strands. Each discipline has intellectual and practical demands and a curiosity to explore and break new boundaries, refine processes, skills and specialist knowledge. The relationship with the body is more direct in fashion than textile design, although there are exceptions, as discussed later in the chapter. This section contextualises the role of the body within the 360 degree equation of design.

13.2.1 Fashioning the body

Much has been written about the relationship between the body and dress. Entwistle and Wilson (1998: 107) note that the body is rarely viewed in unadorned nakedness, but rather as 'Art', where it can be governed by social conventions. The covering of the body can be dependent on many variables including garment function, social, political or cultural context, season, the identity and body image of the wearer, but ultimately the vision of the designer. Within haute couture, where this is most dramatic and influential, the core aim is to create new silhouettes and manipulate the form and aesthetic appearance of the body in new ways.

Throughout history the exposure of the body has changed and evolved on a continuum, embracing total coverage through to near nudity. For example, Rudi Geinrich's dresses from 1970 were controversial at the time, his Topless Dress described as: 'a liberator of the human form, but more often as an objectifier of the female body' (Design Museum 2009: 50). At couture level, Issey Miyake (1980) and Alexander McQueen for Givenchy (1999) designed bodices from embossed leather and plastic to create a realistic second skin (Fukai 2002: 609). In 1998 Hussein Chalayan shocked audiences with his Between collection which combined traditional Muslim garments with semi-naked models. Many designers including Issey Miyake (1989), Jean Paul Gaultier (1995), John Galliano (1997) and most recently Acne (2010) have produced tattoo printed body stockings that masquerade as the decorated surface of the body. The degree of impact of these garments and the perceptions of the fashion observer are dependent on a particular global context. Today could be a virtual space, such as Second Life where avatars can 'purchase and wear' designer clothing.

13.2.2 The haute couture body

The physical body is perceived in distinctive ways by different sectors of the market, resulting in contrasting approaches to the integration of 2D and 3D design.

Although haute couture garments account for only a small percentage of total clothing sales, the ready-to-wear collections produced by these design houses are the most influential factor on fashion styling trends in the mass clothing market (Entwistle and Wilson 1998: 107). The cut of a couture garment is carefully devised through creating patterns based on meticulous hand measuring, modelling on the stand, a live model and countless fittings followed by adjustments using manual and CAD pattern cutting techniques. Such garments are created with exclusive fabrics, sourced through specialist suppliers or commissioned from textile designers, with no expense spared to bring the couturier's idea to fruition.

The bespoke approach allows for the application of exclusive hand crafted and highly technological surfacing approaches that do not have to be replicated in high volumes. Some couture pieces are archived immediately after catwalk shows and never actually worn. A parallel within menswear of this exquisite craftsmanship for the individual client would be the tailors of Saville Row. Martin Margiela's Tailors Dummy Jacket (1997) shown in Fig. 13.2 provides a direct reference to the haute couture process.

13.2.3 The mass clothed body

Essentially, the relationship a commercial fashion designer has with the body is one based on computerised pattern design systems (PDS) using garment blocks cut to a company's standardised measurements, which are updated periodically through consumer data and national sizing surveys such as SizeUK (2003). Mass produced garments are generally made in sizes 8, 10, 12, 14 and 16. These sizes are based on average dimensions of bust, waist and hip and are designed to accommodate as many body shapes as possible. Companies such as Marks and Spencer, Top Shop and Next supplement their standard ranges with Tall and Petite, reflecting the requirements of their broad customer profile. Creating a wide range of garments in different sizes requires careful selection of corresponding surface embellishments that can be re-scaled to work aesthetically across varying sized pattern pieces.

13.2.4 The designer body

Designer clothing interfaces between mass and couture approaches. Designer labels consist of diffusion/ready to wear ranges marketed by couture houses to make a profit from their exclusive catwalk collections, and independent companies vying

13.2 Martin Margiela (1997) tailors dummy jacket, Maison Martin Margiela 20: The Exhibition MoMu, Antwerp (© Townsend 2008).

for a stake in the cutting edge fashion market. The designer body belongs to an individual who is aware of their shape and knows how to dress it. In contrast with haute couture and mass clothing, designer garments are not generally constructed on a made-to-measure basis or to standardised measurements, but for a size range that reflects their individual, yet relatively small customer profile. While ranges are more limited than those offered by the multiples, a more creative approach towards pattern, or 'style cutting' can result in a creative fit that can accommodate more than a single body shape.

Designer collections provide the most creative yet affordable options for the individual consumer. The approach to textile design is often more conceptual than commercial, particularly from independent designers and recent graduates who are willing to take more risks to get noticed in a highly competitive field.

13.3 Silhouette

The silhouette is a key consideration when bringing together the three central variables of the body, textile and fashion garment. Decisions have to be made by the designer as to the key points of accentuation and manipulation. The line of the garment or 'cut' is embraced within the silhouette, which can be divided internally using single or multiple horizontal, straight, vertical or curved lines. The layering of more than one fabric may affect the shape of a silhouette. As Jenkyn Jones (2005: 99) states: 'Garments are three-dimensional, and while we may think of the overall outline and shape of the garment as its silhouette, this changes as the garment is viewed in 360 degrees – moving, bending and revealing its volume.'

She lists key silhouettes as: Straight Column; Natural; Trapeze; Hourglass, Egg Shape and Shoulder Wedge. Good examples of these different silhouettes were represented in the exhibition Skin and Bones: Parallel Practices in Fashion and Architecture (Hodge and Mears 2006). The relationship between the selection and treatment of the textile and the resulting shape of the silhouette provides insights into the interrelationship between 2D and 3D design considerations by expert practitioners.

Straight Column

Yohji Yammamoto: dress from collection spring/summer 2000, a straight, full-length cotton shift featuring visible stitches that mark darts, seams and folds – like notations on a dressmakers pattern – as if the garment is in the process of being constructed.

Natural

Junya Watanabe: dress from collection S/S 2002, constructed from numerous pieces of recycled (deconstructed) denim stitched and draped to maximise fluidity and movement of the body.

Trapeze

J. Meejin Yoon: Mobius dress (2005), made of white felt, the dress takes the shape of a Mobius strip, a loop made by flipping one end of a rectangular strip and then connecting it to the opposite end. The garment encloses the body in a stiff A-line shape, that when unzipped, unfolds and cascades to the floor.

Hourglass

Alexander McQueen: dress from It's Only a Game, S/S 2005, garment with voluminous skirt made from silk/cotton with embroidery and metal fringing, prosthetic leather.

Egg Shape

Issey Miyake: Rhythm pleats dress, autumn/winter 1989. Knee length, pleated, circular shaped polyester dress created by cutting and sewing two circles together then feeding into heat press machine, resulting in an organically shaped garment.

Shoulder Wedge

Viktor and Rolfe: Ice Blue coat dress, December 2003 – The dress was custom made for *Vogue* and is a one-of-kind sculptural coat made of multiple tiers of collars and plackets that fanned from the models' necks to their shoulders, pushing ideas of layering and stacking to achieve an extreme, cantilevered form.

Traditionally, a single silhouette would dominate the seasonal collections, but today there is greater focus on key lines, which for autumn/winter 2010 were predicted by Shulman (2010: 54) as: 'Fifties – referencing fuller skirts and fitted tops and the contrasting Minimal Cool'. New textiles and finishes are the key informant of silhouette, with particular colours, qualities, textures or weights determining structural decisions. Fabric leads the dialogue between the body, textile and garment at the design stage, with considerations of fabric behaviour such as drape, hand and movement, inspiring modelling or flat pattern cutting approaches. Similarly, the manifestation and placement of detailed graphic imagery and embellishment may determine a simple cut that will expose the beauty of the cloth. Inspirational new garment silhouettes can consistently be identified in contemporary fashion collections; the designer's vision illustrating the unity between the re-shaped body through strategic fabric manipulations. Figure 13.3 shows Margiela's changing silhouette over a 20-year period.

13.3.1 Underpinning the silhouette

The space between the body and garment is usually interfaced with undergarments. The form, shape and silhouette of the outer fabrication have a relationship with that which lies beneath and which is a consideration for the designer and the wearer.

13.3 Martin Margiela (2008) Silhouettes 1989–2008, Maison Martin Margiela 20: The Exhibition, MoMu, Antwerp (© Townsend 2008).

There are numerous examples within fashion history where the undergarment has changed and informed the garment silhouette – sometimes this has been radical and at other times subtle. Lingerie is a paradox within womenswear, being instrumental, but generally hidden. Foundation garments are the starting point for shaping the body, the identity of the outerwear and the wearer. By contrast, some undergarments can be purely functional, made from fabrics that relate to the movement of the body, as in the case of activity and sportswear where 'techno-natural' blends of breathable fibres and technical textiles affect and enhance the performance of the wearer (Braddock and O'Mahony 2002: 7). This is in stark contrast with the role of undergarments from the early 20th century where the convoluted shapes of post Belle Epoque and late Victorian dress relied on the crucial shape-making component of the corset. The corset allowed the bust, waist and hip contours and measurements to be significantly changed and focus to be drawn to these areas of the body.

The relationship between the design of under and outer garments has continued, but with the exception of the New Look introduced by Christian Dior in the late 1940s, styles have generally become more fluid, following the advent of synthetic fibres in the 1930s, resulting in the softening of the silhouette towards a more natural body shape. The introduction of Lycra© (elastane) and innovative blends of microfibres has led to ultra fine lingerie fabrics which allow for greater experimentation with individual body shape.

Some designers have reversed or combined the roles of underwear and outerwear, such as Jean-Paul Gautier's corsets for Madonna's Blonde Ambition tour and his early 1990s collection which featured corsets for men. In Comme des Garcons 'Dress Becomes Body Becomes Dress', for spring/summer 1997, Rei Kawakubo incorporated pads filled with goose down, which accentuated parts of the body, creating extreme shoulder and hip contours. 'Underwear as outerwear' was a key trend for spring/summer 2010, with Marc Jacobs and Roberto Cavalli layering a 1950s style bra over shirts and Bottega Veneta teaming boned corsets with a gauzy knits (Harris 2010).

13.3.2 Styling the silhouette

The 3D silhouette is affected by the variables of posture and movement. Historically, posture was seriously contorted by undergarments, but today the stance of the wearer is affected by diversity in styling. This encompasses shoes, in particular, which have a dramatic effect on posture, affecting shapes created in motion. The way the wearer moves, walks, twists and turns is markedly different if the heel of the footwear is high or flat. Showstudio.com, formed by the photographer Nick Knight in 2000, showcases the latest catwalk collections, fashion shoots, interviews and styling projects. The Showstudio exhibition at Somerset House in 2009 demonstrated the impact of styling on fashion, bringing a range of cutting edge designer's work to life through striking photographs and the 360 degree perspective of film. Conceptual fashion designer Jo Cope designs, manufactures and styles garments and accessories, so is involved in the entire process of creating and communicating her particular aesthetic (www.jocope.com). Cope uses colour to emphasise the relationship between 2D pattern structures and 3D product forms (Fig. 13.4).

13.4 Jo Cope (2010) Nike 78 Project (© Cope 2010).

13.4 Spatial garment forms: sculptural, architectural and hybrid

In this section we consider garment silhouettes as spatial forms, created using contrasting textile qualities which interact with, and iterate, the body in different ways.

Two archetypal shapes: 'sculptural' and 'architectural' are identified and explored as a method for categorising key 3D garment forms and associated styles of 2D surface embellishment (Townsend 2004). A third 'hybrid', more natural shape, which integrates characteristics of both categories, is also discussed, which reflects the sychronisation of polarised approaches in contemporary fashion. The three categories provide general guidelines for the aesthetic integration of 2D and 3D design elements and are summarised as follows:

1. Sculptural
   - a garment shape that works with the natural body shape
   - requires a fluid textile with good draping properties
   - the impact of the body is evident; the shape of the garment is defined by the form.

2. Architectural
   - a garment shape that is supported by the body
   - requires any fabric that will facilitate structural or voluminous shapes
   - the impact of the garment is evident; its shape is often independent of the form.
3. Hybrid
   - a garment that is both supported by, and defined by the body
   - requiring a textile that can work with the garment and body form
   - the impact of the garment is related to the shape of the body, but not defined by it.

13.4.1 Sculptural garment forms

The sculptural model defined in this chapter has developed from the aesthetic of Ancient Greek sculpture, where garments appeared as a draped extension of the classical body. This relates to the 'column' silhouette discussed earlier and has been interpreted in contemporary fashion through Lycra, fine knitted jerseys and technical sports fabrics, resulting in body-conscious silhouettes and recognition that 'it is the body that gives form to clothes, and it is clothes that articulate the body' (Evans and Thornton 1989: 156).

Mario Fortuny's Delphos (1907) is a good example of a sculptural garment from the early 20th century. The tubular silk structure constructed from fine pleated silk, was given its shape by the body, adjusting to accommodate different-shaped individuals. When printed, the Delphos was often decorated sparingly with a single coloured stencil print or embroidery which enhanced the natural, kinetic patterning created by the pleats in movement. Madeleine Vionnet has often been described as a 'sculptress', who used fabric as her sculpting medium, and whose bias cut garments of the 1920s and 30s epitomise the sculptural model. Milbank (1985: 160) suggests that Vionnet was the first designer to approach fabric in a modern way: 'working with the natural body of the twentieth century she moulded the dress to the woman, rather than the woman to the dress'. Vionnet's 'bias cut' transformed the smooth cylinders of the 1920s into pieces that interacted with the form. Her embroidered dresses provide important examples of the considered interrelating of (2D) decorative and (3D) structural design elements with the body.

The designs of Ossie Clark in the 1970s illustrate a highly considered use of textiles and sculptural garment shapes. Clark integrated Celia Birtwell's feminine, floral prints in a manner that flattered the underlying form, sometimes cutting on the straight of grain *and* the bias to align the print with the contours most effectively. The use of Lycra as a fashion fabric from the mid 1980s by independent labels such as Body Map, Red or Dead and Cocky's Shed resulted in garment shapes and associated graphic textiles, directly related to the contours of the form (Townsend 2004). Other pieces created with high elastane content, such as Hervé Leger's and Azzedine Alaia's bandage dresses, literally sculpted the body into shape (Steele 1997: 124). The form was central to Gianni Versace's opulent printed and embroidered gowns of the 1980s and 90s, moulded to the 'supermodels' that wore them.

A sculptural approach can be identified in the recent work of Rick Owens (Fig. 13.5) and Sophia Kokoslaki; the dialogue between the drapery and form creating the surface interest of the garment. Kokoslaki's signature style was based on the

13.5 Rick Owens (2009) sculptural garment form (© Townsend 2009).

crafting of contemporary versions of Greek drapery, by skilfully manipulating fine silk jerseys. In 2003 she created a futuristic pleated leather chiton working in collaboration with Ruffo Research. Owen's dresses of the late 1990s and early 2000s (Fig. 13.5) were often fabricated from fine muslins and deconstructed garments, which he melded into alternative body defining creations – an approach which pre-empted current sustainable design approaches.

Following research into some of the designers discussed above, Katherine Townsend's PhD (2004) investigated how new styles of 'sculptural' print imagery could be originated and engineered to work more closely with the body and garment form. The practice-led research focused on the simultaneous generation of textile

13.6 Katherine Townsend (2004) 'Tide' sculptural style, printed garment prototypes (© Townsend 2004).

prints and sculptural garment shapes, using a combination of modelling on the stand and direct printing, to create garment blueprints that were digitally crafted and prototyped. The work explored the creative potential of CAD/CAM, specifically the 'total clothing solutions' provided by companies like Lectra Systems, which enabled designers to work across raster and vector applications. Simultaneous access to textile and pattern cutting software facilitated the merging of 2D graphic and 3D modelling approaches within the same software platform, resulting in new surfacing and structuring strategies (Townsend 2004). Figure 13.6 shows Tide, a silk square manipulated as a diamond shape on the body, digitally engineered with *trompe l'oeil* imagery inspired by Greek drapery and the idea of how bias cut silk works fluidly to articulate the body in movement.

13.4.2 Architectural garment forms

The architectural garment form is synonymous with the 'hourglass' (and 'trapeze') silhouette, providing a strong contrast with the sculptural model; often appearing as a structure that is supported by, yet autonomous of the body. The strong silhouettes promoted through the architectural model can be integrated with a greater variety of surface patterns, as observed by Adaskina and Sarabianov (1991): 'This spatial element, so "emancipated" from the human figure, made possible the vivid decorativeness of the large geometric patterns, the colour expression, the clearly articulated inner logic of ornament that does not quite fit the proportions of the body.'

The first architectural pieces of the 20th century can be attributed to the exaggerated shaping of the Belle Epoque, evidenced by the embroidered and quilted evening dress designs of Charles Frederick Worth (Martin 1998). Prints of plant forms and flowers in all-over and striped patterns were also integrated with the still generous volumes of the period. An interesting reworking of this style was created by the artist Yinka Shonibare in 'How Does a Girl Like You, Get to be a Girl Like You? (1995) which featured a collection of architectural garments based on the unlikely combining of Victorian dress with African wax print cotton textiles. Similarly, in Radical Fashion (2001) Vivienne Westwood juxtaposed a romantic dress shape from 1890s with a tiger stripe print from the 1990s, which perfectly illustrates how the generous volumes of the architectural model can successfully accommodate dramatic textiles (Wilcox 2001).

Christian Dior's New Look introduced in the late 1940s, incorporated large volumes of skirt material (up to 12 yards) gathered into the re-corseted waists of the hourglass silhouette, providing enormous scope for the use of large bold prints and embroideries. Balenciaga and Jaques Fath created simililar styles around this time, while Horrockses (Manchester) produced ranges of printed dresses for the mass market employing large florals and directional prints to emphasise full skirts. Strong references to 1950's hourglass shapes could be found in the A/W 2010 collections of Prada, Louis Vuitton, and Paul Smith whose corresponding use of graphic, textured weaves, leather and cabbage rose prints reinforced contemporary versions of the New Look – an archetypal architectural shape.

Geometric shapes cut closer to the body can also be emancipated from it, depending upon the fabric they are constructed in. Pierre Cardin's Egg Carton dress (1968) was fashioned in a permanently moulded, three-dimensional Cardyne Dynel fabric, forming an independent shell around the body (Steele 1997: 68). The Italian fashion designer Roberto Capucci designs architectural shapes that incorporate a strong 3D element that is rooted in 'the Renaissance's horizontal lines and articulated shapes: clothes that demand big rooms and high ceilings' (Falkman 2002: 58). Falkman likens the appearance of Cappucci's garments to that of static Murano vases, and describes them: 'not art in the sense of sculptures, but rather fanciful adaptations of past fashions with the addition of a modern idiom. It is therefore more apt in Capucci's case to talk about architectural shapes.'

Alexander McQueen's Lampshade Skirt (1999) is an inspired example of architectural shaping that borrows from Paul Poiret's creation of the same name from the early 1900s. McQueen's skirt was rendered in metal, having no material possibility of interacting with the form that supported it. Hussein Chalayan's After Words (2000) explored a similar concept through garments that converted into pieces of furniture, with space treated as an architectural zone around the body, surfaced with polished panels of wood veneer. His Dress Before Minus Now collection (2000) featured organic forms reminiscent of romantic silhouettes, fabricated into silk tulle structures. The Poppy Dress, from his Ventriloquy collection (2001) combined minimalism with large digitally printed poppies, echoing the 3D shape of the layered skirt (Wilcox 2001).

Gareth Pugh's collections have consistently featured unconventional materials to create fantastic architectural garments that build on the tradition of fashion as performance. The geometric shaping of Jo Cope's architectural wool coatdresses is exaggerated by the use of primary colour, as shown in Plate XI between pages 166 and 167. Japanese designer, Shinsuke Mitsuoka's 2010 BA Fashion graduation collection for Nottingham Trent University provides a good example of an architectural approach, using laser cut metallic fabrics to create contemporary armour that extends beyond the natural body shape, as shown in Fig. 13.7.

13.4.3 Hybrid garment forms

While it is still possible to identify architectural and sculptural archetypes within haute couture, this became more difficult after the mid 1960s and is chiefly due to

13.7 Shinsuke Mitsuoka (2010) BA Fashion Design collection at Graduate Fashion Week (© Andy Espin 2010).

the increased use of synthetic and mixed fibres, resulting in new fabric qualities and shapes that incorporated elements from both archetypes; structured/tailored (architectural) and unstructured/draped styles (sculptural). The hybrid, more natural shape evolved out of the style explosion of the 1960s and 70s, embracing the stark shaping of Courrèges with the ethereal styling of Biba. The influence of sportswear has also impacted since the late 1980s, resulting in more 'natural' silhouettes.

The designs of Emilio Pucci provide good examples of hybrid, contemporary shaping through shift dresses cut in Emilioform stretch silk that 'skimmed' the body. The combination of a geometric shape integrated with a brightly coloured, optical print was revolutionary. The prints were often executed on a large scale that would have suited the proportions of an architectural garment, but by cutting close to the form, Pucci created a new dialogue between print, cut and the body. Pucci's prints were multi-directional, alluding to pattern itself, as opposed to the body (sculptural) or the garment (architectural).

Many of Jean Muir's shapes fit into a hybrid category. Her extensive use of jersey informed her cut, which was relaxed, but not clinging, comfortable, but 'classic'. Muir's consideration of the form raises parallels with Vionnet's practice, but the shaping is different as Muir exploited the new concept of fabric 'ease'. This quality was heightened through the use of stretch jerseys, allowing the body to move slightly beyond the boundary of the garment contour.

In the early 1980s the Japanese designers Issey Myake, Yohji Yamamoto and Rei Kawakubo introduced the fashion world to a non-Western idea of clothing based on the belief that cloth comes first and that shape follows. The Japanese viewed the figure as a landscape: horizontally, asymmetrically and in the round resulting in new shapes and spaces that concentrated on scale and proportion (the challenges of cutting) and texture and colour (the challenges of fabric design) (Constantine and Reuter 1997: 197). Issey Miyake's training with Guy Laroche and his assisting of Givenchy led him to understand yet reject the principles of couture for a mode of shaping that 'freed the body from the tyranny of the perfect form' (Falkman 2002: 58). His desire to 'design a dress that was neither elitist nor ephemeral, but simply in tune with contemporary function and style requirements' presents a fitting definition of hybrid styling (De la Haye in Wilcox 2001: 29).

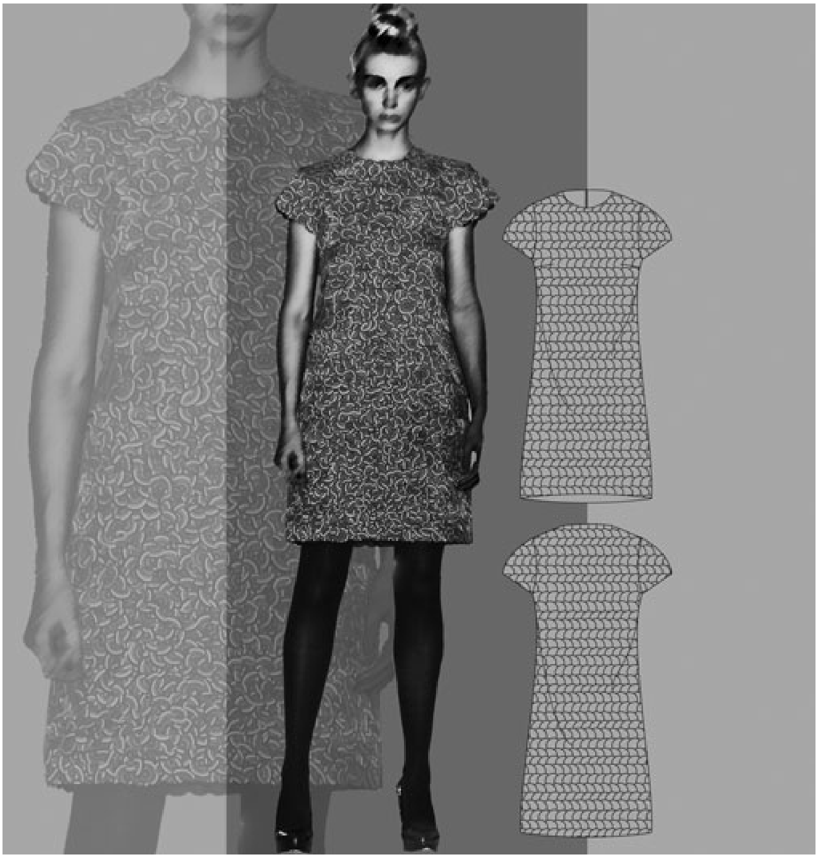
Rei Kawakubo's application of *wabi sabi* and subversive use of new materials and processes has resulted in novel shaping strategies that combine architectural and sculptural features. Kawakubo challenges conventional notions of feminine shape and beauty by creating pieces that orbit the form in new ways. Junya Watanabe has designed for Commes Des Garcons since 1992, creating all manner of shapes. He describes his product as 'techno couture', which he produces by synthesising established and cutting edge design methods.

Many sophisticated hybrid shapes have been designed by the Belgian Six. Helmult Lang has consistently experimented with new materials to cut spare shapes; Martin Margiela's pieces are often based on classic tailoring and narratives around construction and deconstruction; Dries Van Noten's seductive use of textiles often results in minimal intervention with cutting in favour of traditional tunic and wrapped styles, as shown in Fig. 13.8.

At a ready-to-wear level contemporary shapes tend to be configured on a rectangular basis. Donna Karan's DKNY range often features silhouettes that work

13.8 Dries Van Noten (1990s) coat dress hybrid garment shape, incorporating a coat structure which is softened by the use of silk organza (© Townsend 2004).

close, but not too close, to the form. Muicha Prada's Miu Miu label employs 'classic cuts with avant-garde detailing' to create softly structured clothes that work with the body. When shaping remains fairly similar, surface embellishment and the use of 'luxury' fabrics becomes more important, providing 'added value' and an illusion of complexity that is sometimes absent in the garment structure. BA Fashion Design graduate Jenna Harvey (Nottingham Trent University 2010) has exploited this approach by fabricating a shift dress in a 2D/3D textile created through laser cutting digitally printed silk (Fig. 13.9). For A/W 2010 hybrid shapes dominated the 'minimal' streamlined looks created by Hermes, Nicole Farhi, and Celine constructed from matt and patent leather, cashmere and ribbed wool.

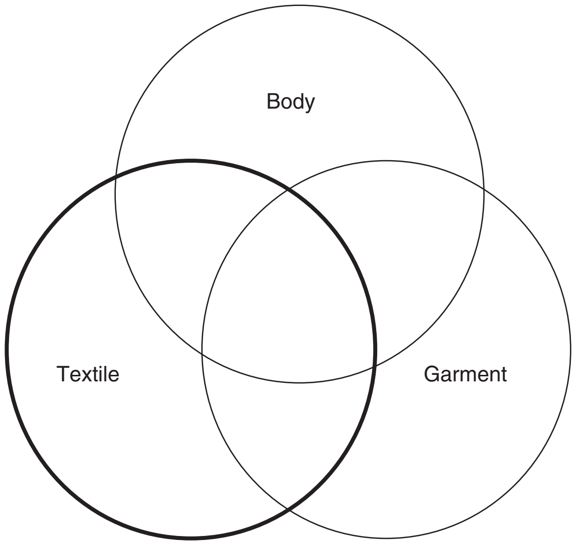


13.9 Jenna Harvey (2010) illustration of shift dress, constructed from laser cut, digitally printed silk (© Harvey 2010).

13.5 Different approaches to textile/garment integration

Throughout history, garments have been created using various surfacing and structuring techniques to articulate the form in different ways. Garments are created using traditional techniques such as modelling on the stand and form, creating flat patterns from blocks, using 2D and 3D computerised pattern design systems and modelling software. Textile design has been used strategically as a device that can positively contribute to fashion, by enhancing the process of iteration. The treatment of a textile through carefully constructed (knitted, woven, non-woven, 3D formed) and surface design techniques (printed, embroidered, manipulated, embellished) contributes aesthetic and financial value to a garment and wearer.

This section discusses three significant design approaches towards the integration of a (2D) textile design and (3D) garment shape: 'textile-led', 'garment-led' and 'simultaneous' (Townsend 2004). Each approach places a contrasting emphasis on the role that the textile, garment or both elements play within the design equation (Fig. 13.10).



13.10 Diagram of body, textile and fashion (© Goulding 2010).

13.5.1 Textile-led

The term 'textile-led' is used generically in the fashion industry to describe garments that are designed to accommodate the characteristics of a particular textile. A textile-led garment is cut with prior knowledge of the appearance, hand and texture of the fabric in which the garment will be fashioned. Many fashion designers are inspired by the textile, and cannot begin to design until they have researched or identified the fabrics for a collection. This initial 2D approach can lead the fashion designer to shape a garment in accordance with the placement, direction or repeat structure of a design. Working with the textile as catalyst can dictate issues such as length, width, fullness, grain and overall style considerations, with cutting edge qualities leading to new approaches to cut and construction: 'Although it seems obvious that textiles are an intrinsic foundation of clothing, the invention, development and manipulation of fabrics has long remained the hidden art of fashion' (Black 2006).

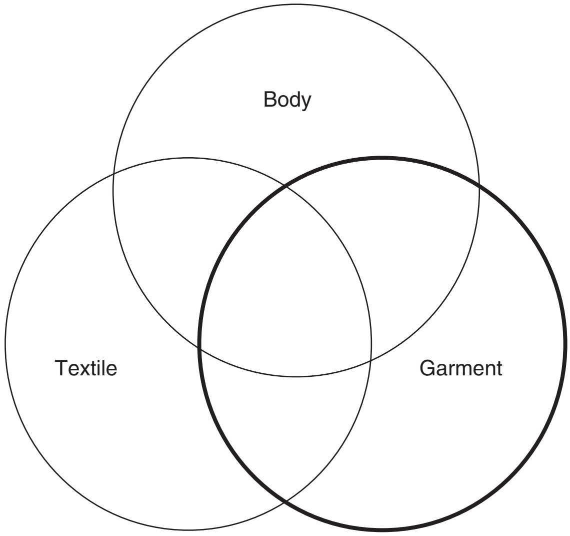
'A pioneer of contemporary fabric design for fashion, Zandra Rhodes passion for the relationship between hand-screen print and the three-dimensional garment has influenced countless designers, from Jonathan Saunders to John Galliano' (Black 2006: 137). Inspired by Asian and Native American textiles, and traditional craft techniques, Rhodes interpreted her drawings as well as the language of knit and stitch, as print vocabulary that worked in harmony with the shapes of her dresses and the bodies that wore them. Her Kaftan with Indian Feather Sunspray (1970) illustrated in Fogg (2006) gives the impression that the feathers are sewn or embroidered onto the fabric with cross-stitch; the structure of the print cleverly echoes the proportions of the form through layers of horizontally placed feathers. Rhodes couture and garment collections for Top Shop reflect a dedication to enhancing the form through the strategic placement of imagery, as shown in Fig. 13.11.

13.11 Zandra Rhodes (2004) textile-led dress design, illustrating the strategic use of a border print design to use the full width of the cloth and emphasise the bust and hem of the garment (© Townsend 2004).

13.12 Tessa Acti (2010) homage to Vionnet digitally embroidered dress.

Dries Van Noten makes no secret of the role textiles play in his collections, which often feature designs incorporating up to five different print or embroidery techniques. Van Noten keeps shaping to a minimum in order to retain the visual integrity of the cloth; 'when the fabrics arrive they are so beautiful that it seems a great shame to cut them up. Perhaps that's why we've always had so many wraparound skirts' (Van Noten in Tucker 1999: 13).

Van Noten has worked with the Swiss textile company, Jacob Schlaepfer, who reinvent historical processes while experimenting with new technology, most recently laser cutting/engraving to create complex visual effects that become the focus of the garment. Jacob Schlaepfer works with many haute couture designers, notably Christian Lacroix, who sees the company as an 'extension of his design studio' (http://www.jakob-schlaepfer.ch/en/). Lacroix's use of sophisticated hand and digital embroideries, fine crochet, knotting and lacework, has resulted in some of the most elaborate textile-led garments on the catwalk. Textile designer and



13.13 Diagram of body, textile and fashion (© Goulding 2010).

researcher Tessa Acti's practice focuses on pushing the boundaries on multi-head embroidery technology. Her Homage to Vionnet dress shown in Fig. 13.12 explores the beauty of thread through extending the digital stitch length to the limit of the technology's capability.

13.5.2 Garment-led (3D-led)

In this section, the term 'garment-led' (Fig. 13.13) describes designs in which the garment shapes are conceived of prior to the surface embellishment, which is originated, or selected to complement these shapes. This approach dates back to the rise of the couture houses that grew up in Paris in the late 19th century, where the couturiers were revered but the artisans who brought their creations to life were often anonymous.

In her book, *Couture: The Great Fashion Designers*, Milbank refers to Balanciaga, Charles James, Roberto Capucci, Piere Cardin and Courrèges as 'architects', who are considered as 'garment-led' designers. Unlike Vionnet and Grès, they did not look at the individual nature of women's bodies, but focused on them as a starting point for their own designs. As Milbank (1985: 318) states: '. . . the clothes themselves have an actual shape, and are more like pieces designed by an engineer than sculptural dresses with no inherent shape of their own. These clothes never look as if they happened naturally, but show what went into them. They celebrate the shape without actually mirroring it.'

Clear parallels can be drawn between architectural and garment-led approaches, as in both cases it is often the construction rather than the fabric of the garment that is the key focus. A garment-led design is generally focused on the shape and volume of a piece, rather than the surface treatment, as illustrated in Fig. 13.14 by fashion researcher and lecturer Maggie Bushby whose innovative pattern cutting

13.14 Maggie Bushby (2010) NCC Harmston Jacket featuring box shaped sleeve detail and skirt with bustle, illustrating a garment led approach (© Bushby 2010).

synthesises investigation into historical tailoring, utility wear and contemporary Japanese influences. One the key shapes employed within her MA collection was the 'box' structure, informed by: 'collapsing industrial structures, the effect created by the drape of the miner's overall over his protective knee pads and modern packaging such as the TetraPak'.

13.5.3 Simultaneous design

The simultaneous design approach discussed here was inspired by the principles of Cubism and the practice of Sonia Delaunay, whose early paintings of Simultaneous Contrasts concentrated on colour and its relationship with form, space and movement. By 1913, Delaunay had designed her first 'simultaneous dress', constructed to echo the proportions, curves and gestures of the 3D female form. She was fairly unique in her time as a designer of both the fabric and the garment; her design ethos stemming from the belief that '. . . the cut of the dress is conceived by its creator simultaneously with its decoration. Then the cut and the decoration suitable to the shape are both printed on the same fabric' (Delaunay in Damase 1991: 58).

Delaunay's design philosophy pre-empted the current objectives of CAD/CAM and rapid prototyping; the symbiosis of geometric-style textile prints, weaves and embroideries with rectangular garment shapes, providing unique examples of a modern integrated approach. As well as considering the 2D graphic aspect, Delaunay considered the 3D form, pre-empting the effect of the textile design on the body (Townsend 2008).

Jonathan Saunders graduation collection from Central Saint Martins resonates with Delaunay's simultaneous style and approach. Inspired by the artist/designer Oskar Schlemmer's 'Means of Transforming the Human Body by Use of Costume' created for the Triadic Ballet (1922), it references the Bauhaus style of 20th-century minimalism. While Saunders subsequent work is clearly influenced by 'the pixilated, intricate markings of advanced computerised printing' he translates his designs using screen printing and is committed to traditional drawing and crafting techniques for originating his designs at full scale (Fogg 2006). CAD is used as a means of working between two and three dimensions, by engineering the 2D graphic within garment pattern shapes that will enhance the 3D contours of the wearer.

'Print for me is not just about decoration – it is much more than that. My clothes aren't about titillated decoration added on as an extra. I have an innate desire to decorate the body, very much in the way of tattooing or body painting. I like to frame the body' (Saunders in Fogg 2006: 81).

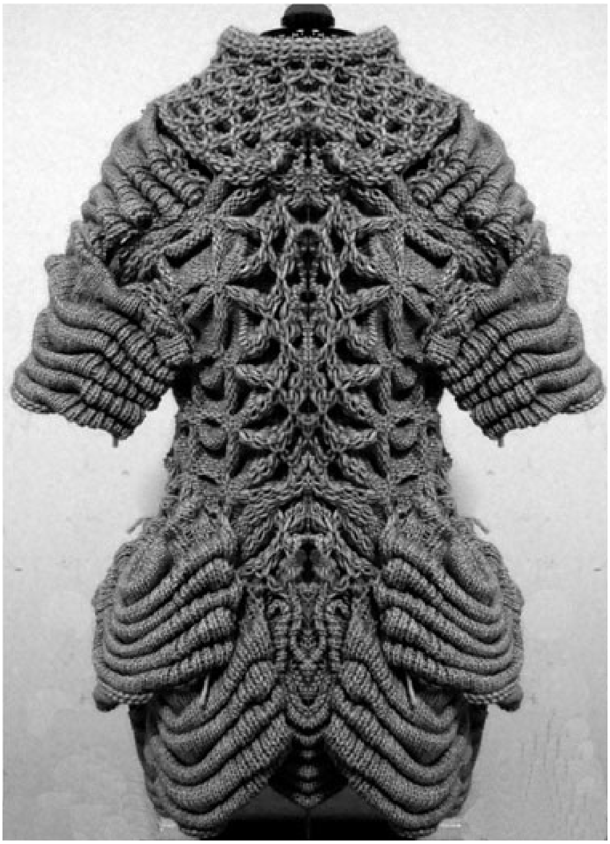
The close working relationship between Mark Eley and Wakiko Kishimoto, has led Eley Kishimoto to create outcomes that consider surface and structural design elements equally. Other contemporary designers whose work illustrates a simultaneous design approach include Emma Cook and Shelley Fox, whose involvement in the textile and garment fabrication process has resulted in holistic design statements. Fashion designer Rosie Legg adopted a simultaneous approach to the conception and creation of pieces for her MA collection (Nottingham Trent University 2010) by combining research into origami-inspired pattern cutting with textiles developed from her own images of contemporary Japanese architecture, taken on a Paul Smith Scholarship in Tokyo (Fig. 13.15). The consideration of the placement of the diagonal, vertical and horizontal elements within the digital prints, challenged the original shapes of Legg's toiles, leading to a reconfiguration of the print imagery in relation to the re-cutting of the 3D garment, to achieve a harmonious equation.

Fashion knitwear design commands a simultaneous sensibility, with practitioners creating both the textile and the product. Louise Goldin and Mark Fast create garments using distinctive textures and volumes that fuse cutting edge Shima Seiki 3D power knitting technology with flat bed knitting. Sandra Backlund's Ink Blot Test collection featured 3D knitted structures that completely informed the mathematical, organic shapes of her final garment forms. Her approach celebrates 'the freedom to be able to make your own fabric while working' on the fashion component (Udale 2008: 69). Japanese fashion and textile designer Motohiro Tanji's Techno Gothic MA collection (Nottingham Trent University 2010) demonstrated a similar principle through garments that appeared to have been grown organically, constructed using knitting and laser cutting techniques, as shown in Figs. 13.16 and 13.17.

13.15 Rosanna Legg (2010) printed dress. Tokyo printed dress, designed using a simultaneous approach to print generation and pattern cutting.

13.6 The garment as canvas

The term 'garment as canvas' describes printed garments that employ clothing as a 3D canvas. A 'canvas approach' describes images or concepts that have been configured specifically within or around the parameters of the garment shape. These are often pieces that 'intersect the disciplines of art and fashion' (Wollen 1999: 7). The practice of commissioning an artist to design textiles for a collection began with Paul Poiret and Raoul Dufy in 1909, whose beautifully composed prints and jacquards raised the profile of the textile designer. In the 1930s Schiaparelli commissioned artists to design prints for her collections using the dress as a frame for an



13.16 Motohiro Tanji (2010) textile-led knitted garment from MA Exposition, Nottingham Trent University (© Tanji 2010).

illustrated narrative. The Tear Illusion Dress (1938) featuring a print designed by Salvador Dali represents an early use of surreal imagery in fashion.

Artists Robert Rauschenberg and Andy Warhol explored the potential of clothing as a vehicle for photographic imagery (Biennale di Firenze 1996). Fashion designers have used graphic software to transform garments into theatrical, memorable pieces, as illustrated by Jean-Paul Gaultier's Cyberbaba collection 1996, when he transposed *trompe l'oeil* prints of male torsos onto women's garments. Printed fashion designer, Charlotte Allen translates her drawings using Adobe Illustrator and Photoshop, then digitally prints them onto classic, minimally cut shapes that frame the curious Gothic objects within the garments as shown in Fig. 13.18.

The printing of tee shirts in the 1960s marked the invention of fashion's most enduring canvas; the synthesising of image with text, resulting in a new articulation of the form as a walking advertisement. In the late 1990s Sarah Caplan reinvented the 'paper poster dress' of the 1960s by transfer printing photographs of New York onto simple A-line dresses made of Tyvek. Harry Gorden's 'Eye' Paper Poster Dress (1968) was one of the original examples of this art form, the simple A-line shape allowing the photographic-style imagery to dominate the composition. The

13.17 Motohiro Tanji (2010) laser cut garment from MA Exposition, Nottingham Trent University (© Tanji 2010).

exhibition RRRIP!! Paper Fashion (2007), first shown at MoMu, Antwerp, illustrated many other graphic and conceptual garment fabrications using paper.

Since 1993, Issey Miyake's Guest Artist Series has enabled artists and photographers to explore the artistic potential of his Pleats Please collections, through a range of contrasting image-making processes, as shown in Fig. 13.19. Hussein's Chalayan's ethereal Buried Dress (1993) touched on issues of mortality, through the patina of age and erosion accrued following the act of burying the garment with iron filings. In 1999, Alexander McQueen's used a garment literally as a canvas, by spraying it through 360 degrees on the model (Wilcox 2001: 101).

13.6.1 Digital intervention

CAD/CAM technology enables designers to approach a garment as a both a 2D and 3D canvas. Firstly, the use of computer graphic software encourages a compositional approach to be adopted towards textile/garment design, enabling designers to combine a range of concepts and perspectives within a single form. Secondly, the

13.18 Charlotte Allen (2009) printed jacket illustrating canvas approach developed for Bolongaro Trevor A/W 2010 (© Allen 2009).

use of integrated CAD enables textile and garment designers to visualise and design a textile and garment shape in relation to the form. Katherine Townsend's research into the simulation of draped and pleated effects as new textile imagery, illustrates how volume and movement can be integrated into a simple shape, such as a circle, through the combined use of scanning, draping grids and inkjet printing (Plates XII and XIII between pages 166 and 167). Basso and Brooke's 2010 exhibition at the Design Museum illustrated the potential for creating surreal imagery on garments, by digitally engineering and mirroring effects.

The use of digital projection onto garment and body forms has resulted in new approaches to surface design encompassing transient imagery. Vicktor and Rolf's autumn/winter 2002/03 collection used panels of Chromatte 'blue-screen' fabric within garments that were digitally animated with moving images of fish, cities and landscapes which animated the garment. Hamish Morrow's Digital Echoes collection (2004) explored the concept of virtual textiles in conjunction with the human form. Working in collaboration with the textile designer/researcher, Philip Delamore, image-makers Warren du Preeze and Nick Thornton-Jones and United Visual Artists

13.19 Issey Miyake Pleats Please garment with traces of dragon firework trail burnt onto the garment (© Townsend 2008).

(UVA), Morrow extended the boundaries of digital print, by exploring it in three dimensions and real time (Black, 2006: 130).

The research work of Rosemary Goulding embodies experimentation with 2D textile designs and the 3D form of the body. Pattern cutting techniques evolved from craft practice demand knowledge and understanding of the visual dialogue between the body and the fabric that covers it. Both manual and computer-aided design techniques require aesthetic judgements within the creation of new ideas for draping and shaping. Her digital projections incorporate drawings and technical graphs from the NTU School of Art and Design Lace Archive, through the visualisation of mark making on the surface contours. The transposition of the 2D drawings historically used in lace design and production, fuse with the body, challenging the boundaries of the traditional and virtual, within a visual narrative. The passage of light onto the 3D surface of the model creates new compositions, affording creative spontaneity as the patterns and codes are transformed (Fig. 13.20).

13.20 Rosemarie Goulding (2009) body, skin and lace, digital projection (© Goulding 2009).

13.7 Sustainable design approaches

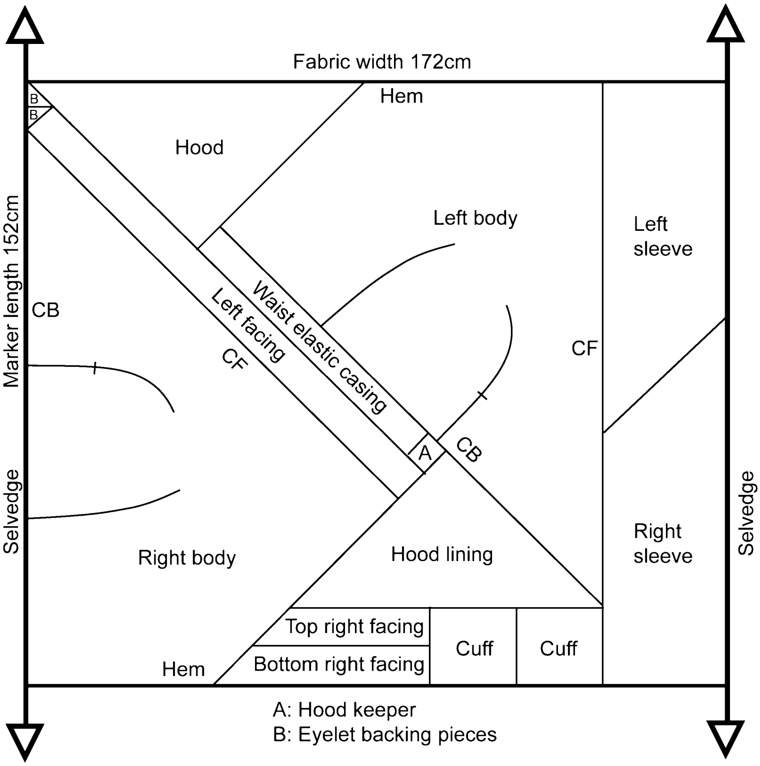
Recycled, up-cycled and no waste approaches are changing the way fashion is perceived both on and off the body. The sourcing of materials from pre-consumer and post-consumer waste streams is influencing the ways that designers think about *designing*. The 2D textile is no longer only available as a continuous bolt of cloth, but can take the form of off-cuts from factory floors, worn or unwanted garments destined for landfill. This section discusses some notable approaches that embrace 'cradle to cradle' thinking by encouraging the fashion and textile industry to rethink the 'the way we make things' (McDonough and Braungart 2002).

13.7.1 Minimum waste

In *Green Fashion: Why now*? Timo Rissanen discusses 'Creating Fashion without the Creation of Fabric Waste' (Hehorn and Ulasewicz 2008:184). Rissanen's research focuses on designing out waste through creative pattern cutting and production methods. He acknowledges that 'cut and sew' is the most popular approach, whereby garments are cut out using pattern lay plans on lengths of cloth. The average waste is between 10 and 20%, depending on surface design continuity or repeat matching, with plain or textured textiles yielding the least waste. Rissanen presents three broad methods that can improve upon this situation: 'fully fashioned', encompassing whole garment and integral knitting and weaving; 'A-POC' (developed by Miyake and Fujiwara) enlisting similar technologies, and his own 'jigsaw puzzle' design approach, which refers to cut-and-sew that wastes no fabric (Ibid. p. 187) (Figs 13.21 and 22).

13.21 Timo Rissanen (2008) 3D Zero Waste hooded top (© Rissanen 2008).

‘To create a zero-fabric-waste garment, one attempts to create these interlocking pieces within a two-dimensional whole and then cuts them out to make a three-dimensional garment. The aim is to simultaneously design (1) a set of garment pieces that take up a given length of fabric in two dimensions like the pieces in a finished jigsaw puzzle and (2) the garment in three dimensions (Ibid. p. 185).’



13.22 Timo Rissanen (2008) 2D jigsaw pattern design (© Rissanen 2008).

Moving towards minimum waste production is leading to innovation in the way a garment is designed and cut, which is becoming more strategic; the lay plan is a complex problem to be solved pragmatically *and* creatively. Working back from the whole cloth in a reversed jigsaw approach requires that the designer, in line with other 'green' approaches, is altruistic. The relationship between the textile and the silhouette is strategic; the fabric informing shapes and volumes that are empathetic to the qualities and quantities of cloth. The silhouette may therefore be determined by utility as well as trends, resulting in the repetition of key shapes over a number of seasons by adapting patterns to be re-interpreted using different fabrics, saving on production and material costs.

The 2D to 3D Research Group in the School of Art and Design, Nottingham Trent University, have also explored minimum waste design approaches using knitted, digitally printed and embroidered textiles as a starting point. As well as pre-programming power knitting and jacquard weaving technology to produce bespoke 3D outcomes, researchers have explored the potential for using 2D digitally printed lengths in their entirety. This has been achieved by draping and manipulating fabrics directly on the form, in a return to the classical styling of the Greek chiton and the geometric cutting of the Japanese kimono, which both traditionally utilise the whole cloth.

13.23 Martin Margiela (date) foil printed and painted vintage petticoat and jacket (© Townsend 2008).

13.7.2 Recycling

The outerwear designer Christopher Raeburn's strap line 'Remade in England' cleverly reflects his magpie technique of sourcing and deconstructing army surplus uniforms and products such as parachutes, which he redesigns into contemporary parkas and jackets constructed from multiple panels. The ethos of patch working new and vintage fragments of cloth together has been a recurring theme in fashion, which can be traced back centuries and was practised through necessity (christopherraeburn.co.uk). The re-appropriation of tailored garments, details and fabrics is a significant element of deconstructed fashion as practised by Martin Margiela who has consistently recycled found materials to create new garment concepts. In 1991 he made sweaters from military socks; in A/W 2005–06, exact replicas were made of found vintage garments; in S/S 2006 vintage sandals were fashioned into a jacket and a top was constructed from vintage leather gloves, which cleverly uses 3D accessories to create a 2D fabric. Figure 13.23 shows vintage garments 'frozen in time' by Margiela's treatment using the foil printing process (Debo 2008).

Orsola de Castro's label 'From Somewhere' perfectly illustrates the potential for utilising pre-consumer designer waste from Italian CMT units in Italy. The garment structure is determined by the size of the off-cuts; the use of panels resulting in signature pieces where the most exclusive fragments are framed in the centre front of the garment. De Castro initiated Esethica, the first sustainable fashion forum at British Fashion Week. Now in its fifth year, the area showcases a growing group of designers including Junky Styling. Formed in 2000 by Annika Sanders and Kerry Seager the London label has always favoured 'old men's suits' as the basis of their raw materials, but their creations belie the original identity of the suit by challenging the traditional image of how it is worn (Sanders and Seager 2009: 85). The company list 17 possible new styles that can be made from the suit jacket, with the Full Jacket Dress one of the most striking (Ibid. p. 102). The relocation of garments cut for one part of the body to another, subverts the traditional role of the 'suit' and how it works as a 3D object to enhance the body.

13.7.3 Up-cycling

Up-cycling is different from recycling, in that it involves the customisation of an existing garment or product, as opposed to the re appropriation of materials to create a new product. Rebecca Earley is a well known advocate of up-cycling, which she has championed since the early 1990s through pieces like Lace Dress (1994), created through the application of a heat photogram process in association with worn garments. Derived from photography, the technique allowed her to use 2D objects as masques to transfer print directly onto fabric at a scale of one-to-one. The resulting pieces featuring ghosted images, often of, or on vintage garments, re-conceptualised the relationship between the 2D textile and 3D garment and body, with the viewer being forced to re-think the notion of the physical and *trompe l'oeil* forms of representation (Townsend 2008). Earley continues to push the creative boundaries of upcycling used garments, sourced from various waste streams through AHRC funded research projects such as 5 Ways (Fletcher 2008) Ever and Again (Fig. 13.24) (Earley 2007) and Top 100 collection (beckyearley.com).

The reinterpretation of iconic silhouettes and textile patterns has always pervaded fashion, but the re-using and enhancement of discarded garments and the worn qualities associated with them has influenced how we perceive, value and redesign using 'waste' materials. The sustainable approaches listed above demonstrate how the resourcing and conserving of textiles as a valuable commodity is changing the way garments are made, look and work with the body. A new aesthetic is emerging whereby silhouette is determined by creative pragmatism, leading to new trends based on longevity and values that reach beyond seasonal parameters.

13.8 Future trends

The relationship between 2D textiles and 3D garments is changing as designers embrace smart materials and technologies. The integration of electronics, smart textiles, biotechnology and new environmentally friendly yarns and fabrics are forming a new technological landscape.

13.24 Rebecca Earley (2008) Ever and Again top (© Earley 2008).

Innovations such as nano technologies are challenging the ways in which we think about the unity of the body, the textile and the shape of a garment (or product). Biodiversity patterns are being simulated as designers use the principles of biomimicry to inform new organic textile and garment concepts, as explored in 'Suicidal Textiles' by Carole Collet and Sir John Sulston as part of the Nobel Textile project in 2008 (www.textilefutures.co.uk). Ethical design considerations are superseding aesthetics, as biodegradable polymer fibres replace resource-hungry 'naturals' and closed loop production systems become more feasible (Pittman and Townsend 2009). The functionality of garments is being enhanced through the use of intelligent substrates and embedded technologies, contributing to the physical and psychological wellbeing of consumers.

Wider use of body scanning, 3D CAD and rapid prototyping (garment) technology, has encouraged developments in mass customisation, enabling companies to produce 'one-off' pieces on a made-to-measure basis. Hamish Morrow was one of the first designers to experiment with this approach through his Digital Couture jeans label in Selfridges. 3D printed garments and products have been explored by Dutch designers Freedom of Creation, who experiment with the potential for synthesising 2D and 3D approaches. Paco Rabanne predicted that in the future clothing could evolve as an aerosol to spray on the body, a concept developed by Manel

Torres as the 'spray-on dress' with the company Fabrican (Lee 2005). The ultimate simultaneous garments are those 'grown' by Suzanne Lee for her Biocouture label, where a skin-like surface is cultivated from bacteria in laboratory conditions into futuristic fashions (www.biocouture.co.uk).

The integration of flexible wearable technologies with textiles has resulted in unique modes of communication and new dialogues between light, movement and sound giving rise to radical propositions and creative possibilities. Jane Harris's search for 'beauty in the computer graphic beast' resulted in installations such as Potential Beauty 2002–03 which presented a fashion or body-related idea as an art statement, created through a dancer wearing motion capture sensors (Harris 2005). Wearable Futures (2004) explored the potential for embedding technologies into garments to facilitate interactive functions such as the displaying of LED illuminated messages. Clothes continue to be developed as a key interface for giving graphic expression and form to wearers' moods (Lee 2005). Screen Dress (2007), an interdisciplinary design and performance piece developed by Michèle Danjoux (fashion) and Jon Hamilton (motion graphics) explored the relationship between motion graphics and dress (Townsend 2008).

Digital technology has facilitated new ways of displaying images of light, besides projection. Hussein Chalayan's collaborative work with interaction designer Moritz Waldermeyer resulted in a video playing dress for A/W 2007–08 and another incorporating multiple laser lights for S/S 2008. The latter comprised 15,600 light emitting diodes (LEDs) and Swarovski glass crystals displaying landscape images, so that according to Chalayan: 'the bodies themselves became the seasons' (Jacobs 2008: 256). Anke Jacobs Alienated Body series points towards the growth of the role of light and digital images within textiles and the built environment where light is used like a 'virtual cloth' wrapping around either the human or architectural body, covering its skin with exuberant patterns and colours. In terms of 2D/3D explorations in fashion and textiles, Issey Miyake has the last word on 'Future Beauty' with his '1 3 2 5' collection (2010). Fabricated from polyester pressed with metal foil, the origami style cloth sculptures form a carapace around the wearer, then can be collapsed to settle as octagonal, relaxed shapes (Fukai *et al*. 2010).

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Plate X Akihiko Isukura: natural weaving and dyeing, silk coasters, 2010 (Image courtesy of Nottingham Trent University. Photography: Debbie Whitmore).

Plate XI Jo Cope (2008) yellow coat (© Cope 2010).

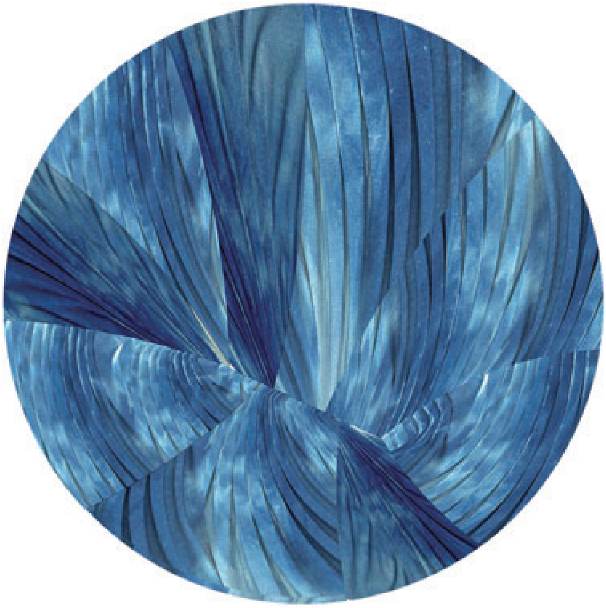

Plate XII Katherine Townsend (2004) 2D circle contour prototype (© Townsend 2004).

Plate XIII Katherine Townsend (2004) 3D digitally printed skirt prototype (© Townsend 2004).

14
The design of technical textiles

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Abstract: Technical textiles has become a distinct area of research and development over the past twenty years, placing its emphasis on the functionality of a fabric rather than its aesthetics. With an annual growth rate of between five and seven percent, the sector continues to expand, offering new opportunities and challenges to existing businesses, and underpinning innovations in many other fields. This chapter outlines the sector according to current industry classifications and highlights advances at different scales of application, as they are led by materials, processes, and design concepts. It reflects on the design processes at work, provision for technical textiles in education, issues facing the sector, and finally, promising directions for the future.

Key words: technical textiles, industrial textiles, performance textiles.

14.1 Introduction

The term 'technical textiles' covers a huge range of industrial and smaller scale activity, from chemical engineering to fibre processing, fabric finishing, construction and joining technologies. It indicates an explicit emphasis on the properties of a fabric with regards to specific end uses over and above aesthetic considerations, and expertise in this sector increasingly underlies innovation in other economic and cultural domains. While the industrial history of textiles has been well documented, the recent growth in such trends as nanotechnology, biomimetics and smart materials, and an increasing realization of the economic importance of technical textiles, has led to a need to describe this new field of highly engineered and multidisciplinary textile activity.

Fibres themselves may be of a wide range of materials, such as naturally sourced cotton, flax, wool and silk, and familiar synthetics such as nylon and polyester. However, as textiles are also sourced from less obvious materials such as glass and carbon, a debate remains around the very definition of the term 'textile'; indeed, the industry has origins in several different technologies including that of paper[1] (Byrne 2000). Originally meaning a fabric produced by weaving, *textile* has come to cover a broad spectrum of knitted, felted and foamed fabrics in addition to all kinds of lace, nets, yarn and cord. Taylor (1993) holds that the defining feature of a textile is its flexibility, but even this is now in contention as FINA (Fédéracion Internationale de Natation), the regulating body for swimming, debates criteria for competition

[1] Paper technologies have brought wetlaying and pulping processes to technical textiles; wetlaying may be used with other raw materials, for example viscose, and underpins the huge non-wovens industry.

level swimwear, which combine a number of properties to optimize their movement through water. As it stands, the body has ruled that 100% polyurethane suits are not 'an allowable textile' and are being banned from January 2010 (BBC Sport 2009). Simultaneously, the industry terminology 'flexible engineering materials' is sometimes used to make clear the inclusion of, but not restriction to, obviously textile-derived forms of material, process or product.

With a world market estimated at $120 billion in 2010[2], and an annual growth rate of between five and seven percent[3], the technical textiles sector continues to expand, and has the potential to be a lifeline for those traditional textiles companies hit by global changes in supply chains who are willing to embrace new skills and development. Innovation has become increasingly important for the industry to survive and prosper, and as it does so, it is creating new products and markets, and intersecting with a wide range of other disparate sectors. As a result, textiles have a role to play in such diverse areas as healthcare, security, aerospace, communications, transport and the energy industry. Flexibility and softness are often cited as the key benefits of textiles in innovative products, but these are not the only characteristics that are driving growth: a high strength to weight ratio, the existence of mass production infrastructures, and the ability to take functionality-changing coatings or to become a structural part of new composite materials are also crucial.

This chapter will give an overview of technical textiles and their interrelation with other sectors. It will attempt to give a rich account of current trends and provide the necessary resources for the interested reader to learn more. Section 14.2 will provide an outline of the sectors involved, attempting to sketch a picture for the reader of the complexities and opportunities of the technical textiles supply chain, and the different design processes at work. Section 14.3 will then reflect on scales of application and highlight some notable innovations and directions. Section 14.4 then deals with problems facing the industry today, leading into an account of how technical textiles are being provided for in the UK education system (14.5) and future trends are outlined and anticipated (14.6). The chapter finishes with a selection of resources for further reading and information.

14.2 Sectors using technical textiles

Because technical textiles are defined by their design for specified end uses (The Textile Institute 1994), the sectors that they support are extremely varied, with more markets and cross-sector research being sought all the time. TechTextil (2009), the leading international trade fair serving the industry[4], continues to group these sectors under twelve headings, which have become something of a standard. These are as follows:

[2] Source: IFAI 2010.
[3] Source: Jean Francois Bracq, CLUBTEX, in FuturoTextiel (2008, p. 79).
[4] TechTextil has run biennially since the late 1980s, and has been hosted by Frankfurt, Osaka, Moscow and Delhi, extending in 2009 to include an annual North American event, alternating between East and West coasts.

Agrotech: includes woven and nonwoven crop protection covers; capillary matting; land netting; fishing ropes; fishing nets; fishing line and baler twine; forestry.

Buildtech: covers tarpaulins; textile structures; awnings; roofing felts; sewer linings; woven roofing; roof scrims; housewrap, shingles and hoardings; scaffold nets; concrete reinforcement (fibre and scrims); composites.

Clothtech: includes woven/knit, nonwoven interlinings; waddings; laces; shoe components; sewing threads; hook and loop fasteners; zips and other fasteners; labels.

Geotech: involves ground stabilization; soil reinforcement; pit-linings; erosion control.

Hometech: includes woven/knit, nonwoven wipes; vacuum filters; HVAC filters; pillow tickings; mattress tickings; mattress components; spring wrap; spring insulators; platform cloths; dust cloths; fibrefill; furniture components; webbings; curtain tapes; woven and nonwoven primary and secondary carpet backing; carpet ground yarns; sewing threads; composites.

Indutech: the third largest application area in both volume and value terms with a market share of approximately 15% (fibre2fashion.com 2009a); includes textile materials for industrial non-apparel and non-decorative uses such as conveyor belting; hoses; drive belting; brushes; battery separators; other electrical goods; abrasives; PCBs; other electrical composites; woven filters; cable components; nonwoven air, dust, liquid, other filters; cigarette filters; paper-making felts; woven/knit, nonwoven wipes; seals and gaskets; fibrefill; anti-corrosion composites; lifting webs; ropes; silos; oil booms; other coating substrates.

Medtech: includes woven, nonwoven gowns and drapes; woven/knit, nonwoven woundcare; sterile packaging; medical mattresses; coverstock; cotton wool; wipes; hygiene products.

Mobiltech: covers car, CV tyre cord; drive belt; hose; cabin filters; seat belts; air bags; tufted, needled carpet; carpet backing; woven and knit, nonwoven trim; upholstery; insulation; truck covers; tiedowns; ropes; marine composites; in automobiles, railway, shipping and aerospace industries.

Oekotech: deals with innovations with an ecological drive such as in waste disposal and recycling, and has the fastest growth rate of the twelve categories at about 7%. It includes housewrap; erosion control; pit linings; woven filters; nonwoven dust filters; automotive insulation.

Packtech: includes flexible intermediate bulk containers (FIBCs); laundry bags; sacks; twine; teabags, food soaker pads; other nonwoven packaging; netting; fibre strapping; other woven packaging.

Protech: involves fire retardant (FR) and nuclear, biological or chemical (NBC) protective systems; cut/slash, ballistic, dust, disposable chemical, durable chemical protection; foul weather clothing (FWC); face masks; hi-visibility; harnesses and other products for personal and property protection.

Sporttech: covers boat covers; bookcloth; shopping bags; sports bags and luggage; leather substrate; sailcloth; artificial turf; ropes; nets; balls; flags; air-sport fabrics; tents; sleeping bag fill, fabrics; webbing; equipment composites. Sporttech is, perhaps surprisingly, one of the smallest groups in terms of volume, but due to high unit values and use of expensive fibres and coatings, it is the second largest in value terms (Fibre2fashion 2009c), and provides valuable levels of cultural visibility.

Other generic terms sometimes used to encompass these textiles include 'industrial textiles', more usual in the USA, 'performance', 'functional', 'engineered' or 'high tech' textiles. There tends to be no particular differentiation between these, although they may be found more commonly according to the application sector describing them – for example, 'performance textiles' is commonly used by businesses in the Sporttech cluster, and categories continue to evolve from their early origins within historically separate manufacturing sectors (Byrne 2000).

14.2.1 The industrial technical textiles design process

From initial need to new material

Individuals working in the industrial technical textiles sector tend to have come from an engineering, chemistry or materials science background in which design is entirely needs led. Practitioners trained in art school environments may be used to a design process in which their own creativity is emphasized, often resulting in beautiful fabrics, but in the industrial design process, this creativity is spread across disciplines and organizations, with new products driven most often by customer demands. These may be to modify an existing product to meet new safety or production regulations, to further optimize production costs or savings to an end user, to solve problems emerging when the product is in use, often in extreme conditions, or to create a market position through improvements and differentiation.

A case study highlighted by Scott & Fyfe (2003) details how this business-to-business relationship operates as a design process, approached initially to prepare costings for the production of a polyester braided tube, Scott & Fyfe drew on their experience with raw materials and conversion techniques, delivering a prototype knitted tubular structure which exhibited better performance characteristics than specified by the client. To put this into production as a cost-effective proposition, the company then had to make capital investment in new machinery, the view being that the client had opened new market possibilities for them in which they could contribute depth of experience.

Many technical textiles companies have either first-hand knowledge of their specialist domains (examples include Vascutek, creating embroidered vascular and cardiovascular products, which emerged from research across three institutions – Coats Paton textile technology, Strathclyde University Bio-engineering, and the Glasgow Royal Infirmary clinical output, while Picasso Racing Components, specializing in tailor made composite components, originated with its owner's continuing involvement with motor sport), or continue to develop very close relationships with clients in order to develop not only successful products, but the materials and production processes that make them viable. Vascutek, for example, is also an ISO 9001 approved facility for original equipment manufacture (OEM) to the medical textiles industry, and Coriolis Composite are now commercializing fibre placement systems which use robotic cells and software, and which will serve the aerospace, boat construction and wind turbine industries (Butler 2009).

Aesthetic appropriation

Of course, materials developed in this way quickly come to symbolize progress, modernist ideals and optimism. Styles and patterns in the 1950s took their lead from the general mood of scientific invention, creating futuristic interiors, and by the 1960s, with the Space Act requiring NASA to make its developments available to industry, there began a process of familiarization with the materials and finishes themselves. Discoveries resulting from the space programme, including Teflon, could now be licensed for use in everyday objects and other specialized areas like medicine (McCarty 2005). As McQuaid says, 'high-tech, high-performance products with lightweight, reflective, metallic, and durable properties are now common to us' (2005 p. 156). Conceptual fashion designers make use of new materials for their wider associative meanings as much as for their inherent expressive properties, but in the process, introduce a wider public to a new visual language, which may become further appropriated by sub-cultures. Projects include the early use of lightweight fabrics in casual sportswear, Shelley Fox's use of architectural non-woven fabrics, and NBCs (nuclear, ballistic and chemical resistant fabrics) utilized by Vexed Generation. Product designers appropriate scaled-down processes to incorporate new materials into interior products, and through the trend of high profile 'name' designers, give them a wide-reaching impact on the public consciousness. Examples would include Marcel Wanders' Knotted Chair, which uses a carbon-aramid hybrid fibre in a macramé structure hardened using an epoxy resin, and Ross Lovegrove's carbon fibre Gingko table (Braddock-Clarke and O'Mahoney 2005, McQuaid 2005, FuturoTextiel 2008).

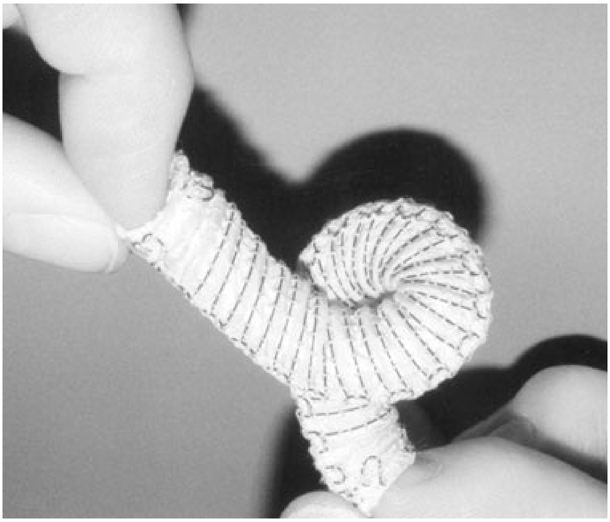
14.3 Recent innovations and directions in technical textiles

This section organizes its overview of technical textiles in two ways: first, by scale of application from the body, through the lived environment, to the geographical, and second, by sources of innovation, from raw materials through production techniques to, finally, design concepts. In this way it is hoped that what are sometimes abstract technological developments may become more accessible to textile designers coming to the field from a broad range of practice-based contexts.

14.3.1 Scales of application

On the body

The safety industry is concerned with everything from visors to full body suits, and is interested in protection against extreme temperatures, chemicals and bacteria. Passive reactive coatings can act as a warning system, while composite layers protect against ballistics and intense heat. Sanitary products account for one of the largest textile markets in the form of nonwovens: designs can involve many layers of textiles with different properties to create an effective composite product. To give an example, the Ambaba nappy has a slim-fitting absorbent inner made from natural and organic fabrics such as hemp, bamboo, nettle and cotton: these fabrics have inherent antibacterial and anti-viral properties that inhibit the bacteria responsible for nappy rash (NESTA 2009). Medical textiles includes all soft furnishing and



14.1 Embroidered stent; Ellis Developments Ltd.

uniform products for hospitals, and is subject to stringent specifications as busy environments are controlled as far as possible for the exclusion of bacteria. The antimicrobial properties of silver and bamboo, for example, are being exploited in the design of hospital curtains and staff coats. In some products, the silver is bonded permanently to the fibre, which can then be woven as normal, meaning that the antimicrobial agent is active for the life of the product (Toray Textiles 2009). In dressings, bio-active textiles are now being explored, made from chemically altered polymers from mushrooms, algae or insects to speed up the healing process of wounds (FuturoTextiel 2008). Recent trade exhibits have emphasized comfort in such products, echoing 'Huggy Care', a conceptual garment developed by Marina Toeters and knitted entirely from golden yellow antimicrobial silver fibres (Toeters 2009).

Meanwhile, the internal body is fast becoming established as a specialized area of application with the realization of embroidered scaffolds for *in vitro* tissue growth (Ellis Developments Ltd 2009, Zhao *et al.* 2009) and the development of stents created with embroidery and shape memory alloys (SMAs) (Fig. 14.1) (Anson 2008). Over two thousand of these stents have now been successfully implanted, while a range of forms has been developed for the treatment of aortic aneurisms. SMAs have also been integrated into weaves to treat blood clots (Anson 2008) and research is currently underway to test promising bonding methods towards automating production. Vascutek Ltd is analyzing the benefits of adhesive bonding and ultrasonic and laser welding, where previously ring stents have been hand sewn onto the polyester fabric (Materials World 2008).

Of course, at the human scale, factors affecting psychological reception come into play, such as handle and texture, and these too can be engineered for comfort. These factors are particularly important in sports applications, where the psychological dimension can have a significant impact upon performance (Stegmaier *et al.* 2005). Some of the fundamental issues for sportswear and performance clothing include maintaining thermal balance through the control of radiation, convection, conduction and evaporation. The fibres most commonly used are wool, for its warmth and resilience; down, because of its fineness and large surface area, which traps air; and synthetic fibres which mimic the properties of down. These include synthetic wadding, textured yarns, hollow fibres, micro fibres, fibre pile and Polarfleece. The insulating benefits of these may, however, be reduced by external conditions as wind and moisture will displace trapped warm air. To be resistant to the elements, fabrics may be either tightly woven or coated and laminated, but to allow vapour transmission, waterproof breathable fabrics are constructed to allow smaller vapour molecules to pass through while barring larger water droplets. The UK company Finisterre has successfully developed new fabrics for outdoor sports with increased durability and breathability combined with waterproof characteristics through the study of fur physiology. By mimicking the fur density of an otter, for example, a fabric can repel water on its outer face while the inner face remains dry (Podkolinski 2009).

The term wicking refers to the ability of a fabric to transport moisture either in a horizontal or a vertical plane, and for this, synthetic fibres are generally preferred. Because of its particular relation with fashion and related channels for adding value, sport provides a rich ground for inspiration and the motivation to explore new markets for functional textile solutions (Salazar 2008, Shishoo 2005); the Italian label Prada, for example, is well known for making a feature of its use of technical textiles in its diffusion Sport line. Significant advances are being made where the integrated nature of the design problem is recognised, and where different partners mine their expertise in specific textile domains to compare approaches. The European ConText project brings together weaving, printing, lamination and embroidery to identify the most promising techniques to monitor electrophysiological activity from the body in as unobtrusive a way as possible (ConText Consortium 2008). Projects like this are able to bring the state of the art product manufacturing processes to bear on the production lifecycle of complete electronic textile circuits, including antennae, sensors, busses and buttons, and can exploit techniques such as ultrasonic welding, laser cutting and computer guided sewing to resolve design issues (Möhring *et al.* 2006). The third newsletter of the project includes plans to develop a hockey hit analyzer as a potential commercial application of this research (Fig. 14.2) (ConText Consortium 2008).

Lived environment

Trends in interiors include the use of optical fibres and inflatable structures to create soft and responsive domestic products. Recent prototypes include a lamp mixing Jacquard woven wool, linen and PMMA (polymethyl-methacrylate) optical fibres to produce a fluid form and soft glow (FuturoTextiel 2008). Other designers are encapsulating textiles in resins to make furniture, or using carbon fibre (Fig. 14.3) to explore extreme forms which would be otherwise impossible to realize (Design Museum 2007).

Flexible composites are a group of materials that have developed as a result of specific requirements in the aerospace industry. The failure of a ceramic heat shield

14.2 Hockey hit analyzer; ConText project.

14.3 Carbon fibre. Image supplied by Teaching Resources Ltd (www.mutr.co.uk).

on the Columbia Space Shuttle in 2003 led to a search for a flexible lightweight structure that could withstand the extreme temperatures experienced by the craft on re-entry to the earth's atmosphere (Giovangrossi and Adami 2009). Related research uses thin silk films as templates on which to incorporate inorganic nanoparticles, forming strong and flexible composite structures that have unusual optical and mechanical properties (AZoM 2009), while exciting conductive materials are also being developed by growing multiwalled carbon nanotubes on a patterned silicon substrate, which can be later peeled away. The flexible composite produced by this method can withstand extreme tensile and compressive strain while retaining its electromechanical properties, making it useful for strain gauges, tactile and gas sensors, and as flexible field emitters (Jung *et al.* 2006). The researchers are now investigating applications in thermal management, gas sensors, and portable display devices (Sealy 2006).

Carbon fibres are also being mixed with plant fibres to build strong, lightweight automotive forms with improved ecological credentials (Fig. 14.3). The Eco-One car has tyres made of potato and cornstarch, while its bodywork is composed of jute, hemp, beetroot fibres and glass fibre. While these raw materials at first sound far removed from the high performance demands of the automotive and aeronautics industries, both academic research and commercial innovation consistently demonstrate the important wider impact of the principle of an improved weight to strength ratio (McCarthy 2009). The new Boeing 787 Dreamliner is the first airliner in the industry to be built extensively using composite construction, with composite reinforced plastic sections in the wings, the tail and fuselage. This gives a 20 percent increase in fuel economy, thereby dramatically reducing fuel costs and carbon-gas emissions (Krebs 2007). Performance textiles in competitive sports like swimming and yachting have demonstrated to the public consciousness the powerful cumulative effect of incremental improvements in design for competitive sports, and of course the same holds true for other sectors such as the automotive industry (Bennett 2009, Technical Textiles International 2007). Any reduction in weight leads to reduced fuel consumption and emissions not only for individual vehicles, but across commercial transport fleets. General Motors decision to use a composite in its C/K Truck fender lowered the vehicle weight by thirty pounds, leading to savings of an estimated 5.8 million gallons of fuel over the projected life of the fleet (Krebs 2007). Further, reduction in weight can lead to lower costs for transporters through a higher loading capacity (Bachstein 2009), and as fibre reinforced composites are resistant to corrosion, weather and UV light, vehicles suffer less damage and so have an extended lifespan (Bachstein 2009).

Where traditional textiles can be very absorbent, and so suffer from distortion over time, textiles developed for tensile membrane architecture may be pre-stressed at the rate of one metric tonne per metre to give improved lifespan and dimensional stability (Textile Architecture 2009). Fibres for textiles in tensile structures can also be environmentally produced and form part of an extended product lifecycle with few harmful emissions. An example attracting interest in the United States currently is Kenafine, made from a plant fibre traditionally used to make cording in Asia and Africa, and now to be found in insulation, animal bedding materials and decorative fabrics. Used in textile architecture, Kenafine has a lifecycle of about six years, after which it can be recycled as paper products with fewer harmful emissions than the wood pulp paper making process (Bealer Rodie 2009). Tensinet is an example of a tensile architecture project originally funded by the European Commision between 2001 and 2004, comprising 22 participating organisations and including coating and weaving expertise as well as engineering and architecture (Tensinet 2009). The benefits of textile architecture include the quality of light as it travels through the whole surface, the ability to create large free spans and a great deal of freedom in the use of shape. As Quinn (2006) says, 'the cutting edge in architecture is not sharp, but sensuous and soft', as it draws on ancient traditional techniques such as braiding, weaving and pleating to create 'supple skyscrapers and bioclimatic enclosures'. A very current example can be seen in the concertina roof at Wimbledon's centre court, which uses 5200 square metres of Gore Tenara fabric to admit light while keeping the elements out.

A less obvious use of textiles in architecture can also be found in the soft concepts currently revolutionizing the way we think about buildings, as structures become based on flexible skeletons and networked skins capable of withstanding dynamic external forces such as earthquakes and high wind (Beesley and Hanna 2005). Highly visible examples include Foster and Partners' Swiss Re headquarters in London ('the gherkin'), a mesh structure on the bias, and Herzog and de Meuron's 'birds' nest' for the 2008 Beijing Olympics, a lattice of steel ribbons incorporating two textile skins with maximum translucency to give an even light for media filming (Technical Textiles 2009d). Beesley and Hanna (2005) draw comparisons between today's developments in carbon fibre composites and early wattle and daub structural fabrics, and the woven flexible branches of the first dwellings designed to last for generations.

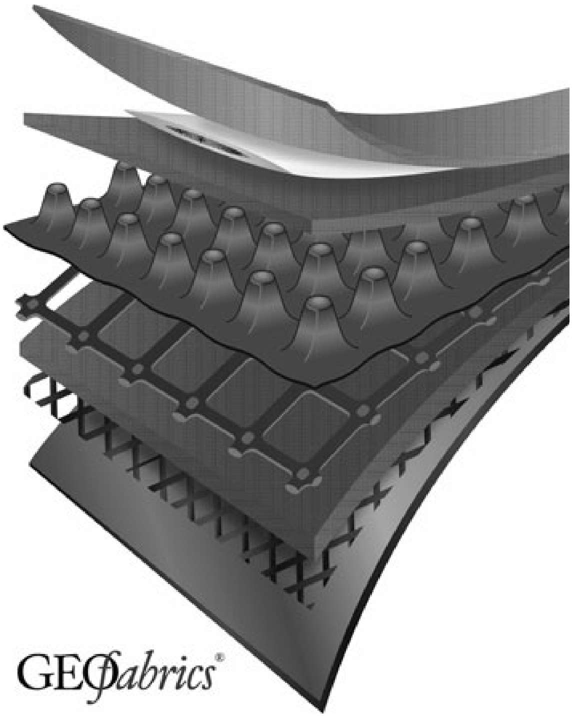
Geological

Geotextiles are manufactured in three basic forms: woven, needle punched, and heat bonded, and have a wide range of civil engineering applications in coastal, river and flood areas, the control of landfill and contaminated land, road, railway and airfield engineering, structural waterproofing and water and sludge containment. They are by no means a new phenomenon, with early evidence of woven fabrics and meshes being used by the Romans in road building, for example (Byrne 2000). The term covers many specialized sub domains such as geosynthetics, geotextiles, geogrids, geomembranes, and hortifabrics, each of which is developed with specific functional aims, including separation, filtration, reinforcement, protection or drainage. (Braddock-Clarke and O'Mahony 2005). Because of the scales of application involved, it is crucial to manage the specification of a product carefully in order to control cost, and in general, products are developed in close collaboration with land engineers and consultants to deal with particular contextual hydrological and geological conditions (Horrocks and Anand 2000). One of the largest applications for impermeable geomembranes is currently in the containment of hazardous wastes, which can produce gases and leachates, threatening neighbouring buildings either chemically or structurally through excessive build up. In these cases geomembranes may be used with mesh underliners as reinforcement or protection (Rowe 2009).

Rising costs associated with the use of traditional mineral aggregates combined with environmental restrictions have led to an increase in the development and use of geocomposite materials, (Fig. 14.4) which bond selected membranes, textiles, drainage cores or grids to create customized products which, at widths of up to six metres, can be laid at the rate of thousands of square metres a day (GEOfabrics Ltd 2009). Geocomposites may be deployed vertically as virtual curtains, or horizontally to control gas migration in the protection of nearby soils and structures.

14.3.2 Sources of innovation

Although the primary driver of innovation, identifiable needs are not the only source of development in technical textiles and the relationship of materials to end



14.4 Geocomposites; GEOfabrics.com.

uses is not always as straightforward as needs analyses might suggest. As in other creative domains, breakthroughs may also be triggered by chance discoveries in the chemist's laboratory, advances in industrial processing, or artistic conceptual exploration. This section provides an overview of the raw materials of technical textiles, that is, fibres, which have driven innovation since the beginning of the twentieth century, before going on to discuss developments in techniques and concepts.

Materials

Fibres are derived from three main groups: natural, harvested from plant and animal sources; regenerated, chemically treated natural fibres; and synthetic or man-made, generally coal or oil based. Natural fibres tend to be shorter, staple lengths, while chemically derived regenerated and synthetic fibres may be longer filaments, which can be cut if needed. These last two are most closely dependent on industrial processes, with new products such as micro fibres (of less than one denier) being made possible by meltblowing molten polymers into high velocity streams of gas (Braddock-Clarke and O'Mahoney 2005), or non-woven spunlace, used primarily in wipes, being made economically attractive through the design of wider production lines capable of operating at increased linear speeds (Rieter Textile 2009). Matsuo (2008) organizes fibres for technical textiles into three broad groups: conventional, high mechanical and functional. This section follows much the same pattern, introducing PET (polyester) and PP (polypropylene) before briefly discussing aramids, carbon and inorganic materials, and finally giving a short account of optical and conductive fibres.

Conventional fibres include natural materials, and the early stages of technical textiles can be seen in the use of jute, flax, sisal, wool and silk at the start of the twentieth century, for example in Dundee, where whale oil was used to lubricate coarse imported jute fibre in the manufacture of sacking, furniture, roofing felts, linoleum flooring and twine. Silk, produced by spiders, has always been highly sought after and admired for its strength and lightness, although it tends to play a relatively small role in the technical textiles market, really only being used in specialized applications like surgical suture thread (Byrne 2000). New research, however, combines the protein silk from spiders' webs with genetically modified casein from goats' milk, achieving spun nanometer diameter fibres to give a fabric product called BioSteel. This extraordinary material may be used to create bulletproof vests that can be recycled, and manufacturers are currently looking at medical and microelectronic applications (Nexia Biotechnologies 2009, Sinclair 2007).

Other organic raw materials used to add functionality to textiles include chitin, a natural polymer found in fungi and crab shells, alginate derived from brown seaweed, and chitosan, extracted from the shells of shrimps. Chitosan is an anti-allergenic used in the medical sector, and is used in the manufacture of underwear to prevent skin inflammation. The aptly named Crabyon is a commercial example of a chitosan and viscose blend which is both easy to assimilate into manufacturing processes, and which exhibits high humidity absorption, and aids in the inhibition of bacterial growth (Swicofil *n/d*). The first synthetics became available between 1910 and 1920, when viscose rayon grew in importance in the mechanical rubber goods industry, in turn supporting the feasibility of the automobile. Polyamide (nylon) and polyester were introduced in 1939, and are used widely in ropes and other end uses requiring energy absorbing properties such as sails and parachutes.

By the end of the 1950s, economies of scale meant the clothing and household markets had driven through lower priced processing of polyester. In the 1960s, polyolefins were introduced, polypropylene being the most common, although polyethylene was also available. These took over from much of the existing natural fibre processing due to cost and processing benefits and good abrasion and moisture resistance. Soon these properties saw them being used in the production of bags, sacking, carpet backing, packaging, ropes and netting, while properties initially seen as negative, such as low resistance to heat and 'complete hydrophobicity' (Byrne 2000, p. 8), were turned to advantage in the development of nonwoven fabrics, bonding solutions and wicking in hygiene products. Indeed, in 2000, these conventional fibres accounted for over 95% of all technical textiles, excluding the non-organics (glass, mineral and metal fibres) (Byrne 2000, p. 8).

High performance fibres have been providing 'dramatic impulses to the evolution of technical textiles' since the early 1980s (Byrne 2000, p. 8). These include the aramids (aromatic polyamides), further classified as meta-aramids (highly temperature resistant) and para-aramids (with high strength and elasticity modulus), and are typically used in a range of end uses such as bullet proof vests, tyre reinforcement, hoses, friction materials, ropes, air filtration and the creation of advanced composites. Global production in 2008 was estimated at 69,000 tonnes with main application areas being aircraft, automotive, protective clothing, ballistics, friction, reinforcement material, heat and cut resistance applications and civil engineering or geotextiles (Oerlikon 2009). Although the aramids account for only 0.5% of global technical fibre usage in terms of volume, the market is worth 3–4% in value (2000). They have become symbolic of the emergence of technical textiles, generating increased investment in industry infrastructure and the interest of high profile product designers.

Carbon fibre meanwhile, has taken somewhat longer to be adopted: although available since the 1960s production costs have constrained it to high value markets and so it is has been particularly susceptible to external market forces such as cutbacks in military spending (Hearle 2000). Kevlar, a para-aramid, is used where elasticity may be a problem: the cables of an aerospace Automated Transfer Vehicle, for example, may be made of Kevlar threads, resistant to temperature changes from –150° to +150° Centigrade, allowing uniform unfolding of the craft's wings (Futuro-Textiel 2008). As with aramids, carbon fibre gets its strength from the alignment of crystals along the axis of the fibre, and while variants can differ in their flexibility, electrical conductivity, thermal and chemical resistance, in general its properties are high tensile strength, low weight and low thermal expansion (Stegmaier *et al.* 2005). Fibres may be twisted to create a flexible yarn or used in composites with other materials, and as production costs come down, it is expected to replace traditional materials in many applications (Oerlikon 2009). Other speciality fibres, generally becoming available in the late 1980s, included phenolic fibres and polybenzimidazole (or PBI), ultra-strong high modulus polyethylene (HMPE), polytetraflouroethylene (PTFE), polyphenylene sulphide (PPS), and polyethletherketone (PEEK). Again, these are used in protective heat resistant clothing (PBI), ballistic protection and rope manufacture (HMPE), and filtration and chemically aggressive environments (PPS and PEEK) (Byrne 2000 p. 9).

Glass, ceramic, and metal are classed as the **inorganic materials**, yielding a wide range of high performance technical fibres. Glass, asbestos and ceramic have a high elasticity modulus, meaning they are stiff and brittle and are best used in a matrix form where the fibres can be protected from surface damage, for example by embedding in epoxy resins, polyester and other polymers. Evidence has been found suggesting that glass fibres were used in ancient Syria and Egypt in clothing (Miraftab 2000); more contemporary uses include printed circuit boards (Bajaj 2000). These fibres may be spun, knitted and braided quite easily, or coated with rubber, polyacrylate and silicones; however, care must be taken as they can cause severe skin irritation.

Asbestos, the only naturally occurring mineral fibre which cannot be completely destroyed by fire, has been found in prehistoric clay pots in Finland, and was initially valued for its heat resistance combined with fineness, strength and flexibility; however, it is easily breathed into the lungs, and since becoming known as a carcinogen is being replaced altogether with other fibres such as the aluminasilicate compounds.

Ceramic fibres are capable of withstanding temperatures of up to 1400°C, but are very abrasive in staple fibre form and can cause processing problems. Other examples of high performance inorganic fibres would include silicon, silicon nitride, tungsten, boron, alumina and carbide: silicon carbide (SiC) is an outstanding material with greater resistance to oxidation at high temperatures than carbon fibre.

It also has a higher compressive strength and better electrical resistance and can function at up to 1800°C with little loss of mechanical properties (Miraftab 2000). Such good resistance to heat, however, means many silica-based fibres also act as thermal conductors, which may result in serious burn injuries if the type of heat transmission is not taken into account when designing protective wear – i.e., whether the heat is likely to be transmitted by conduction, convection or radiation (Bajaj 2000).

An important application area of glass fibres is communications, with Corning selling over thirty million kilometres of its 'Leaf' optical fibre (Croning 2009). For the most part, glass optical fibres are made using silica, although fluorozirconate, fluoroaluminate, and chalcogenide glasses may be used for longer wavelength applications. Glass is an inert material and does not absorb water, making it relatively safe to use in many application areas as communications are built into global and domestic scale infrastructures.

Future trends include 'bendable fibres' which will retain their effectiveness when bent around tight corners, as the domestic market demands faster reliable communication in small spaces. Plastic optical fibers (POF) are polymer based (typically PMMA), with a 'jacket' to force the path of the light. They cannot match glass fibres for propagation and transmission capacity, but they are mechanically more robust, immune to radio frequency, electrically insulated and cheaper to install in some areas. Neither do they require the level of mechanical protection of glass fibres. POFs are typically used in industrial environments, residences and vehicles where distances are shorter and the trade-offs are acceptable. They are also more likely to be used in textile applications, where glass brittleness is a negative factor, and where the surface of the polymer can be abraded to allow light to leave the tubular path, offering opportunities for flexible displays. A collaboration between Caen, developer of electronics equipment to the nuclear physics industry, and the textiles sector, resulted in the commercially available product Luminex, for example, which will take on the colour of the originating LED source, and which can be used in relatively static applications, such as curtains and seat covers, using a transformer, or in clothing, using a rechargeable battery (Luminex 2009).

Optical fibre sensors embedded into technical textile also offer passive solutions for healthcare monitoring where magnetic imaging is not possible, or where a patient's condition will benefit from long-term observation. OFSETH, a large European project, is researching methods for measuring various medical parameters such as cardiac, respiratory rates, oximetry, and even pH and glucose concentration through optical devices embedded into textiles. At the same time, it is exploring techniques for processing optical fibres together with textile yarns that 'will not degrade their sensing properties' (OFSETH 2009). Cedric Brochier meanwhile, has filed a patent for a semi-automatic Jacquard weaving process using glass optical fibres to produce luminous patterned fabrics (Patent Storm 2006).

Other chapters in this book deal in depth with smart materials, including conductive textiles, but they should nevertheless be mentioned here to complete our overview. Metal fibres have been used in textiles for thousands of years to visibly denote status and occasion. Now, stainless steel, silver, nickel and copper are all important in the development of conductive yarns and fabrics for electromagnetic shielding, power transmission, and sensing. TITV's Elitex conductive threads, for example, provide the basis for developments in electronic textile switches, woven transponder antennae, luminescent textiles and textile bus structures (Möhring *et al.* 2006). These fibres can be produced to a given resistivity per metre whilst retaining textile properties similar to a polyester or polyamide. New projects flagged up by TITV at the 3rd NEST Conference in 2008 included Texoled, using their Elitex fibres in textile based light sources, and TexSolar, textile-based solar cells (Möhring 2008). Stretch conductive yarns and textile structures are a rich area of research at the moment, with researchers trying to develop materials which either maintain a consistent level of resistance when elongated, or which exhibit repeatable changes in resistance relative to mechanical change (Langenhove 2007, STELLA 2007).

Techniques

> Viscose rayon was the result of the human race's first attempts to mimic nature in producing silk-like continuous fibres through an orifice.
>
> Miraftab 2000, p. 27

There are many diverse principles of textile manufacturing that are being extended to meet the requirements of technical and performance products. A fact sheet prepared by the Industrial Trust lists these as including: web structure, bonded structure, pore structure, carding, and web. Within these main categories may be found airlaying, wetlaying, spunbonding, melt extruded polymer resins, meltblowing, chemical bonding, thermal bonding, hydroentanglement, needle punching, and stitch bonding. While it is beyond the scope of this chapter to introduce all of these in detail, it is in their combination and manipulation that many advances are being made. A basic principle is that of layering various spunlaid fibre webs (spunbond, meltblown and flashblown) to give composite materials with specific characteristics. The orientation of fibres for composites is an important area of research, with a wide range of applications.

Tailored fibre placement takes account of the stress in a composite form and optimises fibre placement according to a product's final contours to create semi-finished products (Ellis M 2009). Cetex is currently investigating the partial reinforcement of multiaxial fabrics, applying carbon stitching, threads and tapes to glass fibre during the production process to create lightweight 'bionic' structures (Technical Textiles International 2009c). **Three dimensional weaving** techniques give layered fabrics created by inserting weft and shedding both horizontally and vertically, and may be solid, hollow, shell or nodal 3D structures (Chen 2005). They are to be found predominantly in protective clothing, the automotive industry and in **textile preforms** for fibre reinforced polymer composites. More recently they have emerged as a promising process for creating integrated textile circuitry: multi-axial fabrics and fabrics with controlled interconnects between layers mean electrical continuity and insulation can be controlled within the fabric (Govindaraj and Brookstein 2008). While other technologies are a linear process from raw material, through fibre to finished fabric, **spunlaid nonwovens** skip a production stage, giving a finished textile product from the polymer material, and creating a sustainable growth area in technical textiles (Oerlikon 2009). Applications tend to be in the medical arena, and include hygiene products and protective apparel, although there has been expansion into the construction industry with coating substrates, battery separators and packaging solutions.

Concepts

Technical textiles as a sector can also contribute to wider concerns for **sustainability** through the development of surfaces, which require less washing, drying or ironing. Similarly, man-made fibres from natural sources can help reduce the environmental impact of textile consumption: Tencel is made from wood, and Ingeo, is made from corn and can be composted in commercial composting facilities (Allwood *et al.* 2006). Inspiration for some of the self-cleaning mechanisms for textiles also comes from the natural world, with chemical and geometrical surface modification mimicking the natural features of lotus leaves or butterfly wings, for example (Daoud 2008, FuturoTextiel 2008). Titanium oxide coatings are being tested on a range of fibrous materials by researchers at Monash University, which cause the chemical decomposition of dirt particles when the fabric is exposed to incident light (photocatalytic purification). Sustainable textiles and disposable and biodegradable fabrics are forming an important trend with manufacturers at once seeking ways to adhere to new regulations, and to appeal to the ethical consumer (fibre2fashion.com 2009b, Niiranen 2008, Braddock-Clarke and O'Mahony 2005). Nike, for example, has pledged to use only 100% organic cotton in the near future. High performance fabrics are increasingly being developed from renewable natural resources (plants and animals), with total annual production in worth in the region of US$40 to the world's farmers.

Polymers for use in technical textiles and sustainable nonwovens are being developed from materials such as caster beans, while discarded coffee grounds are used to produce melt-spun polyester yarns and fabrics. Trade conferences are exploring in more depth the range of issues facing sustainable textiles, including emerging natural and synthetic materials, recycled content in textiles, energy use and conservation in textiles, carbon and water footprinting related to textile production, and many companies are beginning to use the Global Organic Textile Standard (GOTS) in quality management (Global Organic Textile Standard 2009). Issues facing the industrial use of natural fibres include competition from synthetics and the need for reliability and conformity to standards, and more research needs to be done on manufacturing processes that can cope with the inherent deviances in natural materials (EMTEX 2009, Oerlikon 2009). Nevertheless, world demand for chemicals in textile manufacture is projected to increase to $19 billion in 2012, an increase of 2.8% a year. Colourants are the biggest sector, with faster gains in finishing chemicals (Freedonia Group 2009):

- Global demand for manufactured fibers will rise 4.7 percent annually through 2012. Polyester will continue to dominate output while specialty products such as spandex, aramid and carbon fibers grow the fastest. The industry will remain concentrated in Asia, where the fastest growth is also expected (World Textile Fibres to 2012; 2402).
- Global demand for geosynthetics is projected to increase 5.3 percent annually through 2013. China will account for the largest share of new global demand as

it continues to develop large-scale infrastructure and erosion control projects. North America will remain the second largest regional market. Geogrids will achieve the fastest gains (World Geosynthetics to 2013; 2512; July 09).

- Global demand for nonwoven fabrics is forecast to rise 6.9 percent annually through 2012. Gains in developing parts of Asia/Pacific, Eastern Europe, Africa/Mideast and Latin America will outpace demand in developed countries. Spunmelt nonwovens, the largest segment, will also grow the fastest (World NonWovens to 2012; 2482; March 2009).
- US coated fabric demand will reach 655 million square yards in 2012. Sales will be spurred by gains in motor vehicle production, protective clothing output and building construction. Vinyl- and other nonrubber-coated fabrics will remain dominant, while natural rubber-, neoprene-, silicone rubber- and other rubber-coated fabrics will grow the fastest. Coated Fabrics to 2012; 2448; Jan 09

While smart products where electronics are integrated into textiles have been covered elsewhere in this book, smart functions in technical textiles refers to variable responsive characteristics of a cloth, such as insulation, resistance to water, sensitivity to sunlight, or mechanical form. A currently available commercial product by Chenel, *Smoke Out*, employs a weave that opens up when exposed to heat in the case of fire, allowing smoke to escape and the water from sprinklers to pass through. The company make textile- and paper-based installations such as a knitted textile ceiling using a combination of fire resistant polyester and regular 'melt lines' which allow the fabric to open up (Lefteri 2008). Shape memory alloys (SMAs) are being researched for their ability to effect great change in response to a relatively low power input. Already used in embroidered medical implants (Fig. 14.1), SMAs are also to be found in quarrying and demolition, where the strong forces they generate are put to use splitting rock and marble without generating internal weaknesses which might result from explosive methods. The most common shape memory alloy is Nitinol (nickel-titanium), which acts to 'remember' its form, and returns to it when heated to a certain temperature. Current European research has resulted in a patent to bring down this trigger temperature from 400°C to 200°C, removing some of the processing problems involved in using these wires with textiles (Reade 2009), while other alloys can be selected to be set and triggered at a wide range of temperatures according to application.

14.4 Innovation and commercialization issues in technical textiles

While technical textiles play an important part in the innovations of many sectors, the supply chain remains complex and diverse, posing both a challenge and an opportunity to companies wishing to define their unique offering in the marketplace (EMTEX 2009), and many traditional family run businesses with strong nineteenth-century roots continue to be wary of R&D. Indeed, textiles are often perceived as being less innovative than other sectors, partly because traditional ways of measuring innovation, such as patents, are simply not suitable, and investment in research and development may not be adequately captured by official statistics (Niiranen

2008, Scottish Textiles 2007). The protection of intellectual property has now become a severe problem, restricting market growth especially with regards to smart products, which may combine existing technologies with novel inter/re-active functionality or traditional techniques. Boots, the health and beauty company, has taken the radical step recently of moving to an open innovation model through the opening of their Centre for Innovation (Boots Innovation 2008), something that is recommended by Sabine Seymour of Moondial (Seymour 2009) and being put into practice by new smart textile product company Lost Values (Corchero 2009), although until more investors place their faith in this strategy, innovation will continue to be stunted. In the meantime, there is by no means an agreed definition of open innovation, only perhaps that it does not necessarily publicise its knowledge in the manner of open source models. Related to these issues, procurement channels can also remain opaque, with regulations and standards lagging behind the pace of development (Berzowska 2005, Niiranen 2008). The sector further suffers from its increasingly hybrid nature, with a problematic skills gap in interdisciplinary areas. Individuals tend to have trained in manufacturing and engineering, or are from design backgrounds with little understanding of technical demands. There is little opportunity to train as a composite engineer, with the result that many high profile developments have come to be produced by companies 'in-house' (EMTEX 2009): academia obviously has an important role to play here in the provision of new training and in collaboration to establish research centres around technical clusters (Scottish Textiles 2007). One last issue to note is that of the potential for a mixed public reception to explicit 'scientifically proven' innovation (Allwood *et al.* 2006): coruscating passages in Margaret Atwood's novel *Oryx and Crake* on 'wave of the future' algae-activated, energy-sensing bathroom towels bear all the hallmarks of being based in credible academic research into transgenic and bioactive textiles (Atwood 2004, p. 237, Croes 2008, Nexia Biotechnologies 2009).

14.5 Technical textiles in education

To achieve innovation, Oliver pinpoints functionality in production as well as in consumption and outlines the need for materials innovation to be matched by a level of 'designer friendliness' (Oliver 2008). He maintains that while there are high levels of creativity involved in the development of new materials, they need to be made available to designers in quantities that facilitate serious play. A large quantity of material is required so that designers feel uninhibited in their explorations of novel materials, and the materials industry needs to understand that designers work through many 'wrong' concepts and product realizations before arriving at aesthetically considered resolved products. This point is illustrated neatly by a recent technical textiles project at Nottingham Trent University, where the textile practitioners involved had no previous experience with smart materials, and approached a commercially available carbon rubber stretch sensor from an aesthetic position (Breedon *et al.* 2008). Supporting Oliver's analysis that there needs to be more effective interaction between disciplines, this project financed a facilitator role through a combination of internal academic seed funding and external industry and arts sector awards, resulting in a great number of 'wrong' samples, followed by a

14.5 Aeolia; NTU (Tina Downes).

series of beautiful suggestions for embedding stretch sensors into fabric structure on the body[5] (Fig. 14.5).

The proposal for education at all levels then, is to draw on models of physically integrated workshop activity (Mitchell 2009, National Research Council 2003, Oliver 2008). Commercial examples of this model can be seen in Greyworld and the Jason Bruges Studio, characterized by a mix of traditional and digital tools, and an emphasis on making things in shared spaces – as Andrew Shoben (2008) of Greyworld says, 'nothing takes you out of the studio' or interdisciplinarity doesn't happen. Other issues in the UK education system include the dropping of the term 'craft' from the curriculum – students now take Design and Technology, and the craft is implied. However, emphasis on tools such as SpeedStep software are allowing stereotypes to dissolve, and boys may suddenly see textiles as 'cool' (Sinclair 2008). There remains a need for strategies to take emerging technologies into schools to increase accessibility and facilitate stronger links between textiles and electronics, although examples of resources for teachers delivering mandated areas such as systems and control can be found in the Technology Enhancement Programme, with novel and smart materials available in small quantities from Middlesex University's Teaching Resources initiative (Fig. 14.3) (TEP 2008).

Another important link is provided by the Industrial Trust, a leading national provider of out-of-school and in-company education in the UK, which organizes an annual technical textiles competition for students aged 14–25 years with support from the Worshipful Company of Drapers. Previous entrants have looked at D30,

[5] Aeolia was led by the author with Dr Philip Breedon (product design) and Amanda Briggs-Goode (textiles). The collaborating specialists were Tina Downes (embroidery), Martha Glazzard (knit), Nigel Marshall (weave) and Karen Harrigan (fit). The project was supported by awards from the Drapers Company and Alt-w, managed by New Media Scotland and the Scottish Arts Council.

the intelligent shock absorption material for use in skiwear (D30 2009), or attempted to re-create the adhesive properties of a Gecko foot with textiles (Industrial Trust 2008). The competition culminates in an awards ceremony and exhibition at the prestigious Drapers Hall in London, where students and teachers can meet leading industrial experts and see examples of technical textiles. David Lussey of Peratech commented at last year's event on the ease with which young designers assimilate apparently daunting new concepts such as quantum tunnelling textile technology (Industrial Trust 2008, Peratech 2009).

The average level of skills needed is higher now than it was only a few years ago, as basic operator roles have been shifted offshore, and UK business begin to focus on higher end craft and technical roles (Skillfast–UK 2009a). New specialist diplomas at GCSE level have been introduced for 14–19 year olds, designed with the input of the industry sector to ensure relevant skills for employability and the continued development of the textiles and fashion supply chains. These explicitly mix theoretical with vocational study (Skillfast-UK 2009b). There are relatively few specialized courses focusing on textile technology, and Skillfast report (2008) that some sector employers are now looking for general science graduates for R&D and other technical roles, but that this poses a problem as they enter into competition with other sectors for talented graduates. The Sector Skills Council for Fashion and Textiles has recently updated its provision of modern apprenticeships to help alleviate some of these issues, with apprentices attached to an organization for up to two years.

14.6 Future trends

With such high profile associations as the Olympics, Formula 1 racing and Wimbledon, Technical Textiles are being heralded as a platform for innovation and value added performance (Carr 2008). Many of the advances detailed so far are recent enough to warrant inclusion in this section, yet there are a number of external factors identified as pertinent to future trends for the sector which are worth looking at in more detail. Raymond Oliver of Arrow Consulting at a recent smart materials workshop proposed four compelling public needs that could prove to be drivers of smart and technical textiles and apparel:

- an ageing and obese population
- emotional design and increasingly personalized products
- intelligent, connected and ambient products
- socially acceptable energy harvesting and storage.

Oliver (2008) sees materials production as being characterized by 'dots, lines and surfaces', with novel materials increasingly focusing on the latter as technology (with textiles playing a central role) continues a formal trend from boxes, to cards, to second skins. In this view, 'dots' covers printable solutions, 'lines' refers to materials available in lengths over 1 km for spinning and fibre processes, while 'surfaces' refers to extruded products, increasingly including solar power and the built environment.

Technical textiles consultant Julian Ellis (2009) has further highlighted three major trends specific to technical textiles:

- bio-composites
- nano-composites
- self-reinforced plastics.

Bio-composites account for half of all research in composites, and command a significant online presence. These promise to improve impact on the environment, although further work on the end of the lifecycle phase needs to be done. One of the key areas for improvement is in the selection of textiles for the composite application: textiles that are strong by themselves may be useless when in composite form, exhibiting twisting or misalignment. Natural resins and textile waste resources may be used in this area, potentially leading to excellent ecological credentials. The development of nano-clays, in the meantime, facilitates research into new nano-composites with remarkable fire resistance characteristics. The layered nature of the clay greatly increases the surface area and creates a 'tortuous path' which means heat cannot get in and gas cannot get out. Clay reinforced polyesters are showing good fire resistance, although repeatability remains an issue, and processes still need to be scaled up from initial research to manufacture. Researchers at MIT are also looking at stitching on the nano scale, as a response to otherwise high performance composites being weakened by unsatisfactory bonding technologies. After testing stitching, braiding, weaving and spinning, all of which damaged the carbon plies in the composite, engineers are seeing good results filling the gaps between the carbon with nanotubes. This method of 'stitching' may make aeroplane skins and other aerospace materials up to ten times stronger than at present (Technical Textiles International 2009b). Finally, self-reinforced plastics are a form of composite, not of different materials as in glass and resin, but of different states of a single material. By controlling the molecular orientation of the plastics polymer chains, researchers can achieve the strength of glass-reinforced plastics without the added weight. In the automotive industry this has significant knock on effects for fuel consumption and transportation. While commercial products are available, new processes are being explored such as hot stamping and moulding, and bonding issues are being investigated. Despite the current global financial situation, the composites market is expected to grow steadily at a rate of 4% per annum (Ellis M 2009). In all textile composites, age-old technologies are demonstrating their continued value, as spinning expertise becomes essential for fibre placement. Composites are not yet a mature market, with many lines to the supply chain, and this means there is room for growth as manufacturers work to identify and refine their place within it.

To finish, we might add to these the following as exciting directions in technical textiles:

- coating technologies
- hybrid materials
- display solutions
- functional stretch materials
- radicalization of traditional techniques.

To date, there has been a relatively low take up on nanotechnologies for coating processes, although it is recognized that it is the 'last molecule' that can radically change a material's properties. Companies are working towards simpler and more flexible solutions, while bearing in mind the potential impact on existing technologies.

A recent European-wide research and development call by the Technology Strategy Board highlighted the importance of hybrid or multi-purpose textiles as an important market driver (Technology Strategy Board 2009). Coating, composite and finishing technologies offer routes to being able to combine functionality, promising cost and compliance savings as compared to legacy technologies. The issues facing this field include increasing the range of suitable substrate materials, longevity and reliability, and combining functions without compromising them. Demands from clients such as the US Air Force illustrate some of the demands placed upon single fabrics, expecting next generation battle dress to be waterproof, flame resistant, anti-bacterial, repellent to mosquitoes, and to have built in odour suppression: this particular design problem is being tackled through the finishing of a standard 50/50 cotton/polyamide fabric by curing it in a conventional microwave (Technical Textiles 2009a).

Jonathon Halls of Cambridge Display Technologies recently presented on OLEDs for fashion. Organic Light Emissive Displays are not commercially viable just yet but the projected timescales are very short, with the first commercial products expected to come on the market in 2011. Potentially, this display technology may be printed onto fabrics and even spin coated to scale high resolution displays to very large and flexible areas (Halls 2008). Outstanding issues are with the colour blue (continuing an historical theme), although there have been some prototypical demonstrations of OLEDs in clothing (Pioneer in 2003 and ETRI in 2007, for example). The potential design space for such chameleon-like change in textiles promises an exciting step change, and industry partners are working hard to mature the necessary manufacturing technology and resolve robustness issues.

The inherent stretch properties of textile materials are being investigated for the creation of new electronic functions in a number of R&D projects. Passive sensors may be constructed by carefully taking into consideration the structure, size and form of a textile incorporating conductive fibres. These can then relay information on their deformation to give feedback on limb movement or swelling in medical rehabilitation or prevention (STELLA 2007). Fibres may retain their resistivity, as in TITV's conductive elastic, which is stable up to an elongation of 80%, or may change resistivity with deformation as the spaces between conductive particles or fibres increase or decrease (a piezo-resistive effect). The complexity of a fabric structure introduces many new parameters into the design of these new devices, such as the introduction of the conductive yarn along warp or weft and the mechanical change on number of contact points with fabric manipulation. Any rearrangement of fibres in the fabric will affect the conductivity of the whole structure (Langenhove 2007).

These interrelated and dynamic factors can currently be used to great effect in arts projects, but require a great deal of work before they can be put to use as reliable medical sensors. In the meantime, simple knitted structures are also being looked at in radical arts led projects as a potential technique for construction. Peter Schmitt of the Future Cities group at MIT, builds his own CNC milling machines to in turn create custom circular knitting beds. These are programmed to move vertically as they produce their tubular knit structures using epoxy resin impregnated yarns, and set these structures with UV light as they go. Schmitt (2008) suggests that with some further development, he will be able to build domestic structures in one, with utilities and cables fed dynamically into vertical structural cavities during the knitting process.

14.7 Sources of further information and advice

For ease of reference, these resources are grouped under the following headings: associations and networks, conferences and fairs, databases, online resources and suppliers, projects, research centres and funding, publishers and finally, trade news.

14.7.1 Associations and networks

ACTE is the **European Textile Collectivities Association**, representing territories with a presence in the textile, clothing, leather, footwear and fashion accessories sectors.
URL: http://www.acte.net/content/about_acte/about_acte_en.htm

EMTEX in the East Midlands was established to help the region's clothing and textiles businesses to face the challenges of a rapidly changing industry.
URL: http://www.emtex.org.uk/index.asp

Industrial Fibres Association International (IFAI) is an important trade association representing the global specialty fabrics/technical textiles industry, sponsoring the largest industry tradeshow in the Americas, IFAI EXPO. IFAI publishes seven trade magazines and buyers guides: *Specialty Fabrics Review*, *Fabric Architecture*, *Fabric Graphics*, *Geosynthetics*, *InTent*, *Marine Fabricator*, and *Upholstery Journal*.
URL: http://www.ifai.com/

The Materials Knowledge Transfer Network website provides a wealth of news, information, reports, events and access to a range of networks related to technical textiles. Other KTNs of interest might include the nanoKTN and also Sensors and Chemistry Innovation.
URL: http://amf.globalwatchonline.com/epicentric_portal/site/AMF/?mode=0

NEST (**N**ordic Centre of **E**xcellence for **S**mart **T**extiles and Wearable Technolgy) is a network of participants from universities and research institutes in the Nordic countries with the aim of creating a platform for continuous collaboration and transfer of knowledge between research and industry within smart textiles and wearable technologies.
URL: http://www.smarttextiles.se/Ambience08/nest.htm

Smart textiles groups together a cluster of Nordic companies and research institutes with Borås as a centre. The website details research and development and upcoming events, including the cluster's own **Ambience conference**.
URL: http://www.smarttextiles.se/

The **Textile Institute** is a registered charity covering the textiles, footwear and clothing sectors. It aims to 'facilitate learning, to recognize achievement, to reward excellence and to disseminate information'. A paid subscription is needed to

access events listings, but the publications sales are worth searching through. At the time of writing, all five Textile Institute World Conference Proceedings were available on CD-ROM for a substantial discount.
URL: http://www.texi.org/

14.7.2 Conferences and fairs

FuturoTextiel is a recent important addition to the technical textiles calendar and brings art and design together with technical innovation. It styles itself as a laboratory rather than an exhibition, showcasing advanced textile applications. A conference, Textiles of the Future, was hosted alongside the exhibition in 2008, which was also accompanied by a useful publication (see references). However, at the time of writing the Futurotextiel site seems under-populated, and the conference site is sadly not available.
URL: http://www.futurotextiel.com/#/en/Futurotextiel08/

TechTextil is the leading international trade fair for technical textiles and nonwovens. The complete global market of the future technical textiles is showcased annually at the most important forum for the industry.
URL: http://techtextil.messefrankfurt.com/global/en/home.html

14.7.3 Databases, online resources and suppliers

AZOM is the A to Z of Materials and the AZo Journal of Materials Online.
URL: http://www.azom.com/default.asp

IMATEX is a database run by the Textile Museum and Documentation Centre in Terrassa for those interested in viewing the fabrics, garments, pattern books, original designs, swatches and complements in the collection.
URL: http://imatex.cdmt.es/

Innovation in Textiles is a free to use online news and technical resource for the global technical textiles industry, supported by a panel of industrial and academic experts spanning fibres and yarns, design, technical textiles and nonwovens manufacturing, research and development and journalism.
URL: http://www.innovationintextiles.com/about.php

MUTR is Middlesex University's Teaching Resources initiative, and is a useful place to buy small quantities and samples of novel and smart materials, as well as simple guidelines on their principles and uses.
URL: hrrp://www.mutr.co.uk

Ovid – a scientific and healthcare communities resource, giving an extensive list of journals cited in World Textiles, covering textiles and fibres.
URL: http://www.ovid.com/site/products/fieldguide/elwt/List_of_Journals.jsp

Scottish Textile Heritage Online provides a one-stop guide to Scottish textile collections. The project database contains approximately 3000 descriptions of textile-related museum and archive collections and objects, and an online resources section contains essays on a range of textile related subjects, with maps showing the distribution of the textile collections across Scotland.
URL: http://scottishtextileheritage.org.uk/

The Textiles Technology Facilitator Service (TTFS) is a new service funded by Scottish Enterprise's to work with the textiles industry to identify and develop potential opportunities for higher value textile products and processes.
Contact Carol Scullion cas@synaptech.co.uk

14.7.4 Projects, research centres and funding

The **ConText** project was an EU funded project under the 6th Framework programme researching contactless body monitoring through woven, printed and laminated textile sensor integration techniques.
URL: http://www.context-project.org

Eduwear is a European Commission project which aims to contribute to the reduction of inhibiting factors in smart textiles and wearables development, through the provision of an educational low-cost construction kit for wearable and tangible interfaces.
URL: http://dimeb.informatik.uni-bremen.de/eduwear/

The **Framework Programmes for Research and Technological Development** is EU's main instrument for funding research in Europe. The FP7 areas of interest include nanotechnology, materials and production technologies with specific textiles and clothing related topics. First projects addressing textile and clothing research priorities started in early 2008. Further opportunities will be available in future calls for proposals.
URL: http://ec.europa.eu/research/fp7/

TexEng is a consultancy focusing on 3D textiles. The site has some very good papers and details of this emerging area.
URL: http://www.texeng.co.uk/index.php

TITV is The Institute of Special Textiles and Flexible Materials, based in Greiz, Germany, carrying out research into textile micro system technology, textiles for use in medicine, bionics and biotechnology, coating and lamination technologies, and textile technology.
URL: http://www.titv-greiz.de

14.7.5 Publishers and publications

Berg – publishers of related journals including *Textile: the journal of cloth and culture*, *Fashion Theory,* and *Fashion Practice*.
URL: http://www.bergpublishers.com/Home/tabid/36/Default.aspx

Elsevier – publisher of related journals including *Geotextiles and Geomembranes*, *Composites Science and Technology*, *Composites Manufacturing*, *Composite Structures*, *Materials Today*, and *Surface and Coatings Technology*.
URL: http://www.sciencedirect.com/science?_ob=HomePageURL&_method=userHomePage&_btn=Y&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=6b8f8a0bb11c4ebe676f09e6d7da52c8

Emerald Insight – publishers of titles such as the International Journal of Clothing Science and Technology and anthropological research on the textiles and clothing industries.

URL: http://www.emeraldinsight.com/Insight/viewContainer.do?containerType=Journal&containerId=10729

MADE – The Magazine for the Materials and Design Exchange, brings together the communities of design and materials technology, frequently featuring articles on technical textiles development and application. A special issue in September 2009 focuses on the combination of traditional textiles techniques with new materials for performance fabrics with industrial potential.
URL: www.made.uk.net

Sage – publishers of related journals including *Clothing and Textile Research*, *Journal of Industrial Textiles* and the *Textile Research Journal*.
URL: http://online.sagepub.com/

Springer – publisher of related journals including *Fibre Chemistry*, *Fibers and Polymers*, *Journal of Materials Engineering and Performance*, *Applied Composite Materials*.
URL: http://www.springerlink.com/journals/?sortorder=asc&o=10

Taylor & Francis – publisher of related journals including *The International Journal of Fashion Design, Technology and Education*, *Textile Progress*, and *The Journal of the Textile Institute*.
URL: http://www.taylorandfrancisgroup.com/

The **Textile Research Journal** published by Sage is a highly technical research journal covering fibre, yarn and fabric structure.
URL: http://trj.sagepub.com/

Woodhead – The textile technology series by Woodhead covers technical aspects of textiles in far more depth than can be achieved here, and includes sections on natural textile fibres, synthetic fibres, fibre/fabric properties and testing, yarn technologies, fabric technologies, colouration and finishing, design and product development, environmental technology and management, high performance and technical textiles, intelligent and medical textiles, and clothing, as well as textile training CDs.
URL: http://www.woodheadpublishing.com/en/menuList.aspx?name=Textile

14.7.6 Trade news

Ecotextile News is a business-to-business online magazine dedicated to the production of sustainable and ethical textiles and apparel. It aims to provide retailers, fabric specifiers and buyers with up-to-date news on sustainability and ethical manufacturing, and to impact on legislation by being heard at government level.
URL: http://www.ecotextile.com/WhatIs.php

Fibre2Fashion is a vast website featuring news on all areas of the global textiles and garment sectors. Registration required for access to full news stories and industry reports.
URL: http://www.fibre2fashion.com/

International Newsletters publishes regular newsletters covering the technical textile industry, including *Smart Textiles and Nanotechnology*, *Technical Textiles International*, *Advances in Textile Technology*, *Advanced Ceramics Report*, *Biomedical Materials*, *Medical Textiles*, *New Materials Asia*, *Advanced Composites Bulletin*, and *High Performance Plastics*.

URL: http://www.technical-textiles.net

Just-Style offers a portfolio of research reports and newsletters covering key topics in the apparel and textile industry. There is a membership fee for full access.
URL: http://www.just-style.com/briefings/

Technical Textiles.net supplies the latest news on technical textiles from around the world. It includes a useful listing of organization websites and notices of upcoming conferences and events, and users can sign up for newsfeeds, although access to full transcripts may require a fee-based subscription. Many reports on the industry are available to buy.
URL: http://www.technical-textiles.net/index.htm

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15
Designing future textiles: new developments in textile structures and surface treatments

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Abstract: Technology in its various forms has revolutionized the nature, performance and appearance of textiles. This has impacted all areas of fabric design and production as well as applications in product, fashion design and architecture. This chapter looks at the latest and most innovative of these developments incorporating the broadest possible range of materials and processes as well as the disciplines utilizing them.

Key words: textile, yarn, fiber, textile design, fashion, nanotechnology, biotechnology knit, weave, composites, printing, embedding, coatings, finishes.

15.1 Introduction

Advances in new technology are having a dramatic impact on all aspects of fiber and fabric production to the extent that the very definition of what textile is is being reassessed. Natural and synthetic are coming together in innovative ways so that the best qualities of both might be combined. This is accelerating the move from industrial applications to other areas such as apparel and automotive, where the demand is for performance to be married with aesthetic. This is having an impact on industrial textile production as manufacturers recognize the potential in design and architecture applications and refining their products accordingly. The commercialization of nanotechnology and biotechnology has begun and we are already seeing applications emerge, mainly in the coating and finishing treatment sector. This is pushing speculation of how new materials not previously conceived of might take shape. Meanwhile, sophisticated technologies are becoming more available to all aspects of fiber and fabric production is encouraging researchers, manufacturers and designers to broaden their expectations and allow their imagination free reign. We are already seeing some spectacular new products that are truly innovative, a trend that looks set to continue well into the future.

15.2 Design of future fibers and yarns

Advanced fibers and yarns are no longer confined to technical and performance-driven applications. They form the basis for much of the fabric that we are in contact with on a daily basis, while in industry they can be found in the development of products that are increasingly smart. The reason for this is the bringing together of the technical and the aesthetic so that performance is matched by comfort and aesthetic.

In engineered fibers (15.2.1) we can see yarns being spun, twisted and extruded in whole new ways, this includes both natural and synthetics. Much of it has been driven in the growth of the health and safety industry. There is an increasing realization that workers perform better if they are comfortable as well as safe. Hybrid yarns (15.2.2) sees the bringing together of natural and synthetic. They are no longer perceived as alternatives but combining to provide the consumer with the best of both worlds. Coated fibers and yarns (15.2.3) concentrates on the coating and finishing of the yarn. One of the emerging trends in this area is the coating of fibers as an alternative to the treatment being applied to the fabric for more comprehensive coverage.

Nanotechnology (15.2.4) and biotechnology (15.2.5) are rapidly emerging as forces to be reckoned with and both seeing products come to market. The decision process in selecting fibers and yarns is no longer a simple choice between natural or synthetic, the options are now far greater and the decisions increasingly complex.

15.2.1 Engineered fibers

The extent to which both synthetic and natural fibers can now be engineered is transforming the way that designers and engineers work with them. While synthetics by their nature have been subject to technological intervention, the engineering of natural fibers is relatively new. It seems ironic that synthetic fibers were originally designed to simulate natural materials but now it is natural fibers that are being engineered to perform like synthetics.

Nylon, acrylic and polyester yarns are now being engineered in novel ways such as hollow fiber yarns that provide thermal insulation and are used in clothing. Polyester, in the form of recycled soda bottles, is used as the basis for fleece sports and leisure garments from companies such as Patagonia (USA). Processes such as extrusion and pultrusion are where heated granules are drawn or pulled (respectively) through a cooling process to form a yarn referred to as a monofilament. Glass fiber is produced in this way, as are aramids (Kevlar) and other polymers such as the high-temperature polymer polybenzimidazole (PBI) now used for flame-resistant workwear because of its ability to withstand the dangers associated with firefighting, arc flash, and flash fires. A polymer is a material formed by the chemical combination of monomers with either the same or different chemical compositions. One of the difficulties with high-strength yarns is the lack of elasticity. One solution is the recent development of stretch-broken yarns. The idea of creating a stretch-broken yarn is to give greater flexibility to high-performance yarns that have little inherent elasticity, aramids, para-aramids and carbon fibers to be used as prepegs in composites or sandwich-type structures.

Engineered natural fibers include wool, wood pulp and even seaweed. Smartfiber AG(Ger) produce a lyocell fiber based on wood pulp with enhanced health properties. Their SeaCell yarn uses seaweed as an active ingredient in the lyocell fiber. Seaweed has long been used in Chinese medicine and is recognized as offering protection for the skin and containing anti-inflammatory properties. Smartcel Ceramic is made by Smartfiber AG and brings together cellulose and ceramic resulting in a 100% ceramic fiber. It can be produced in different forms including hollow and spiral structures, while a sintered PZT ceramic fiber has the ability to stretch when exposed to alternating voltage producing sound waves in the process. This gives it an application in ultrasound products such as sonar systems for locating obstructions, and medical imaging.

15.2.2 Hybrid yarns

Hybrid yarns are where two or more fibers are brought together to combine the performance and aesthetic of both. Although environmental concerns are encouraging many manufacturers to focus on the use of a single fiber, there are still and will remain reasons for bringing fibers with different qualities together particularly for performance and health and safety applications.

The Schoeller Spinning Group (Swiss) are producing a number of aramid-based hybrid fibers. Panox consists of 70% Panox and 30% Kevlar. Panox is a preoxidized acrylic fiber suited for heat resistant, thermal and acoustic insulation in technical textiles. The combination of the two fibers means that the resulting yarn has the cut and abrasion resistance of the aramid alongside the heat protection of the preoxidised acrylic. Sheath fibers are where a core fiber is surrounded by another. The same Swiss company are using the technology for an aramid stretch-broken fiber that forms the core, with another protective yarn surround. The core comprises 10% Kevlar and 50% glass filament with the Kevlar 40% sheath surround. This is used as a backing for aluminized protective suits and cut-resistant protective clothing.

15.2.3 Coated fibers and yarns

Conventionally, coating and finishing treatments are applied to fabric structures rather than the yarns. However, for high end performance uses it is sometimes desirable to coat the whole yarn in case of movement during use and loss of performance.

In Switzerland, the Schoeller Spinning Group have developed a hybrid wool and stainless steel yarn for use in anti-static clothing. In the yarn, the Merino wool is randomly interspersed with less than ten percent Inox stainless steel fiber. The resulting yarn can be easily dyed, knitted and finished with treatments such as dirt-repelling Teflon without interference with the shielding performance. The ability to combine capabilities such as these in a single yarn is relatively new. Less than a decade ago this would not have been possible without reducing or even destroying the performance of one or both functionalities.

Photo voltaic (PV) cells are being used to gather and convert solar radiation into current electricity. The majority of systems use flat solar panels but there is growing interest in more flexible and discrete systems that it might be possible to incorporate into textiles. In America, Georgia Institute of Technology are looking at ways of creating a PV fiber that can be woven into a fabric for use in architectural membranes. To achieve this, researchers are nanocoating fiber optics with a dye-sensitized photovoltaic coating. The cladding of the fiber optic is first removed, replacing it with a conductive coating and seed layer of zinc oxide. Zinc oxide nanowire is then grown on this prepared surface so that the result is a coating of fur nanowires. This is then coated with a dye-sensitized PV material before being immersed in liquid electrolyte to collect current from the photovoltaic reaction. The ends of the fiber are directed at the sun so that light enters the unclad fiber optic carrying it along and through the wall to the nano PV so that it covers a very large area, with researchers confident that it will prove much more efficient than conventional systems of collection.

TITV – Das Institut für Spezialtextilien (Germany) are working on various aspects of smart materials including their conductivity. They work on the premise that the best and most efficient functionality can only happen if the small electrical components can be integrated into the textiles. ELITEX threads are metalized and their electrical conductivity modified by using a special electrochemical finishing treatment. The polyamide thread is coated with a fine layer of silver.

15.2.4 Nanotechnology

Nanotechnology operates at a molecular level denoting a factor of one thousand-millionth in units of measurement. It combines some of the principles of molecular chemistry with physics, computer science and engineering. Although anxiously awaited, results coming to market have been slow and are only just starting to emerge. Textiles are one of the first areas to see it used in coating and finishing treatments and now in fibers.

Nano coatings have been used on fabrics in recent years but are now starting to appear on individual fibers. Nano-silver with its anti-microbial properties, is currently being researched by Centexbel (Belgium) for potential use as a coating and a component during the yarn extrusion process. The possibility is to create a yarn that is much more effective but uses less silver than conventional processes where the whole fabric is coated.

Nanofibers are now becoming a reality thanks to processes such as electrospinning. The technique takes a polymer solution and subjects it to an electrostatic charge to eject fine jets of liquid. These are then stretched in an electric field under simultaneous evaporation of the solvent. The result is a deposition of a nanofibrous nonwoven fiber mat. Fibers can be produced using either single or multiple capillary needles or by electrospinning from a liquid-free surface.

Much of the nanotechnology focus is on the potential offered by carbon nanotubes. These can be measured in billionths of a meter with structures resembling honeycomb. They have the possibility to be very strong as well as highly conductive. As with all areas of nanotechnology research, cost is a major issue as is the ability to repeat the process on a large industrial scale.

15.2.5 Biotechnology

Biotechnology refers to any technological application that uses biological systems, living organisms or their derivatives to make or modify products or processes. Researchers at Biopro and project partners BASF SE are looking to biotechnology as a means of producing an alternative to polyamides such as nylon fibers. The biopolymers/biomaterials cluster are in the process of developing bio-based materials through fermentation. The motivation behind the research is to look at ways to extend the capabilities of nylon, in particular how to make them more malleable without the loss of mechanical strength.

Du Pont's Applied Science Division (USA) have developed a way of turning corn starch into fibers. Sorona is made from starch extracted from the kernel of corn, and the company is also looking at ways of extracting starch from the stalk and other parts of the plant. The starch is put through a fermentation process where glucose is fed down pipes into a three-storey vat that contains genetically engineered organisms, water, vitamins and minerals. The resulting monomer is polymerized with a petroleum–based polymer and cut into pellet form that is converted into fibers. A key reason given by Du Pont for the growing interest in this area is the increasing cost of petroleum that had previously been less expensive than sugar.

15.3 Design of future fabric structures

The structure of a fabric, whether knitted, woven or part of a composite, forms the cornerstone of the material's performance and aesthetic. With the growth of technological advances on all levels we are seeing these structures inspire new designs and even whole new products not previously imagined.

Knitted and woven fabrics can combine a vast array of yarns and be used to create both two- and three-dimensional fabrics as well as eliminate the need for seams. Composites are where two or more materials are brought together to create a third new material with enhanced capabilities. Within this we are seeing embroidery used for its structural rather than decorative qualities alongside innovative fiber laying techniques for yacht sails and other large-scale products. Surface treatments range from coating to finishing and are used either to enhance existing capabilities or to provide the entire performance with the fabric element acting as a carrier for the technology.

All of these developments combine to see textiles used in unexpected areas, as we see them used in medical implants and to make car and truck bodies. Increasingly they are replacing heavier materials such as metals or even concrete, a move influenced by environmental concerns as well as international legislation. This is a trend that looks set to continue well into the future, transforming both the textile industry and the world around us.

15.3.1 Knit

The knitted structure shows a looped yarn process that can be done by hand with knitting needles or by machine for larger production runs and technical applications. One of the basic differences between it and a weave is that the knitted fabrics in general allow for greater stretch. The machine process allows for warp and weft knitting, as well as circular or seamless and three dimensional. The scale of what is possible has been impacted by these new developments in machine technology with tiny devices for cornea surgery being prototyped as well as large-scale parachute breaks for fighter aircraft.

Circular, tubular or seamless knitting is as the name suggests in structure. It forms the basis for much of the hosiery, lingerie and swimwear and it has been used in fashion most famously by the Japanese designer Issey Miyake in his A-Poc series. Three-dimensional structures are distinctive in having a flat fabric top and bottom layer with interconnecting yarns connecting the two. The space between can be a few centimeters or half a meter. These are often referred to as spacer fabrics and were originally used in trainers to provide cushioning for the foot. Now they are finding applications in a great many areas including luggage.

While the idea of a functionally gradient material has been considered for some time, technological advances are now making it commercially feasible. It offers the chance to produce a garment needing different performance criteria in different zones using a single material in one process. WarmX produce climate control underwear using a number of materials and processes including a variable knitted structure. The design for SilverSun is based on body mapping principles. The intention is to provide the optimum in comfort and warmth aimed at the outdoor market. A silver plated yarn is used in areas where perspiration is likely to reduce odor and combat bacteria, while an elasticated hybrid yarn is used for the main body of the garment to ensure that heat is distributed well around the body.

15.3.2 Weave

Woven structures are where a textile is made by interlacing warp and weft threads. There are three main structures: plain, twill and satin. Three-dimensional woven fabrics are becoming more common though not to the same level as three-dimensional knitted fabrics.

Woven fabrics are being given added functionality as part of their structure as loom technology has improved. In the early 1990s manufacturers had great difficulty weaving glass and carbon fiber, as they damaged the equipment, making them very expensive to produce. Though both are still costly, they are becoming more affordable with many applications in industries such as architectural membranes (glass fiber) and in sports equipment, automotive and aerospace (carbon fiber). With the end of the Cold War and a tightening of government spending, military and space agencies have been forced to look at commercial partnerships for their technologies. NASA run a Spinoff programme while in Europe the European Space Agency (ESA) have worked with Grado Zero Espace (Italy) to look at the commercialization of some of the technologies developed for space. In one prototype, they have incorporated a shape memory metal (SMA) into a woven fabric for shirts to enable it to change shape according to temperature.

Three-dimensional structures include shaped materials for building and transport, ‘I’ profile beams as lightweight alternatives to metal fabrication, for example. Multiaxial structures are also being developed. This highly specialized weave consists of one or more layers of fibers with different orientation stitched together, usually with a finer thread. This technology is expensive to produce so remains very much in the research laboratories until a more affordable production process can be found.

15.3.3 Composites

Composites are structures where two or more identifiable materials are brought together to create a new material with enhanced performance characteristics. The construction and transport industries have been particularly interested in this group of materials using them as a replacement for heavier materials such as concrete and metal. The structure can be made in a number of ways depending on the intended use.

Composites that are made using a honeycomb-based core structure can vary dramatically in performance depending on the choice of material as well as final construction. Kraft paper, Nomex paper, Kevlar paper and polycarbonate formed structures are being used. DuPont's (USA) Kevlar honeycomb is a typical honeycomb construction. Sheets of the aramid paper are layered and bonded together to form panels that are then sliced to the desired thickness. These are then opened out to form the honeycomb structure with the structural force applied to the section cut of the structure. Over 90% of the material is open space making it super lightweight but strong. It is used extensively in the aircraft and boat industries.

Tajima GmbH (Germany) produce both embroidery and a stitch laying machine. Stitch laying is the process whereby yarns are laid then stitched into place using either a similar or different thread. The machines can use carbon and glass fibers as well as aramids and hybrid yarns. The laid fibers tend to be high performance, though polyesters and natural fibers can also be used. The thread used to stitch the yarns into place are holding fibers and because the material will generally go on to further processing as part of a composite material, these can often be a lower performance polyester or similar.

The process of filament winding can also form the basis for composites. The process sees fibers and yarns used to create a structure, usually three dimensional, through the use of a mandrel. This is a long cylindrical tool that is computer controlled and fully automated to place the fibers in a precise manner on a tool as it moves back and forth. The machine is suspended horizontally and generally has between two and twelve axes of motion. The fiber is usually passed through a resin bath just before it reaches the mandrel in a process known as wet winding. Where the fiber is impregnated with resin it is referred to as a towpreg. Dry winding, as the name suggests, is done without either but goes on to be used as a perform in another moulding process such as RTM. Very large composite structures such as aircraft fuselage can be undertaken with an automated filament placement (AFP) or an automated tape laying placement (ATP). Both generally involve the use of carbon fiber either as fiber or tape. These can be continuously placed and are designed to meet very stringent strength and rigidity requirements while keeping the weight and material costs to a minimum. Although the production process is highly specialized, the cost saving it allows, especially with costly carbon fiber, means that it is attracting a great deal of interest for technical and economic reasons.

15.4 Design of future fabric surface

The surface of the fabric combines performance alongside a visual and tactile interface. The vast array of treatments include printing, embedding, coating, finishing and applied technologies. The processes are used to add functionality to advanced fabrics but they can equally provide the full performance using the base fabric as a substrate or carrier. They are also being used to add a comfort such as tactile quality to the material or aesthetic quality. The materials themselves are a wide-ranging mixture of chemical treatments, metals, plastics, yarns and non-textile technologies such as photo voltaic cells to convert solar energy into electricity.

As the structural aspect of textile production becomes more sophisticated the possibilities for surface treatments increases proportionally. Light emitting diodes

(LEDs) and other non-textile technologies can now be applied without the risk of destroying the material. Another advance is the ability to combine treatments without them conflicting and causing performance reduction or obliteration. This is especially important in the area of health-giving fabrics so that materials can be both anti-microbial and flame retardant, for instance.

As nanotechnology emerges as a commercial possibility, it is in coatings that we are seeing the first applications in textiles. The future will likely see this area continue to perform as a barometer of what will follow in other areas of nanotechnology textiles.

15.4.1 Printing

The primary function of printed textiles is the application of a pattern to the fabric using process such as silk screen printing or digital inkjet printing (Fig. 15.1). While much of this is for decorative purposes, there have been some new developments in this area that are driven by performance or combined aesthetic and performance requirements.

The process of dye sublimation printing is a computerized process that uses heat to transfer the color onto the fabric. Vaporized rather than liquid color is applied

15.1 Designers are increasingly coming to subvert production processes to achieve unexpected results. In this detail of a design from Shelley Fox, the brush cotton fabric has been printed with a morse code print then vigorously brushed to partly remove the print creating a softer effect (© Shelley Fox).

and this procedure allows for a very fine grading of pattern to achieve photographic quality imagery. Rebecca Earley has created a series of garments using a heat and pressure activated dye sublimation process (Plate XIV between pages 166 and 167). The process of dyeing textiles is fraught with environmental dilemmas. While chemicals such as chromium IV are considered hazardous, the use of natural dyes can also have its impact on the environment through the use of mordants (which include heavy metals) to fix the dye to the fabric. In the Upcycled Silk Shirt series, Earley's shirts are often constructed first, or use pre-worn clothes. These are then printed onto before being slit using a sonic welding knife tool that allows the shirt to be reshaped.

Barcodes and radio frequency identification (RFID) tags are now becoming commonplace for stock regulating and other purposes in textiles. While barcodes have been printed directly onto substrates such as textiles for some time, the transistor-based RFID tag is taking longer to achieve as a printed process. California based Kovio have printed an RFID tag by inkjet using nanosilicon transistors on a flexible substrate launching the product in 2010. DuPont Electronic Technologies has developed a polymeric thick film (PTF) technology to silk screen print antenna onto the RFID labels. This is necessary to allow communication between the smart chip and the data system of the read/write terminal. The polymeric inks are based on silver conductive particles and achieve low resistivity values.

15.4.2 Embedding

The process of embedding chemicals within the fabric has many benefits. The most common is that it allows a more comprehensive application of the treatment so that it does not simply sit on the surface.

TexOLED is a German government-funded initiative comprising various research institutes looking at ways of incorporating lighting into textiles. Each institute takes a different approach with Fraunhofer IZM focusing on the integration of bare die LEDs into fabrics. The institute are using a conductive bonding process to apply the LEDs. The lights have first been cut from their wafer and used without their housing so that the bare LEDs are contacted to the fabric with a machine jetted isotropic conductive adhesive. The adhesive is jetted onto the fabric at a right angle close to the LED. As it touches the fabric it flattens, making it connect with the electrode of the small light while simultaneously contacting the conductor in the fabric. The high viscosity keeps the adhesive in place until it is cured. The next stage in development is to make the embedded LED more robust.

Looking to future developments in this area, researchers at Stanford University in California are developing a way of incorporating batteries into fabric in the form of carbon nanotubes. The fabric, natural or synthetic can be used, is dipped into the ink or dye that contains the carbon nanotubes.

15.4.3 Coatings

The ability to produce increasingly fine coatings with minimal impact on the material below is resulting in the use of performance chemicals on man-made, natural and technonatural fabrics. Schoeller have developed Liquid Shell, which when applied to leather offers improved resistance to abrasion, to UV-A and UV-B rays, good resistance to acid and alkaline sweat without a noticeable loss in handle or aesthetic. It makes the material more suitable for extreme sports and marine applications, areas it had not been widely used in before.

Silicone rubber is a unique synthetic that is made from a crosslinked polymer that has been reinforced with silica. Used as a coating on technical textiles it can provide the benefit of being water, UV and chemical resistant and can be flame retardant. It can also function at temperatures as cold as −85 degrees centigrade. It can be applied using various processes including dip or immersion coating, spraying and extrusion. It is used on both natural and synthetic materials to improve functionality or to modify the appearance and tactility. It can also be used for purely aesthetic purposes, as in the work of designer Eugene van Veldhoven (NL) who has applied it to a cotton/viscose boucle fabric to dramatic effect.

Combing several performance characteristics can require the use of separate processes. This can be because each needs to cure before the next is applied, or because different technologies are needed for each. Dimension Polyant's Formulan Grand Prix woven spinnaker fabric relies on a three-stage process to achieve the required finish. In the first stage the fabric is drawn through a resin bath to completely saturate the material. The second and third stages see a firm UCN resin applied to both sides of the fabric using an industrial knife coating process. This gives the finished fabric high durability and zero porosity.

15.4.4 Finishes

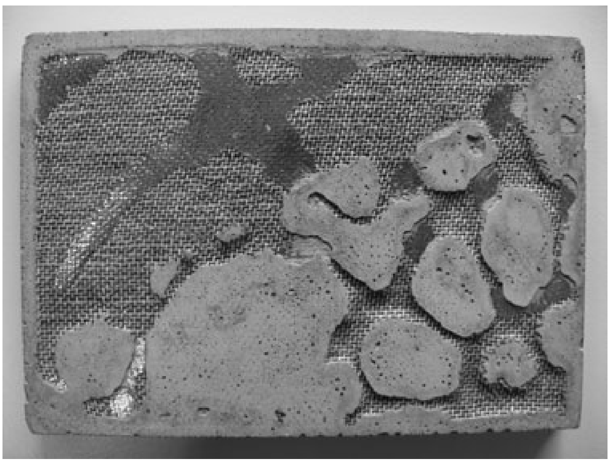
Finishing can be applied as a final process to a textile and is often used to perform a protective function or increase the longevity of the material. Dirt-repelling and flame-retardant finishes are two examples commonly available for applications that range from clothing to interiors and automotive. Finishes can also be purely decorative; embossing, devore and flocking are examples of this.

Embossing is a permanent relief surface made by a heavy metal press that translates a pattern to a textile. If a thermoplastic fabric, such as polyester, is used, it will respond to the heat treatment changing shape and making the result even more dramatic. Devore is a technique that sees the fabric eaten away by chemicals such as sulfuric acid, which is printed or painted on. This is then baked at a high temperature to burn out the design. To achieve this the fabric must have a portion of cellulose fiber, such as cotton or viscose. An alternative is to treat the portion of fabric to be printed with a resist paste. The outcome is a fabric with partially or totally removed areas.

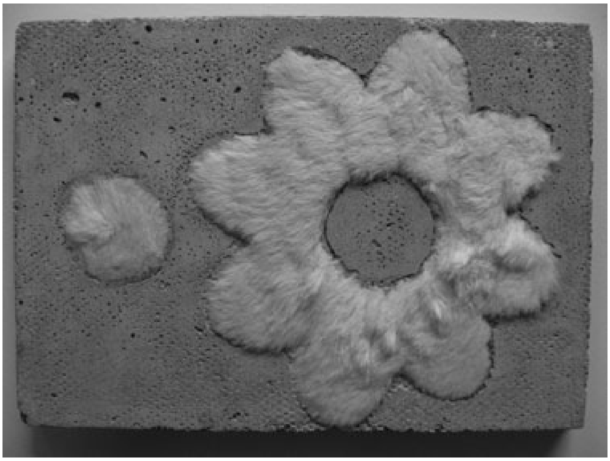
Protective finishes include anti-bacterial and flame retardant treatments. In the luxury clothing market, Scabal (Belgium) produce business class suiting fabric for men's suits. The fabric has a lightweight, airy construction and a nanotechnology applied finish. The special nanotechnology repels liquids and stains without changing the look or handle. Using fabric of up-twisted 2-ply pure wool yarn offers great crease resistance. The intention is to provide a high-performing sophisticated fabric that marries natural fiber with the latest technology.

In the medical market Gore Medical Fabrics (USA) produce Gore Comfortable Liquid Proof Fabric (CLIP). This is an ePTFE fabric designed primarily for use in surgeon's gowns. It provides protection against liquids, microorganisms and viruses as well as comfort. It has good tactile qualities and can be sterilized by steam. Gore Liquid Proof Drape Fabrics is a similar product but for the patient market in a heavier weight and with greater liquid absorption properties.

Flocking is usually applied as part of the printing process and adds texture to the surface. The flock is applied as tiny powdered fibers to the cloth. These processes have been around in various forms for a number of years, but the interest in them has grown as technology offers new possibilities and levels of sophistication in the design and application. Their use by designers has seen many of them elevated from a perception as a cheap process to one denoting luxury as a result. Flocking used to be regarded as a treatment for low-cost fabric and wall coverings. This perception is being transformed in the hands of innovative designers to create fabric for clothing and architecture. Reiko Sudo of NUNO (Japan) has designed a number of fabrics using flock to very different effect. In Graffiti, a fine white semi opaque polyester is used as the basis for a white flock treatment. It is used to offer a tactile contrast with the flock only slightly raised from the base material. In her design titled Calipha, Sudo uses a very different polyester base where the base fabric has been given a short taffeta effect of green and red coloring. The deep burgundy flock accentuated the red from the polyester to dramatic effect accentuating its sculptural drape. Tactility Factory (Northern Ireland) (Figs. 15.2 and 15.3) are developing a building product that combines different textiles with concrete for building. Included in the series is a flock fabric. The intention is twofold: to incorporate acoustic insulation into concrete and to transform concrete into a more human-friendly material by the addition of a tactile aesthetic. The result is intended for indoor and outdoor use with transformation as the result of weathering and ageing part of its quality. This is common for natural materials such as leather but less so for man-made which are seen as disposable once they show signs of patination.



15.2 Irish linen with gold leaf applied to the surface has been embedded in concrete as part of an ongoing investigation into acoustic concrete by the Tactility Factory. The textile element helps to provide sound insulation as well as providing a visual and tactile surface to the concrete (© Tactility Factory).



15.3 A flock print on synthetic fabric is used in this design by the Tactility Factory to provide a tactile and visual aesthetic to concrete, normally regarded as a cold material. The fabric has the additional benefit of providing acoustic insulation (© Tactility Factory).

15.5 Conclusion

The advent of increasingly sophisticated textile technologies is already seeing fabrics used in ways that even a decade ago would have been quite unexpected – from medical implants to solar cars powered by the sun's heat. The near future will see many of these applications refined and the growth of even better-designed products, buildings and clothing. Environmental concerns are having an impact on many industries, with national and international legislation starting to take effect. The automotive is one that has already been impacted in this way but the rest will follow. Though still some way off for many industries, textile manufacturers are taking action now. As an indicator, in the two years between the TechTextile Trade show in Frankfurt in 2007 and 2009, it was noticeable the increase in the number of producers who saw fit to introduce environmental credentials to their fabric specification sheets.

The relatively new processes of biotechnology, nanotechnology and even genetically modified organisms are starting to have an impact. The question is where will they lead to. The difference between these and conventional manufacturing or ways of producing materials and yarns is that they offer the possibility to design whole new materials that may owe more to science fiction than to traditional notions of fabric. These could follow demographic trends such as the growth in the elderly population who want to live longer, more independent lives. Clothing for this population might include heart monitoring or drug delivery systems that can be tailored to the needs of each individual and monitored remotely by their doctor. This kind of work is already in the research laboratories using existing technologies, in the not so distant future we may see these new technologies offer even smarter way of achieving these goals. The future will undoubtedly be one of smart materials and smart design.

15.6 Sources of further information and advice

BASF SE: www.basf.com/group/corporate/en/
Biopro: www.bioprotechnology.com/
Centexbel: www.centexbel.be/
DuPont: www2.dupont.com/DuPont_Home/en_US/index
European Space Agency: www.esa.int/
Gore Medical Fabrics: www.gore.com/en_xx/products/medical/oem/index.html
Grado Zero Espace: www.gzespace.com/
Issey Miyake: www.isseymiyake.com/
Kovio: www.kovio.com
NASA: www.nasa.gov/
NUNO: www.nuno.com/no-flash.html
Patagonia: www.patagonia.com/
Scabal: www.scabal.com/
Schoeller: www.schoeller-textiles.com/
Schoeller Spinning Group: www.schoeller-wool.com/
Smartfiber AG: www.smartfiber.de
Stanford University: http://www.stanford.edu/
Tactility Factory: http://girliconcrete.blogspot.com/
Tajima GmbH: www.tajima.de
TexOLED: www.izm.fhg.de/abteilungen/siit/forschung/. . ./texoled.jsp
TITV – Das Institut für Spezialtextilien: www.titv-greiz.de/
WarmX: www.warmx.de/

15.7 Further reading

Blaine, B (2008), *Transmaterial2 – A Catalogue of Materials That Redefine Our Physical Environment*, Princeton Architectural Press, New York.
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David, C (2008), *Futuro Textiel – Surprising Textiles, Design & Art*, Stichting Kunstboek bvba, Oostkamp, Belgium.
Hauser, J (2008), *Sk-interfaces: Exploding boarders – Creating Membranes in Art*, Technology and Society, FACT, Liverpool.
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Materio (2005), *Innovative Materials for Architecture and Design*, Birkhauser, Basel.
Seymour, S (2009), *Fashionable Technology – The Intersection of Design, Fashion, Science and Technology*, Springer-Verlag, Vienna and New York.

Plate XIV Rebecca Earley's printed garments focus on the environmental impact of the textile printing process. In her work she looks to reduce and refine existing techniques through processes such as the use of exhaust dyeing, reusing the dye bath several times to achieve a paler garment each time (© Rebecca Earley).

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