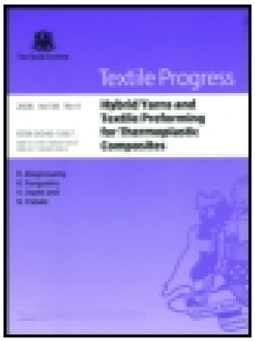

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THE PRODUCTION AND PROPERTIES OF STITCH-BONDED FABRICS

BY P. J. COTTERILL, M.SC.TECH., A.T.I., A.M.C.S.T.

1. INTRODUCTION

Over the past decade, there have been several contributions to *Review of Textile Progress* and later to *Textile Progress* that have been concerned with non-woven fabrics. These have invariably been wide-ranging in scope, as the very name would suggest, and such a review now tends to textbook dimensions. When each section under this heading is supporting a major industry, then it is clear that there must be much to report and discuss. We are witnessing the adolescense of several processes, some now mature, others gaining in breadth of experience. Consequently, there are many students and pundits poring over every bit of information that comes to light, some imparting worth-while knowledge and others making extrapolations that only time can confirm or condemn.

This particular review is confined entirely to stitch-bonding and basically covers the comments, innovations, and deliberations of the 1970s to date. Before proceeding, it is revealing to note the growth of interest in stitch-bonding by recording its appearances as a topic in *Review of Textile Progress* and in *Textile Progress* and noting the space devoted to it.

The first mention is by Barr[1] in 1959, where he refers to the chain-stitching of carded webs: an appearance, but only just. Again, in 1961, Barr[2] refers to chain-stitching, and it appears that, apart from references to Russian, East German, and Czech writings, little progress was being made. More interest was shown in the fleece fabrics, i.e., those without stitching threads.

In 1964, Smith[3] mentions Arachne machines, but again, apart from referring to Russian and Czech experience in wearer trials, concentrates his text on the fleece fabrics. In 1967, Burnip[4] has much more to report, and the term 'stitch-bonding' is introduced into the title of the section. Some insight into patented inventions is also given, and these show much greater expansion, both geographically and in content. In their later review[5] in 1970, Burnip and Newton consider stitch-bonding in some depth, and this is the starting point for the current review.

2. DEFINITION OF TERMS

The author does not wish to join in any controversy over the meanings of words, but it is useful to define terms used in this review for the sake of clarity. As will be seen later, the machinery employed in stitch-bonding can be used in many ways, so the process being carried out at any time needs to be defined. Words that appear frequently in this context are explained below.

Web or Fleece: A mass of fibres formed into a full-width batt by the use of a textile card, web former, etc. As such it has no measurable mechanical properties.

Substrate: Any material fed into the stitch-bonding machine that already has recognizable mechanical properties and can be used without further treatment (for instance, needled webs, woven or knitted cloths, films, etc.).

Stitch-bonding: A primary process in which fibres or yarns are stitched, or formed into stitches, to give a coherent fabric, or in which fibres and yarns are simultaneously stitched to give a coherent fabric (Fig. 1).

Overstitching: A secondary process in which yarns, fibres, or yarns and fibres are stitched into a substrate or substrates for purposes of reinforcement, decoration, formation of a pile, etc. (Fig. 2).

Apart from incorrect usage of terms, as given above, some looseness in the use of the term 'stitch-bonding' has recently occurred. Bradshaw[6] classifies the Pickering Locstitch

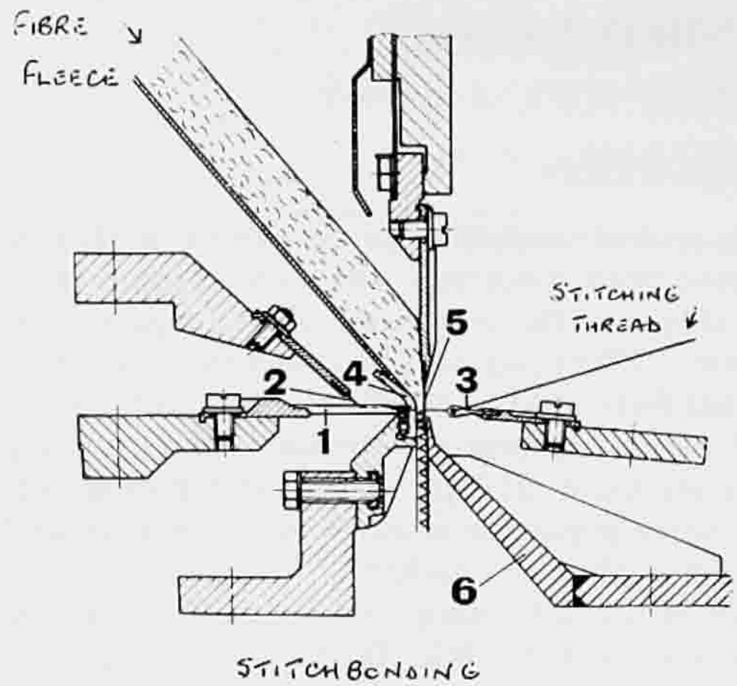

Fig. 1
Stitch-bonding

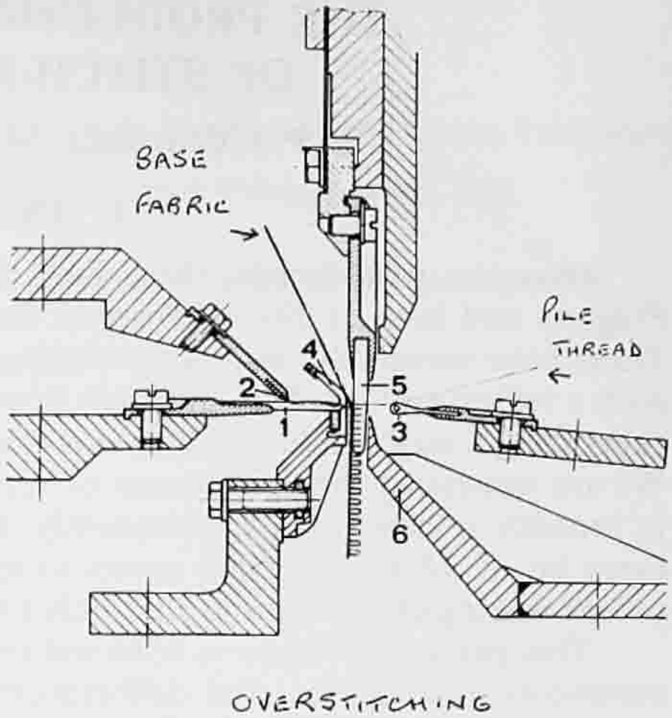

Fig. 2
Overstitching

and Trent Kraftmatic as stitch-bonding machines; at best, they are overstitching machines, a category that could also include domestic sewing machines.

The Textile Institute's definition, as given in 'Textile Terms and Definitions'[7], embraces both stitch-bonding and overstitching as described above.

> *Stitch-bonded fabric*: Fabric in which fibres, yarns, fibres and yarns, or fibres and a ground fabric are held together by subsequently stitching or knitting-in additional yarns.

The use of the word 'subsequently' raises some queries. The definition apparently denies the existence of the continuously linked process lines, particularly for Arabeva and Malivlies, and assumes that all processes are broken and fed by rolled and needled laps or some other substrate. In the continuous processes for these fabrics, and indeed for Maliwatt and Arachne, fabric is only formed at the moment of stitching, and before that there are yarns and fibres, two separate entities, neither of which is in itself a fabric. Again, Malimo is only a yarn lattice until the moment of stitching by the stitching warp.

3. MACHINERY AVAILABLE FOR STITCH-BONDING

It is possibly a little surprising that textile-machinery makers have not produced new versions of the original stitch-bonding machines. When one considers some of the estimates of likely production that were made in the 1960s, serious thoughts must have stirred in the minds of development technicians working with tufting-machinery makers, sewing-machine makers, and warp-knitting-machine producers. Indeed, as was mentioned in the Introduction, developments in tufting machinery have been classified as stitch-bonding machines. Apart from these, there has been no new stitch-bonding machine since those described by Burnip and Newton[8] were developed. However, there has been a considerable increase in the range of machinery available, with many variations on the basic machine. As will be discussed in a later section, the range of fabrics that can be made is now much wider. It is a little ironic that a well-known British loom maker has recently produced a machine that makes a looped terry cloth, very similar to the true stitch-bonded article that was designed to replace woven terry cloth!

These machinery modifications have been the subject of many articles, many of them being very close copies of the makers' catalogue. Details of machines can be obtained from the makers[9] or their agents[10,11,12]. As many reviewers and chroniclers have found, it is extremely difficult to obtain information about the Russian ACHV machines, and the details of any modifications from the basic chain-stitch machine can therefore only be guessed at. Since these machines appear to be enirely within the Russian sphere, perhaps lack of detail is not a major drawback, however unsatisfactory this may be to author and student alike.

The Arachne catalogues give basic details of all the variations, photographs and drawings of the machines, and illustrations of some of the fabrics that can be produced. The drawings are very familiar to any student of stitch-bonding, since they have been reproduced in many papers. A selection of stitch patterns is also given. As with all machinery catalogues, favourable comparisons are made with other methods of production regarding speeds of fabric formation, space, power, etc. It was pleasing to note that there was a pamphlet dealing with all the variations that are available: a definite 'plus' point compared with some other machinery manufacturers, who have machines on sale for years without producing any up-to-date literature relating to them.

The Malimo catalogues are almost identical in content to those of their competitors. The range and amount of information are similar, and the machine diagrams are rudimentary. The presentation has been 'Westernized', the clothes illustrated being modelled, and again there is something about every variation.

It is not intended here to detail any of this information, but, for the benefit of the casual reader, and for the reviewer's later convenience, Table 3.1 lists the name given to each process by the two main manufacturers.

Table 3.1

Name		Raw Materials
Arabeva	Malivlies	Loose staple-fibre web only
Arachne	Maliwatt	Loose fibre web with stitching warp or warps (Arachne)
Araknit		Stitching warps only (warp-knitting)
Arutex	Malimo	Stitching warps binding weftway yarns
	Schusspol	As above but with extra pile warp
Araloop	Malipol	Stitching warp as pile stitching into a base cloth or web
	Voltex	Loose fibre web as pile stitched into a base cloth
Bicolor Araloop		Stitching warps knitted into both sides of a base cloth on a double needle bed
	Liropol	Triple-warp machine forming double-sided pile

From here on, wherever it is pertinent to do so, the author will denote the fabric type being made by these names. This will also, in many cases, identify the machinery being used, since plants with both Arachne and Mali machinery are relatively rare, except in research institutes. There have been numerous descriptive articles about the various machines, and the particular types described are indicated below.

As was mentioned in the Introduction, some of the later developments in fine-gauge tufting machines and pile-anchoring machines have been classified wrongly as stitch-bonding machines. The fact that the same type of products can be made on all these machines has led to articles dealing with them, and, for the benefit of those who may wish to compare the machines and the products, there are three articles that do just that. The first is descriptive of the machines[13], and, in other articles, Kirchenberger[14] goes a little further and discusses the products from each type, and Ward, particularly with reference to double-sided terry cloth[15], performs a similar task.

Articles that deal almost entirely with machinery may be found as follows. Only one description of the Russian stitch-bonding machine is given, and this deals with the ACHV 1802[16]. Descriptions of the BEFAMA–Mali and Malivlies machines are also given[17].

The first of these machines is an arrangement of carding, web-laying, and stitch-bonding in one production line to give a flow from fibre to fabric in the one machine. This practice has been adopted by several manufacturers and removes the need for web consolidation or rolling of webs before stitch-bonding. There are, of course, advantages and disadvantages of each method, one requiring careful balancing of production rates and the other great caution in the amount of web consolidation that is needed. When one considers the speed of fabric production in stitch-bonding, one can understand the attractiveness of a continuous linked system. Web preparation has been omitted from this review, since it has been dealt with extensively in previous reviews on the production of non-woven fabrics. Suffice it to say here that, in the course of preparing this review, the author has come across several papers dealing with needling webs for stitch-bonding and the effect of needling intensity and distribution on the strength of the final product.

A general view of Mali continuous lines is given in a paper by Ploch[18], originally presented at the colloquium on non-woven fabrics at Brno in 1970. This comments on the problems and describes how the machines are linked. A more recent article on the same theme is that by Sobelevskaya[19]. The Aravzor process is described[20], and further details are available in an article by Pillar and Kochta[21], which gives the Elitex standard information on the process. The double-pile Bicolor Araloop machine caused some comment when just launched and was featured in various articles, most of these struggling to explain the complications of the process from the original Arachne drawing[22–24]. The machine for single-sided pile cloths, the Araloop[25], and its counterpart, the Malipol[26], have been described. The other Malimo pile machine, the Schusspol, is described in a series of articles devoted to this machine and its products[27,28].

The Voltex machine is described in an article concerned mainly with the fabrics produced[29]. This variation is so far in very limited use, and detail on the behaviour and characteristics of this type of machine therefore remains minimal. Since there are many competing forms of making fur fabrics and plushes, one looks forward to some meaningful economic comparisons in due course.

Even less information is available about Liropol, the newest of the Mali range, which is shown in Fig. 3. The only detail so far seen has been that contained in the manufacturers' pamphlet[30]. This machine produces either single- or double-sided pile fabrics but, unlike

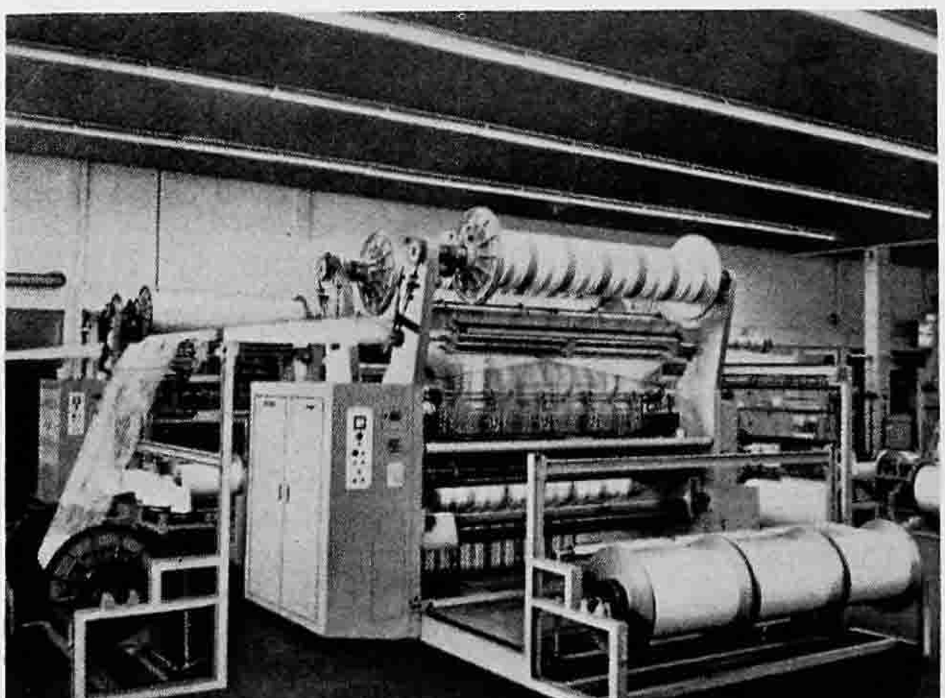

Fig. 3
The Liropol triple-warp machine, forming a double-sided pile

the other pile machines, uses no base fabric. It is based on the Malimo machine, 'weft' threads being provided from beams at each side and the pile and stitching threads again being taken from warps; the stitching threads are on warps behind the operator's platform—as in Maliwatt—and the pile beams are in the warp-knitting position above the machine. The machine is claimed to produce superior terry fabrics with good resistance to pile deformation and weftway slippage. Up to four widths, with interlaced firm selvedges, can be made, the total width being 180 cm, with a weight limit of 600 g/m^2, at a speed of 500 rev/min. All the usual terry patterns can be made by using part-set threading, coloured yarns, etc. Open-end-spun yarn, even in singles form, is recommended.

In a general article on machinery, particular attention is given to the Arutex attachment[31].

Other articles that contain descriptions of all the Arachne range[32–36] and all the Mali range[37–40] go on to further matters. Three more papers give details of both ranges, two in detail[41,42] and the third[43] in brief, since it is part of a much longer paper on machinery and methods.

4. TEXTBOOKS, MANUALS, AND GENERAL REVIEWS

The content of this section is intended largely for students, both those in the stitch-bonding section of the textile industry and those still at college. In view of the scarcity of informed literature on stitch-bonding, it would be remarkable indeed if a textbook devoted to this had been published. The nearest equivalent is probably the standard Arachne textbook[44], which, because of the Czech language in which it is written, is limited to a narrow readership. This volume was published in 1971 as the standard handbook for technicians and operatives in the factories producing Arachne cloths, and, in addition to machinery settings, etc., gives information on production calculations, power consumption, faults and their correction, finishing of cloths, and the end-uses of cloths, these being related to Eastern European standards, which are not necessarily Western standards.

The corresponding volume for the Mali range, this time in German, is written by four of the VEB technicians[45]. This is also intended for knitting management and technicians working on the machines and gives running details of the range of machines. Again, it provides little more detailed information than is available in the Malimo advertising literature.

A more balanced view is presented in an excellent little German book by Kirchenberger[46], a well-known writer on stitch-bonding topics. The book is confined to machinery and has no other information but can be recommended to students of all nationalities, since the diagrams and photographs alone show the variations possible on each machine for the Arachne and Mali types. Apart from several pamphlets that are headed 'Stitch-bonding', the author was unable to locate any other volumes dealing specifically with stitch-bonding. One such pamphlet, by Dawson[47], gives a good survey of general stitch-bonding methods, and, although he deals with the Mali range in particular, the general principles are stressed rather than the machines. There is also some mathematical treatment of the fabric geometry, and a general discussion of outlets and fabric properties is included. When one considers the volume of material now available, it is surely not too much to expect that an English-language textbook devoted to stitch-bonding will appear before the end of the decade. Until that time, English-reading students at least will have to put up with phrases such as 'fantastic production rate', and descriptions of 'sew–knit' fabrics usually referring to Malimo with the odd mention of Arachne and Maliwatt. A quick run through all the English textile textbooks generally available did not produce anything worthy of a positive reference. The few books that mention 'sew–knitting' do so, as they often say, 'for the sake of completeness' in a few lines.

However, stitch-bonding technology is given a very definite mention in Krcma's book[48]. This volume is widely regarded as the best book available for students of non-woven fabrics. Although we are only concerned here with stitch-bonding, the reader will find it impossible to read this book and not absorb some of the general technology of rival methods. Apart from one chapter where individual methods of production are discussed, the book is so arranged that knowledge of all types of non-woven fabrics is acquired. The book deals with all relevant matters, from raw materials onwards—at some length with adhesive bonding—and enters into the vexed area of terminology and classification of non-woven fabrics. The chapter on stitch-bonding—not including web formation and preparation, which are also dealt with—is a little disappointing. Diagrams of stitch formation are shown for the Arachne machine with one guide-bar, these being followed by a single drawing that is allegedly of a Maliwatt machine with two guide-bars. Since this was basically an English translation of the earlier (1969) German version, the later techniques are not mentioned. However, Arabeva fabrics are discussed, and the use of the Arabeva machine for making stitched laminates is mentioned. Despite this mild criticism, much information can be gleaned from this book, and it is well recommended.

Another volume that again deals with non-woven fabrics as a whole is the compendium of papers presented at the University of Manchester Institute of Science and Technology in December, 1970, and entitled 'Non-wovens '71'[49]. This book has various chapters dealing both partly and exclusively with stitch-bonding. It includes a paper of the review type by Burnip, who mentions all the variables then available. A second chapter by the same author presents in detail the physical properties of stitch-bonded cloths. This type of information is vital for the user and finisher of the material and is normally conspicuous by its absence. As will be seen by the reader, stitch-bonded fabrics have unusual physical properties, and these are all noted and tabulated. End-uses, both actual and expected, are dealt with by Noble, who considers marketing and surveys the products from each machine variation to give the student a good idea of the range of fabrics that can be made. Further mention is made in the chapter on design—'the most versatile non-woven'—and in the editor's survey of non-woven fabrics, where stitch-bonded fabrics are classed as being of the durable non-woven type, which should command a price worthy of their properties. Again, in this chapter, the illusion that non-woven fabrics are the last resting place of the world's waste and doubtful fibre is shattered.

A French book, also on non-woven fabrics in general, contains a chapter on mechanical bonding[50]. As with Krcma's book, odd bits of information about stitch-bonding appear in the chapter on end-uses, testing, and general properties of non-woven fabrics.

The sort of information available to weavers and knitters in the way of settings and machine conditions for other than routine cloths does not at present exist in the stitch-bonding section of the industry. A start has been made by giving details of the various patterns that can be knitted on two-bar machines. As more companies become involved in the trade, and machines at technical colleges are used regularly instead of being the subject of an occasional lecture, then more detailed technical information should be available.

A large number of general reviews of stitch-bonding have appeared in the period under consideration. The amount of new information contained in these is, in general, very small. Most authors tend to start their paper with a summary of either the Mali or Arachne machine range. As was previously mentioned, these tend to be almost identical to the makers' catalogues. One reason for this is that many of the papers are given by staff of either Elitex or VEB, the manufacturers in question. Another reason is that very few people have actually worked in commercial stitch-bonding plants, and most of the material that they require on machines is therefore only available either from the makers of the machines or from what is seen at machinery exhibitions.

Reviews on the Arachne range form a large part of several articles[51–54] and those on Mali range a similar proportion of other articles[55–57]. Another useful article that lists both Arachne and Mali machines and compares their products is by Neumann[58].

During the period under consideration, there was, of course, one event that was in itself a review of the whole stitch-bonding field, namely, the ninth symposium on non-woven fabrics, held in Brno, Czechoslovakia, in November, 1970. This conference was devoted entirely to stitch-bonding, and most of the authors mentioned in this review presented papers. On checking the papers of this conference against later work by the same authors in technical publications, it is evident that there are many that are straightforward repeats or basically similar papers with later additions.

A fair proportion of these papers contained general reviews, two papers in particular being of this nature. The first paper on Arachne machines by Kriz[59] deals initially with the derivation of the word 'Arachne' in a 'fairy-tale' manner and then discusses the initial development of the machines up to the late 1960s. The remainder of the paper gives figures of cloth production in Czechoslovakia and the general breakdown into various sectors of the industry. Some of these figures are indicated below in Section 8.

The second paper, by Kochta, again deals with Arachne[60]. This is a very simple discussion paper and concentrates very largley on simple Arachne structures, with details of the use of chain and tricot knitted structures.

Finally, for those readers who have a good grounding in stitch-bonding principles and who wish to see the full scope of the machines, a survey of the patent literature is worth while. Although this is gruelling work, many patents, particularly those claiming fabrics, incorporate a great amount of detail in the form of examples and finishing treatments, etc., which give a very broad picture of the state of the technology.

5. MODIFICATIONS AND PATENTS

5.1 Introduction

In this discussion of patent material, the author wishes to make it clear that only patents filed in the United Kingdom or the United States have been considered. This has been done partly because of language problems but mainly because any invention worth patenting tends to be filed in one or other of these countries as a matter of commercial common sense. Basically, the patents are split into methods and fabrics and further grouped into sections under these two headings.

A study of patents makes one aware of the large volume of time and money that has been spent on research and development by various firms in the stitch-bonding section of the textile industry. Naturally, the machinery makers feature largely in these lists, but several fabric manufacturers have patented very worth-while ideas. Some firms that appear to have done much inventive work are no longer engaged in stitch-bonded-fabric production.

The original machinery patents were granted in the 1950s and 1960s. These laid out the parameters for making cloth and, for the Mali machines, chenille yarn. As has been mentioned previously in Section 4, the patent literature makes very useful textbook material for serious students. Because of the constricted nature of most patents, it is better to have a general idea of the machinery and process involved before attempting to understand patents. Once the principles have been assimilated, the patents give one an excellent idea of the scope of stitch-bonding.

5.2 Methods

The process now known as Voltex is described in a patent granted to Ploch[61]. In this process, a base fabric, which may be anything from a web or foam to a fabric, is fed to a Mali machine; even threads, as in a Malimo fabric, may be used. A fleece is then overfed into the machine at the front and knitted into the base fabric. Pile is formed by passing over a pile comb, which determines the pile height. Many means of feeding in the fleece are claimed, in addition to colour variations, shrinking, and shearing to vary the product finally made.

A method for putting decorative extra threads on a cloth is described in a patent by Burlington Industries[62]. The use of extra warps laid in under a tricot stitch is already known, but this device describes a method of traversing these ends to give a sewn-down thread on one face of the fabric. This can be done during the manufacture of the stitch-bonded fabric or as an overstitch on a base fabric.

A method of making a chenille-like yarn is claimed by Monsanto[63]. In this, a stitch-bonded Arachne fabric is made by using a bulkable continuous-filament web. After bonding, the web is slit between the chain-stitch wales. The yarn is bulked by means of wet heat to give a velvet-textured yarn. This method is hardly new, since it was used long before stitch-bonding was recognized as being a fabric-production method, and Mauersberger[64], in an early patent, also describes a method of making a chenille yarn.

A very significant advance in stitch-bonding was the elimination of the laddering tendency of single-bar chain- and tricot-stitch fabrics. Cosmopolitan Textiles' patent specifications cover this development[65,66]; curiously, there is an almost identical specification for Malimo[67]. By a simple machine modification, resulting in no extra processing costs, a fabric is produced that has an identical appearance and properties to those of conventional stitch-bonded fabric, with, however, the added advantage that the warp-thread stitches are locked by fibre-stitch loops. This is well illustrated in the VEB patent, which shows a fabric being unravelled[67]. The methods used to achieve this are, of course, different, but the end result is the same. This method only works where a fleece is being stitched and is particularly relevant to the single-bar fabrics.

The patent for Bicolour Araloop describes the mechanical conversion of the Arachne machine to form a cloth with pile on both sides in one operation[68]. This is a double-needle-bed machine, that is, it is really two machines back to back. It is not easy to appreciate the fabric construction unless the ordinary single-pile machine is first studied.

A very novel method of producing fabric from splittable film is described in another patent[69]. In view of the increasing use of split-film yarns and fabrics, this could be a patent of considerable value. Basically, a machine set up for a Malimo-type operation feeds in film for a base and cross-laps this with another such film, so that two films oriented at approximately 90° are fed to the needles. These then split the two films in opposite directions to provide warp and weft threads, which can next be stitched with either a conventional thread or with yet another splittable film fed through the guide eyes and split by them (see Figures 4 and 5). Many variations are included in this interesting patent.

One of the problems that occur in the knitting of fleece-only fabrics, such as Arabeva

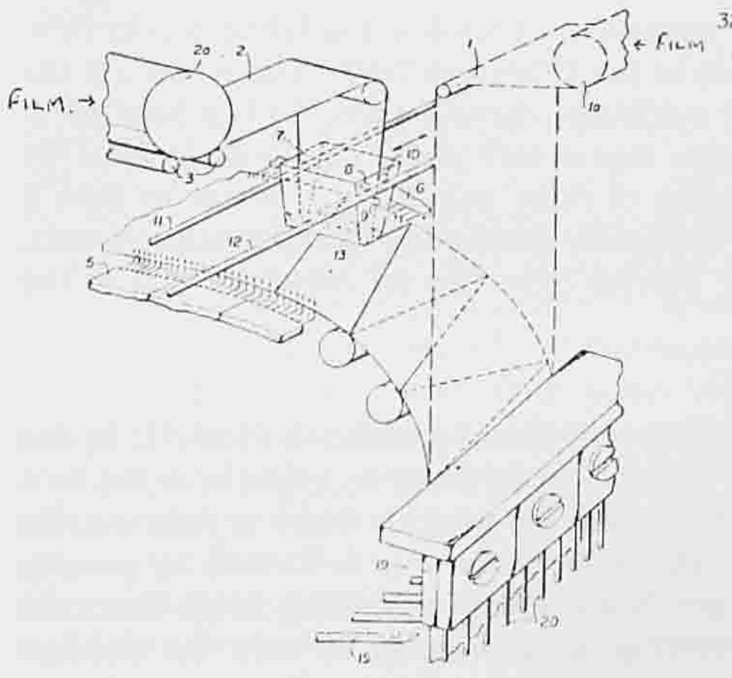

Fig. 4
Method of producing fabric from splittable film: feeding of two films oriented at 90°

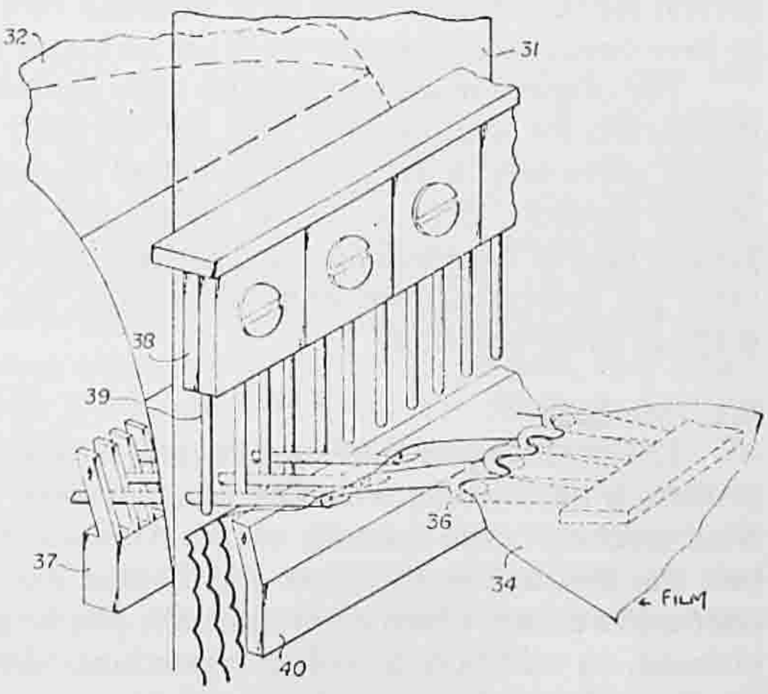

Fig. 5
Method of producing fabric from splittable film: splitting of films to provide warp and weft threads

or Malivlies, is that, to obtain dense fabrics with sufficient strength for further processing, considerable fleece weights are required. This results in the machine's trying to knit far too many fibres per stitch, the outcome being excessive fibre, or needle, breakage. To alleviate this, a patent by the Forschungsinstitut, of Karl-Marx-Stadt[70], has a standard Mali machine with a special indented front plate; this effectively corrugates the fleece at right angles to the needles and, because the needles have a fixed stroke, ensures that fibres are taken from different positions in the fleece—some from one side, some from the centre, and some from the far side, all on one course. By altering the pattern on this plate, which is normally a series of elements, on every course, fibres from different layers may be taken on each needle, but the device is so arranged that needles do not attempt to knit all fibres across the web thickness. Pattern effects on each side of the cloth, including colour changes, are possible by using coloured layers in the web.

One arrangement for Araloop fabrics is described in a patent by Elitex[71]; this is an overstitch method whereby a base fabric is passed through a machine equipped with special sinkers and combs that extend each stitch into a surface loop. Recognizing that stitch-bonded fabrics of the stitched-fleece type tend to have poor weftway tensile characteristics, Elitex have devised a method of providing a laid-in transverse thread[72]. A conveyor is arranged to feed in separate weft threads, which are positioned in the stitching zone, so that they are bound down under stitching loops. According to the relevant patent, this makes possible the production of fabrics for outerwear, since it prevents bagging due to irrecoverable stretch. Before going on to discuss patents concerned mainly with resulting fabrics, the reader may find some of these machinery patents easier to understand if he consults one or two of the basic stitch-bonding-machinery patents, which give considerable detail[73–75].

5.3 Fabrics

The range of fabrics that have been patented gives some indication of the way designers have sought to exploit this remarkable technology. When one considers that the ratio of failure to every success must be at least 10:1, the few fabrics mentioned here constitute only a minor proportion of those attempted. One fabric that was ahead of the machinery designers is a simulated corduroy fabric made on an Arachne machine[76]. A two-bar fabric is made with a chain-and-tricot stitch, which throws the fleece into relief on the face of the fabric; the fleece is then cut part through between each wale to give a burst similar to that of woven cord fabrics. This type of fabric is now made by the Malipol and Araloop types of machine.

Another Archne fabric to give a surface effect is described in patent by V.U.P. of Czechoslovakia[77]. Various types of atlas, tricot, and open loops are used on each bar to give tight and open parts in the stitching. In addition, the use of part-set threading on either or both bars allows the fleece to be very clearly visible on the fabric surface on some areas. If the fleece is allowed to attain bulk in finishing, surface texture will develop, especially if, as is suggested, the fleece has components of different shrinkage characteristics, the higher-shrinkage fibre being used to contract the structure and force the other fibres out from the body of the fabric.

The use of a stitch-bonded fabric for blankets is described in a Lantor patent[78]. A fabric is made in which the fleece consists of a portion of fusible fibres. Further webs are needled to this base, and the whole is then subjected to a heat process, during which the fusible fibres in the stitch-bonded carrier bind in the pile without any surface harshness, since all the fusing remains in the centre. This treatment also improves the fabric stability.

Another fabric to use shrink fibres is described by Société Rhovyl, who employ their own PVC fibre[79]. In order to obtain bulk and stability in fleece fabrics without running into problems already mentioned, shrink fibres are blended into the web, which is then knitted into a fabric of 150–300 g/m^2. By heating, this can be at least doubled in weight to give a firm and stable product, suitable for insulation, flooring, hat-making, overcoats, etc.

Fabric economics when this method is used may cause some concern in view of the extreme negative yield in cloth area.

A clever use of a variable fleece is described in a patent for an electric-blanket fabric[80]. A two-sided fabric is formed by stitching a two-layer fleece of, say, viscose rayon and PVC fibres. Two such fabrics are then placed with the thermoplastic faces inwards and are fused to pattern to weld the two together, channels or pockets being left into which the heating element can be introduced. The outer layers may be raised before fusing if required. Another electric-blanket pad, in which foam or sheet is used as the fusing material, is described in a further Lantor patent[81]. The machine is used as an overstitcher to laminate various layers for pile and fusing. The manufacture of the blankets from two such fabrics is then as previously described.

Another variation on the shrink-fibre fabric is given in a patent by V.U.P.[82]. This time the stitching threads are in part shrinkable and are combined with pattern-knitting to give a sculptured fabric.

A method of making a double-faced pile fabric on a Voltex machine has been patented[83]. A straightforward Voltex plush is made; this is then fed through another Voltex with the pile side on the back, so that the second pile goes on the opposite face. Variable heights, colour, etc., can be used on each side to make rugs, filters, and any other article requiring a 'voluminous textile piece', as it is described.

Stitch-bonding is used to create greater effect in woven jacquard fabrics[84]. Any woven jacquard fabric is bonded to a substrate so that the lines of stitching throw up the warp and weft floats in some areas and intensify their visual effect. By varying the stitching pattern, greater or smaller effects can be achieved.

The use of Voltex fabric as a blanket is a logical development[85]. The ground fabric is a Malivlies type of fabric or needled fleece; this is then stitched with a pile fleece, the stitch side of the base having pile applied. This allows raising of the pile and raising of the fleecy side of the base without destroying the stitches of either but embedding them even more inside the raised structure.

Basic Voltex pile fabrics and their manufacture are described in another patent[86].

The use of stitch-bonding machines for making laminates is not new. This technique appears to have found more application in the U.S.A. than elsewhere. One company in particular, Beacon Manufacturing, seems to have laminated all manner of fleeces, foams, and fabrics in double and triple layers[87–92]. All these were intended for blankets or bed covers. These represent a second series of experiments, since there was a similar burst of activity in the 1960s. The company has since discontinued the manufacture of stitch-bonded fabrics.

Another overstitch application, where the stitching is used as straightforward reinforcement, is in a patent by Indian Head Mills[93]. In this case, foam used for interlinings or insulation is made more resistant to subsequent manufacture. In other applications, paper is reinforced for use in cable-wrapping. An earlier application by the same company[94] describes the use of foam as a sub-fleece in the formation of a corded structure. Because of its resiliency, the foam, being bound from the bottom by tricot stitches, pushes up the fleece above it between the part-set chain-stitch wales to form the cords.

The very opposite effect is claimed in a patent by Uniroyal[95]. In order to obtain a smooth surface for coating in simulated leathers, etc., the cloth is stretched widthways to pull down the fleece ribs that are so much a feature of most stitch-bonded cloths. A stretch of up to 33% is used, which, from the test results given, does not impair the weft strength but reduces warp strength owing to the inclusion of fewer stitching threads per unit width.

These patents are only a selection of those filed and granted during the period under review. Because of the long delay between filing and publication, most of these are pre-1974, so plenty of interesting developments from the newer machine variants should soon be issued, such as Schusspol, Liropol, and Bicolor Araloop fabrics. However, these do show some applications that have been pursued beyond the uses for which the machines were primarily designed.

The final patent that is worthy of discussion is of a mathematical nature[96]. The applicants note that the main causes of poor performance in stitch-bonded fabrics, particularly of the Arachne and Maliwatt type, is slippage of the fleece fibres. Of their own accord, the only cohesion is by inter-fibre friction; this is improved by pressure from the stitching threads. However, the normally occurring forces of distortion tend to overcome this resistance, which causes a non-recoverable weftway extension. This is a property, however undesirable, that is unique to stitch-bonded fabrics and has largely ruled them out of the end-uses, particularly clothing and upholstery, for which they would otherwise be ideally suitable. It is because of this defect that the overstitch cloths described before have become so important to stitch-bonding and its commercial development. These all rely on the properties of the base fabric to give stability, the added yarns and fibres being left to provide bulk and surface-wearing properties. The patent describes a mathematical way of calculating the cloth structure necessary to provide sufficient fibre-binding and anchorage, so that the weft strength tends to approach the fleece-fibre strength. This then makes the cloth equivalent to a woven or knitted structure, in which the same parameters provide ultimate strength, albeit aided by twist and the weave structure, which provide extra composite strength. Basically, what the patent claims is a cloth with a much greater number of stitches/cm than normal cloths in commerical production. In the examples quoted, the cloths had stitches ranging from 90/10 cm up to 240/10 cm. This is applied to fleeces in weights ranging from 400 g/m^2 down to 70 g/m^2, respectively, so that the average fabric is both heavy and of very close construction.

The number of stitches/10 cm is determined by the equation:

$$N = \frac{7589{\cdot}46}{\sqrt{T}} + 100\,B\left(1 - \alpha + \frac{151{\cdot}7{,}9}{B\sqrt{T}}\right),$$

where $B = 2{\cdot}88\,G/TM\gamma\,(0{\cdot}483 + \alpha)$,
$G =$ specific weight of web in g/m^2,
$T =$ binding-thread linear density (den),
$\gamma =$ specific gravity of fibre in web in g/cm^3,
$M =$ filling coefficient (0·40),
$\alpha =$ constant = zero for webs up to 200 g/m^2,
(or = 0·0026–0·400 above 200 g/m^2).

If there is more than one stitching warp, then

$$\sqrt{T} = \frac{(\sqrt{T_1} + \sqrt{T_2}, \text{ etc.})}{n},$$

where $n =$ number of warps.

If the reader cares to try out this formula on commercially available fabrics, he will marvel at the fact that they have any weft strength at all, since the number of stitches indicated for blocking will be higher than those of his sample by a considerable factor.

Economic production rates and the mechanical ability to produce such fabrics must weigh heavily against structures as described in this patent. Indeed, several of the prescribed end-uses are those that are most competitively quoted for other methods of production. Nevertheless, the applicants have recognized a problem and put forward their solution.

6. PRODUCTION PROBLEMS AND METHODS

In this section, it is intended to discuss the work that has been done on the general production of stitch-bonded fabrics, new types of fabric, and the difficulties encountered in their production. The range of fabrics that have been produced commercially has certainly matched the expectations of the machinery manufacturers. Without details of the size of markets obtained, it is often difficult to separate the fabrics that are made in research institutes, by teams of expert technicians, from those that can be produced commercially by average technical staff under normal production conditions. As far as the reviewer is aware, all work in this section refers to feasible constructions and actual mill conditions.

The introduction of Araloop machinery into a carpet mill in Czechoslovakia was described by Kavan at the Brno symposium[97]. The reasons for choosing various types of backing fabric or web, the choice of yarn creel rather than beaming, and the determination of the best loop-yarn linear density for the particular end-use were all given in reasonable detail. The possibility of setting up a continuous production line, with a jute backing web used, was apparently considered, but the idea was not adopted. A costing exercise against tufting and raschel machines was also undertaken before Araloop was installed. Some of the problems encountered in running in were then mentioned, in particular, many yarn faults that would be neither expected nor tolerated in Western Europe. The expected production-fault rate of one fault every 20 linear metres is again not very good.

An installation of Arachne continuous-production lines was described by Nosek at the same symposium[98]. Details of the machines used were given, and there was considerable discussion about the pneumatic feed to the production lines from the opening section and the problems experienced with this. Effects of feed variation on the resulting fabric quality were noted; this appeared to be the biggest problem in the plant of ten units.

The production of asbestos stitch-bonded fabrics was detailed by another contributor to the symposium[99]. Asbestos fibre is not easy to handle, and its appearance in a stitch-bonded version is perhaps a little surprising. At the time of the report, manufacture had been going on for some five years, so this was definitely not a research project. Most of the problems were caused by dust from the fibre and by extraneous matter in the fibre. Laps were made and successfully knitted in a chain–tricot structure on Arachne machines. Proposals to make better heat-resistant fabrics by using glass stitching yarns were mentioned, development work having already been done on these fabrics.

Several authors have discussed the installation of continuous production lines. Details of Maliwatt and Malivlies continuous lines are given by Ploch and Scholtis[100]. The Cross-folder, for transferring card webs into transverse layers before feeding to the Mali, is described, and the linkage of the machines, to allow stops to be made without loss of the web, is also detailed. A Voltex continuous system is also described; this uses dual cards to feed a conveyor, since the fibre in this case requires orienting in the machine direction for pile insertion.

Glaser[101], in a paper on Malimo fabrics, discusses the production of light fabrics for curtain nets and sheer fabrics. These, being the oldest of the stitch-bonded types, seem to receive little attention nowadays, mainly because the products tend to be expensive compared with woven cloths for similar end-uses. Various productivity details are discussed by Glaser: the economic advantages of long warps of fine yarns, patterning facilities, and the wide range of curtain cloths possible. The domestic German market was considered, and types such as 'burn-outs' and others peculiar to Continental Europe formed the bulk of the work. Some lightweight Maliwatt structures were also included.

The finishing of Voltex pile fabrics was the subject of an interesting article[102]. Although this discussed the production of these fabrics, it was chiefly concerned with the finishing treatment of the stitched fabric to produce satisfactory pile effects. Constructions were detailed, and techniques such as backcoating, raising, polishing, and pile-laying, suitable to each construction, were described.

The production of fabrics now known as Aravzor types is discussed in two articles[103,104]. These do not deal so much with production methods as with techniques and stitch patterns. Details are given of the sort of threading and pattern chains to use to give the maximum relief effect. Methods of heightening this effect on the surface, by the use of shrink fibres in the web or the use of shrinkable binding yarns or both, are described.

The article is well illustrated with stitch patterns and cloth photographs and mentions the methods of finishing that were used to develop and stabliize the pattern achieved.

Machine-settings used in the production of Schusspol pile fabrics were given by Hansch and Dübler[105]. The manufacture of carpets forms the bulk of the work, and, after a discussion of the production of the cloth, methods of dyeing and finishing the carpets are reviewed. Material on Schusspol is relatively rare, and this article is worth-while reading for those interested in the heavier end of the stitch-bonded trade.

A general paper on Arachne production methods gives details of machine layouts[106]. The bulk of the work, however, discusses fleece types to use and threading and stitch patterns. The cloths that result are illustrated and general production problems discussed.

More production details about fur fabrics and plushes are given by Rotgers[107]. This paper is largely a comparison of the various types but again details finishing treatments for Malipol, Araloop, and Voltex fabrics.

Another paper on Voltex and Malivlies[108] concentrates on finishing these fabrics and also gives details on dyeing and pigment-printing.

Advice on the choice of machine to make particular fabrics is given by Neumann[109]. Arachne and Mali machines are compared in relation to the production of similar fabrics. The same sort of comparison is made in another paper[110], which concentrates largely on the production of pile fabrics. A comparison of the use of materials by stitch-bonding and tufting machines shows the advantages in economy of pile-yarn utilization that is achieved by the stitch-bonding method, where, of course, the pile yarn remains entirely on the cloth face.

7. FACTORS AFFECTING FABRIC PROPERTIES

The general scarcity of detailed technical information on machines also extends to the products of the machines. For the English reader, the amount of detail on fabric performance is very small indeed, the majority of the published papers being either descriptive rather than factual or else a translation of papers in other European languages. Some of the most detailed work again appears in Russian and Eastern-bloc periodicals, a similar situation to that obtaining at the time of the last review on this subject[111]. However, some of the Russian work is on the production of cloths with limited potential output. One such article deals with the production of a fleece fabric for use in the soundboard of accordions[112], and a second paper discusses the production of a tapestry that, after the hand-feeding of coloured rovings, is stitch-bonded together.[113]. Not all the papers are as trivial, or as narrow, as this, of course, and many show a willingness to report results that are not always favourable to the stitch-bonded product. Failure is not only admitted in Russia, since the complete failure of a viscose rayon–acrylic-fibre–nylon fabric is detailed in an American paper[114]. This cloth shrank most unnacceptably in both washing and dry-cleaning, despite its having had a considerably negative yield in finishing. Moreover, once a thread was broken, the entire structure loosened to the point of disintegration.

Some of the causes of fabric disintegration are indicated by Scholtis[115]. Discussing the production of Malivlies and Maliwatt fabrics, he considers the problem of shape retention. Experiments with various gauges, stitch lengths, and weights, made to ascertain which factors have the greatest influence, indicate that the finer the gauge, the greater is the weftway strength of the fabric and also that the shorter the stitch length, the higher is the strength. Again, fleece-fibre length has an effect on strength. The results reported are based on the use of a single-bar chain-stitch structure and are shown graphically in Figures 6 and 7. Scholtis makes the point that in tight constructions the fibre strength in the fleece becomes of importance; in loose structures, fibre friction has a greater effect, as does the bulk of the fibre.

Work of a similar nature was described by Karpavichene and Reshelyanskas[116]. A series of different fleeces was stitched with nylon, and a viscose rayon fleece was then

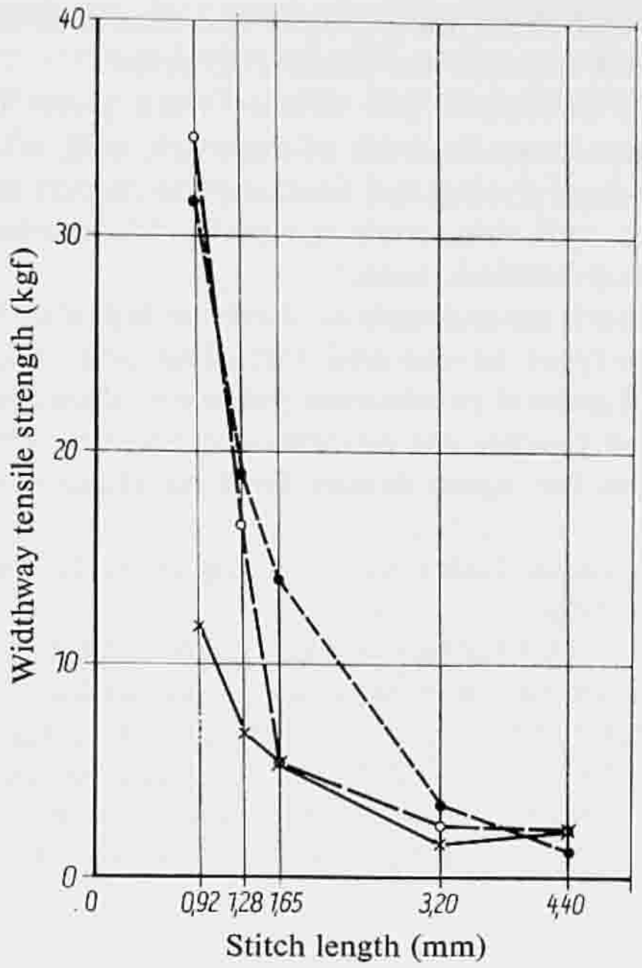

Fig. 6
Relation between widthway tensile strength and stitch length for fabrics of different weights produced from 3-den (3·3-dtex), 100-mm viscose rayon
× 100 g/m²
○ 150 g/m²
● 200 g/m²

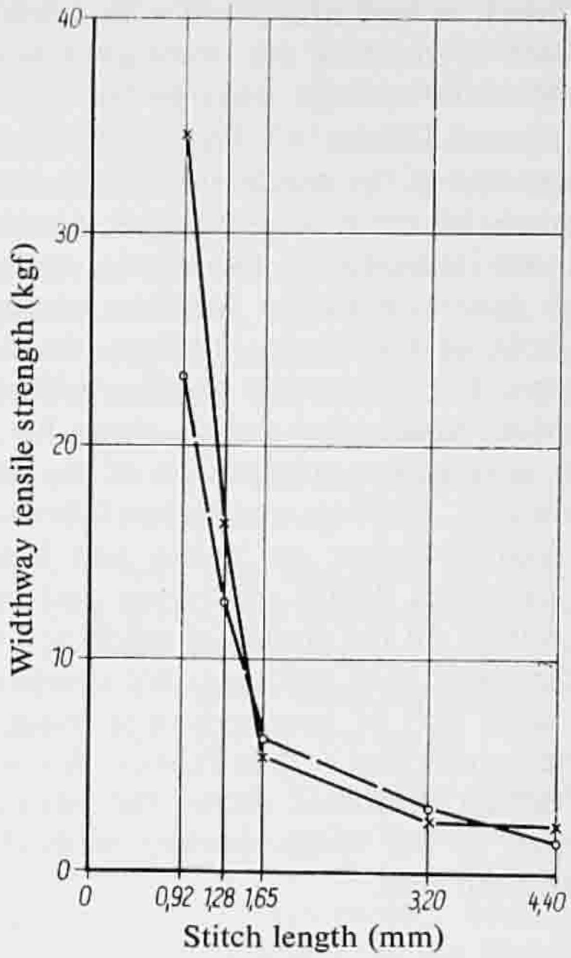

Fig. 7
Relation between widthway tensile strength and stitch length for 150-g/m² fabrics produced from 3-den (3·3-dtex) viscose rayon of different fibre lengths
× 100 mm
○ 60 mm

stitched with a variety of stitching threads. The knitted structure and number of bars were varied. Basically, it was found that the warp strength was independent of the type of fleece fibre and depended only on the stitching-thread strength and type of knitted structure. In weftway tests, the situation was not so clear-cut. The peculiar nature of the graphs, which show short-term fluctuation, was attributed to slip–stick friction conditions in single-bar chain-stitch constructions. The two-bar fabrics, particularly those with a tricot component, did not show this owing to the stitching-thread vector component and not to the better anchorage of fibre as the authors surmise. It was also shown that the warp strength had no decided effect on the weft tensile strength. An attempt to determine the strength of a two-bar carcase by removing the fleece is shown graphically, but this is not a reliable indicator. These two papers, considered in conjunction with the patent on 'blocked' constructions[117], give food for thought in the production of cloths to meet required physical properties.

Some interesting work on the shape of needles and associated problems has been presented by Egry[118]. It is shown that the shape and type of needles are as important to the production of technically sound cloths as the machine-settings themselves. Egry goes on to discuss the forces involved in penetrating the fleece and considers the effect of needle shape, thickness, and surface finish. Machine-settings for depth of penetration and stitch-lock are considered, and the general effects on quality of such factors as stitch density and fleece feed-rate are discussed.

More Russian work on terry-type fabrics is reported[119]. A variety of constructions, including woven terry, woven plain cloth with loop overstitched, and Mali single and double loop, were tested for suitability as towels. Tests of absorbency, shrinkage, washability, etc., generally showed that a single-loop overstitch on a Malimo base proved to be the best value, particularly when production economics were also considered.

Another comparison of stitch-bonded and woven cloths is given by Perner and Jain[120]. Tension measurements on stitching threads were made during the production of stitch-bonded fabrics. In general, it was found that the strength was independent of the knitting tension within a manufacturing range. In a comparison with woven cloths of similar weight and structure, the woven cloth generally had more strength owing to the reinforcing effects of the weave. In another study, bursting strength and abrasion-resistance were compared in woven and stitch-bonded cloths[121]. Again, the woven fabrics had better bursting strength, but in some cases the abrasion-resistance of stitched structures was better, particularly on overstitch types, where the stitch-loop side gave good results. A lengthy paper on woven and stitch-bonded blended-fibre cloths gives test results and properties of the various fabrics and then concludes remarkably that a choice of one or the other depends on the end-use[122].

Moncrieff[123], in a précis of an original Russian paper, gives more comparative properties of woven and stitch-bonded fabrics. Three stitch-bonded cloths are compared with two woven fabrics and a knitted cloth; the results are far from conclusive, since some unusual parameters are considered. However, the stitch-bonded fabrics put up a good performance in tests for tearing strength and abrasion-resistance, though a comparison of Malimo against crêpe, barkweave, or a leno would have provided more meaningful results, since Malimo and, for instance, fustian are not readily compared.

A comparison of knitted and stitch-bonded cloths with regard to draping and flexing is described in a paper by Solovev[124]. This is a straightforward comparison of types in the various bending and flexing tests. The peculiarities of the stitch-bonded structure are well illustrated in this type of test, where it has no real equivalent.

An attempted substitution of a woven cloth by a stitch-bonded cloth is described by Otto[125]. A linen–cotton Malimo cloth was made for use as bed sheets. It failed, owing to poor washing shrinkage—a familiar story! It was also admitted that the cloth appearance was poor and not acceptable in an end-use where clean and smart looks are vital. Finishing research is obviously called for on this topic, though the huge volume of stitch-bonded cloths in commercial uses requiring resistance to washing treatments proves that these cloths can be properly stabilized. The Russians have attempted to lay down finishing conditions, and work on viscose rayon–nylon cloths for use in women's and children's slippers is described in two papers[126,127].

In a paper on Araloop and Arabeva fabrics presented to the Brno symposium, Danhel[128] gives considerable detail, on the performance of these fabrics. Many constructions are given for both types, and a general discussion of finishing techniques follows. Unfortunately, detail is not given of the test instruments used, and this can lead to confusion where, for instance, abrasion-resistance figures as low as 3000 rubs are given for Araloop carpets and upholstery cloths. Again, a different set of tests is used for the Arabeva cloths, even though some of these would be used in similar end-uses. However, an extract from the particulars and test results reported is given in Table 7.1 as an indication of the general properties of the cloths discussed.

The figures for the tensile strength of the Arabeva fabrics show clearly the poor warp strength regardless of the knitted structure or fibre used but demonstrate the way in which the weft tensile strength varies with the construction and fibres used. As can be seen, the introduction of waste does nothing for the fabric properties, but, without a guide to the proposed end-uses, it is difficult to assess the economic worth of such operations.

Another paper presented at the same conference details experiments to determine the change in properties as the cloth parameters are altered[129]. It was found that an increased weight of fleece did not alter the warp tensile strength but increased the weft tensile strength almost in proportion to the weight increase. As the stitch density was increased from 65 to 90 per 10 cm, the weft tensile strength increased by 70%. Warp tensile strengths were in

Table 7.1

Property	Ladies' Coating	Furnishing Fabric	Shoe Lining	Thermal Insulation	Blanket	Floor-covering
			Araloop Fabrics			
Gauge (metric)	40	50	40	40	20	20
Courses/10 cm	70	75	70	70	55	40
Weight of binding yarn (g/m²)	35	29	26	23	—	29
Weight of loop yarn (g/m²)	204	122	222	240	322	705
Weight of web (g/m²)	200	200	220	—	—	62·4
Weight of backing fabric (g/m²)				108	110	396
Total weight (g/m²)	439	351	468	371	432	1192
Finished weight (g/m²)	425	450	435	340	440	1250
Linear density of loop yarn						
(metric count)	10	14	10	10	10	3/5
(tex)	100	71	100	100	100	200 × 3
Fibre of loop yarn	Wool–viscose rayon	Wool–viscose rayon	Acrylic fibre	Acrylic fibre	Acrylic fibre	Polypropylene fibre
Warp tensile strength (kgf)	79·6	58·6	45·4	33·2	—	100·8
Weft tensile strength (kgf)	37·1	37·5	20·4	23·5	—	113·3
Warp extension (%)	50·4	38·7	40·4	24·2	—	10·6
Weft extension (%)	41·9	38·5	49·1	14·1	—	4·2
Abrasion-resistance (rubs)	—	2900	4100	4600	—	3000
			Arabeva Fabrics			
Wales/10 cm	43	40	40	40	20	20
Courses/10 cm	39	38	48	38	36·5	52
Weight (g/m²)	135	227	144	245	265	286
Warp tensile strength (kgf)	4·93	4·88	4·3	4·02	2·58	17·3
Weft tensile strength (kgf)	13·7	25·8	4·1	27·1	3·44	156·2
Warp extension (%)	41·8	31·8	66·3	32·7	44·5	73·0
Weft extension (%)	53·5	41·9	68·7	42·3	60·8	46·0
Fibre*	A	A	B	A	C	D

*A = Viscose rayon, 3·5 den (3·89 dtex), 60 mm.
B = Viscose rayon waste–cotton waste (viscose rayon 3·5 den (3·89 dtex, 60 mm)).
C = Wool waste–cotton waste–viscose rayon, 3·5 den (3·89 dtex), 60 mm.
D = Polyproplene fibre, 4 den (4·44 dtex), 60 mm.

proportion to the stitching-thread strength, and several experiments on this aspect were detailed. Changes due to fleece constituents and stitch type, i.e., chain and tricot, were also noted. Many of these conclusions will already be well known to stitch-bonding users and assessors; nevertheless, the reasons are well explained and useful for those less familiar with the fabrics.

More basic research on similar lines was described in a paper by Zid and Dusek[130]. A considerable part of the paper was devoted to the problem of bagging or bulging, and a theoretical dissertation was presented on binding forces, fibre friction, etc. The effects of using a finer gauge were discussed, together with comments on raw materials and other factors on the same lines as in the previous paper.

The value of the needle-punching of fibrous webs before stitch-bonding is shown in a paper by Beranek[131]. The production of rolled laps is detailed and the value of needling to give maximum strength and cohesion discussed. A great amount of detail on the web strength at various degrees of needling is given in tables and graphs. After the needling process, the resulting fleeces were overstitched. This work was conducted on wool–viscose rayon fleeces, and test results showed that:

(*a*) the weight unevenness was reduced by prior needling;
(*b*) as needling increased from 0 to 16 needles/cm², the weftway tensile strength increased and the elongation decreased;
(*c*) as the weight increased, the tensile strength increased more than proportionally.

This paper is again of considerable value to technicians and fabric designers, particularly those engaged in the manufacture of waddings, felts, and general insulation cloths.

A comparison of theoretical work with practical results forms the basis of a paper by Dawson[132]. In the production of Malimo cloths, the variation in the number of weft threads per stitch is significant, and this can cause fabric defects. Dawson found on a laboratory scale that, although there was some variation, this was largely a function of the weft-sheet geometry and originated from the laying carriage. The higher the stitch length, the less was the variation, but the cloth became more easily distorted. At low stitch lengths, a situation whereby stitches contain no weft can occur, which is another obvious fault.

Details of the undesirable warpway patterning that occurs with two-colour weft blends at certain critical stitch lengths are given. For Malimo producers, this paper has very relevant information and shows very close agreement between theoretical distributions and the fabric analysed.

Finally, a chapter by Burnip[133] in 'Non-wovens '71' is devoted to the physical properties of stitch-bonded fabrics. This work is comprehensive in its scope and thorough in treatment. The whole range of properties is dealt with, as opposed to set topics, which has been the case in most of the work so far reviewed. For those wishing to have an indication of the properties of all types of stitch-bonded fabrics, this is ideal reading.

8. COMMERCIAL AND ECONOMIC ASPECTS

In a review of this nature, the problem of classifying references correctly, to give the reader quick and accurate access to relevant material, occurs frequently; this is particularly the case when one is trying to pick out items that could be classified as economics of production or again as being of commercial interest. Details of end-uses for stitch-bonded fabrics are also included in this section, since these can be deemed to be of commercial interest.

Several authors have included what one might call a 'catalogue' comparison of stitch-bonding machines with other types of competitive fabric-production methods. Buss[134] has based an entire article on such a comparison and freely acknowledges that the information comes from makers' advertising and promotional literature. The figures are all based on West German production, and all results are presented in the form of a tabular histogram showing each method of production arranged from best to worst. The first part of the paper considers floor space used per unit, power consumption, available production width, speed, and rate of cloth production. The machines discussed are various types of shuttle and shuttleless looms, warp- and circular-knitting machines, and standard Maliwatt and Araknit types of machine. In the light of the above-mentioned parameters, stitch-bonding scores on speed and cloth production but does badly on floor space and power requirements, although, of course, in terms of production per unit of floor space, the figure for stitch-bonding is above the average.

In the second part of the paper, financial aspects are considered in the form of depreciation, machine costs, power costs, etc. These figures are then related to operating costs and finally to cloth costs. In terms of fabric cost per machine-hour, stitch-bonding is clearly very viable, and, in terms of over-all cloth cost, it is again above average. Another paper, to be published later, will add details on manning, general factory costs, etc., to complete the picture. As an exercise in relative properties, the paper has some interest.

Another costing exercise is given by Kavan[135], who compares Araloop machinery with a Mayer raschel machine and a Singer–Cobble tufting machine. Although the output of the tufting machine was considerably higher, i.e., about 88% more than that of the Araloop machine, material usage was 40% less on the Araloop, and labour requirements were similar; the investment cost per square metre of cloth on the Araloop was found to be a half of that in tufting machinery and a quarter of that in knitting machinery.

Comparing stitch-bonding and weaving, Kochta[136] found that, to weave 1 million m^2 of cotton duck, 44·5 workers would be required, as against 7·7 to produce an equivalent quantity of stitch-bonded fabric on Arachne machines. He also claimed a labour efficiency 300% higher per man–hour, operating costs 23–30% lower, output 4·5 times as high in terms of value per square metre of floor space, and power used 62% less. All these factors depended heavily on the fact that, in the Arachne cloth, about 75% of the material used needed no prior processing. Similar figures are given for Mali production by Ploch[137]. Considering continuous production lines for Voltex and Maliwatt, he arrived at the figures in Table 8.1.

Table 8.1

	Maliwatt	Voltex
Material-cost reduction	12%	30%
Processing-cost reduction	35%	60%
Power-consumption reduction	40%	65%
Labour-savings	15%	80%
Wages-cost reduction	60%	—

These figures were based on the production of 1 million m^2. Many other articles give figures that are similar to the above; in most of them, it is not clear exactly what is being compared or what is included in the production costs of the competing methods. As an aside to all this, it is very rare for any of the authors to claim very high efficiencies on stitch-bonding machines, which at least is realistic, most of the figures being in the range 60–70%, and the exceptions usually being claims of 80–90% on the Arabeva and Malivlies lines, where there is no warp interference.

In view of these apparently low efficiencies, it is not surprising that some form of production control should be introduced. The Aramet device has been described in the Arachne trade literature[138] and also in two papers[139,140]. This instrument monitors such factors as warp usage, fleece feed-in speed, machine speed, and cloth speed. By ensuring that all factors remain constant, the production quality can be maintained and deviation from it seen quickly to enable adjustments to be made before trouble ensues.

End-uses of stitch-bonded fabrics have been described in considerable detail in many papers; to list all these would be boring and of no great value to the reader. However, as an indication of some of the more uncommon uses of fabrics, the following are worth recording here. Fabrics have been used as filters in cement works, in non-ferrous-metal machine shops, and in mines; indirectly, as a filter in Malimo form, for separating earth and liquid in the making of concrete pillars; and also, remarkably, in the filtration of syrup from sugar beet. Cloths have been used for sacks and bags, and after being coated, for tarpaulins, in which the biaxial strength of certain constructions is valuable while good pliability is retained. The use of a Malimo fabric in a cotton–linen blend, to replace union sheets, although not initially successful, could probably be made so by the use of better yarns. Asbestos and glass cloths have been used for insulation, the pliable knitted structure allowing much better moulding to pipes, etc., than the comparable woven cloth. Again, the creation of the Protes tapestries is an interesting sideline. In East Germany, there is a very wide use of Malimo fabrics for lamination into conveyor belts, where the ability to manufacture cloths with high warp strength, but good availability to bonding adhesives, is an advantage.

Articles dealing with fur fabrics and plush fabrics, terry cloths, and many types of pile cloth make interesting reading[141–145].

In a paper on industrial textiles, Fritsche[146] deals with the use of Malimo cloths in conveyor belts, filters, canvas, and packing cloths. This paper is well illustrated with graphs showing such properties as strength, extensibility, and permeability. Throughout the paper, a comparison with woven cloths is made to show the benefits of the stitch-bonded cloths.

Another paper, which must indicate future trends, discusses the uses of Maliwatt fabrics in light dress goods[147]. Again the author uses standard cloths already in use—in this case, a jersey cloth and a woven cotton fabric—as a basis for comparison. The manufacture of 22-gauge Maliwatt fabrics is described and the building-in of stability and acceptable drape discussed, the effect of various parameters such as the stitch length and fleece weight and of the finishing treatment being demonstrated. Results are tabulated to show the tensile behaviour, the elastic behaviour or the recovery from stress, the crease-resistance, and air and thermal conductivity. Elastic behaviour is also shown graphically. Detail is given about abrasion and pilling properties. Since the elastic behaviour has been the weak point in many stitch-bonded fabrics, the results in Table 8.2, extracted from Scholtis's paper, are of interest. The Maliwatt fabric in this case had a tricot-stitch binding.

Noble[148], in his chapter on the marketing of stitch-bonded fabrics in 'Non-wovens '71', gives general indications of the likely end-uses of the various types of stitch-bonded cloth. He mentions all the current uses of the fabrics, such as furnishing fabrics, print bases, PVC substrates, shoe cloths, insulation, etc., and discusses developments that should follow from this basis.

9. MISCELLANEOUS ITEMS

Several 'conversational pieces' on stitch-bonded fabrics make interesting reading. An article concerning the manufacture of stitch-bonded cloths in the U.K. gives a list of companies involved and discusses the types of fabric being made[149]. Lennox-Kerr[150], discussing non-woven fabrics in general, refutes some of the erroneous ideas about stitch-bonded fabrics and places them with spun-bonded fabrics as the superior products within this field. Frenzel[151] gives a survey of developments within the East German industry, and indications of the increase in stitch-bonding capacity throughout the world were included in a further paper[152].

One of the few articles to discuss the American scene[153] describes the withdrawal of the large companies from stitch-bonding and the setting up of a company that bought up virtually all the development machines. This company, which had 50 machines of various types at the time of writing, was then in the position of selling the bulk of its products to the former owners of the machines. One of the main reasons given for the failure of several users (of different sizes) was an inability to make fabrics of acceptable quality at a competitive price.

Just the opposite case is put by Libbey[154], who gives the history of a new entrant to the field, outlines the problems it had, and indicates how they were overcome. This plant had both Mali and Arachne machines, the latter being used almost entirely on the short runs. The use of continuous-filament and spun yarns is discussed; open-end-spun yarns, which performed much better than the ring-spun equivalents, are gradually accounting for a larger proportion of the latter.

Mauersberger[155] has given a general paper, reported in several periodicals, in which the Mali history is outlined and a few indications of future developments are given, including the introduction of patterning ability on all the range. The author saw no mechanical reason why stitch-bonding machines of a much lighter construction should not run at speeds of up to 8000 rev/min.

Dawson[156] surveys the field in a concise and descriptive form in a short paper dealing with the more general aspects of what is being done with these fabrics.

Several references have been made to papers presented at the ninth symposium on non-woven fabrics, held in Brno, Czechoslovakia, in November, 1970. Another conference on a similar theme was held in Karl-Marx-Stadt in December of the same year and entitled 'Malimo 70'. Although most of the papers presented at these conferences were subsequently published elsewhere and hence have been referred to in this review, at least two reports of the proceedings have been published[157,158].

Table 8.2
Elastic Behaviour

	Stage of Loading					
	Total Elongation at 2 kgf		Permanent Elongation		Fatigue	
	Longitudinal %	Transverse %	Longitudinal %	Transverse %	Longitudinal %	Transverse %
Maliwatt, grey fabric finished fabric*	30·0 3·56	10·8 29·7	23·0 1·56	6·8 17·9	3·0 0·44	1·7 4·08
Maliwatt fabric, contraction by relaxation	27·1	23·5	9·70	8·1	2·80	2·1
Maliwatt fabric, contraction by thermal shrinkage	11·9	40·6	4·33	21·3	1·15	5·2
Circular-rib-knitted polyester-fibre fabric (GRS)	10·4	123·0	1·8	81·6	0·4	11·7
Woven cotton fabric	1·94	2·82	0·48	0·90	0·58	1·06
Warp-knitted cotton fabric (FKG)	18·4	33·8	9·8	24·1	1·7	3·1

*With contraction in transverse direction.

10. CONCLUSIONS

The volume of work cited in the text puts beyond any doubt the fact that stitch-bonding is an industry in itself. This being so, it surely warrants more than a passing mention in textile textbooks as though it were a minor process of little consequence. Warp-knitters, weavers, and tufters view the stitch-bonder as a serious and competitive rival, who is becoming stronger and more adroit every year. It has been estimated that stitch-bonding is responsible for 1% of the world's fabric output, which, in a commercial life of fifteen years or so, is good going.

As market penetration increases, theoretical and practical work also increases, and it is to be hoped that the reporting of such work will also increase. Factual and authoritative material regarding both production methods and fabric test results is still rare.

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