Introduction to various fabric manufacturing methods

Importance of Textile Fabrics

Textile fabrics are light weight, flexible **(easy to bend, shear and twist), mouldable, permeable** and strong as compared to paper

Importance of Textile Fabrics

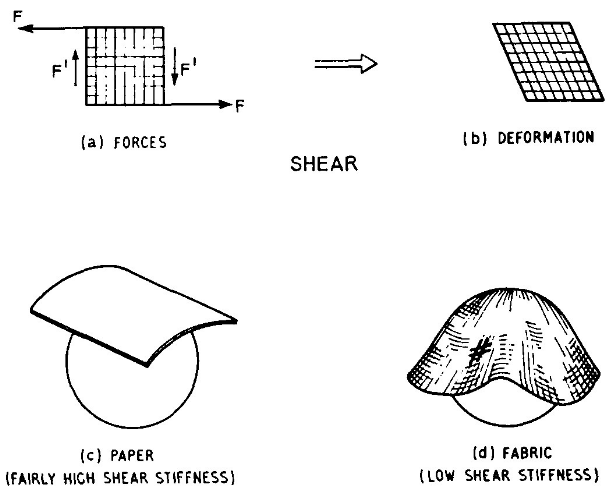


Fig. 2.2. Ability of material to mold, i.e. drape

Textile Fabric Properties

Fabrics intended for apparel use must have **drape, handle, crease recovery, tear strength, air permeability, thermal resistance and moisture vapor permeability.**

There are additional requirements for technical applications

TABLE 1.1 Properties of Some Technical Fabrics

Fabric Type	Important Properties/Parameters
Filter fabrics	Pore size, pore size distribution
Body armour fabrics	Impact resistance, areal density, bending resistance
Fabrics as performs for composite	Tensile strength and tensile modulus
Knitted compression bandages	Stretchability, tensile modulus, creep

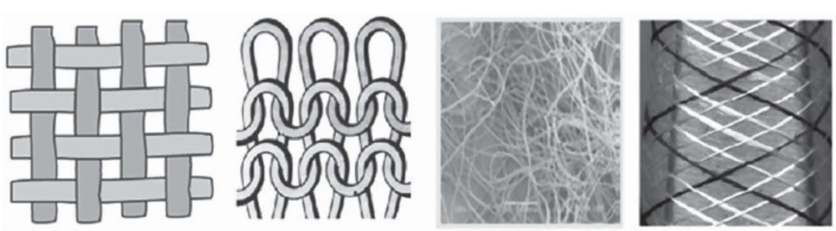
Fabric manufacturing methods

Fabrics are two-dimensional flexible materials made by **interlacing** of yarns or **intermeshing** of loops with the exception of nonwovens and braids.

Fabric manufacturing preceded either by fibre production (in case of nonwoven) or by yarn manufacturing (in case of weaving, knitting and braiding).

Fabric manufacturing methods

1. Weaving…interlacement of yarns
2. Knitting…..interlooping of yarns
3. Nonwoven……entangling of fibres
4. Braiding…….intertwinning of yarns

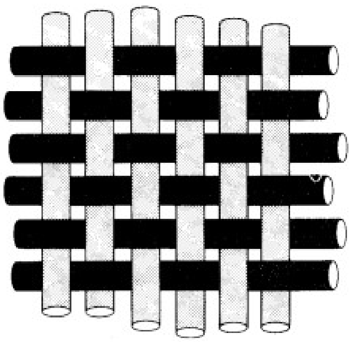


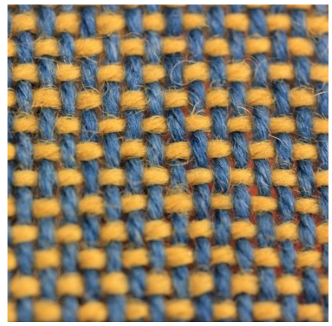
(a) (b) (c) (d)

FIGURE 1.1 Fabrics produced by different technologies. (a) Weaving, (b) knitting, (c) nonwoven and (d) braiding.

1. WEAVING

Weaving is the most popular method of fabric manufacturing and is generally done by **interlacing** two orthogonal sets of yarns – **warp** (or end) and **weft** (or pick) – in a regular and recurring pattern.

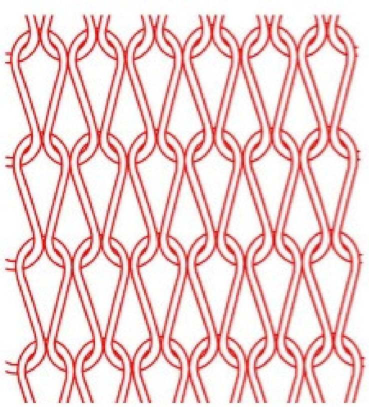


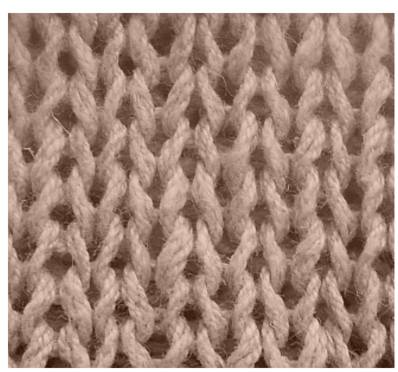


Commonly in shirts, trousers, denim, curtains, bedsheets, etc

2. Knitting

Knitting is a process of fabric formation by producing series of **intermeshed loops**.





Commonly in T-shirts, socks, undergarments, sports textiles, etc

Textile Fabric Properties

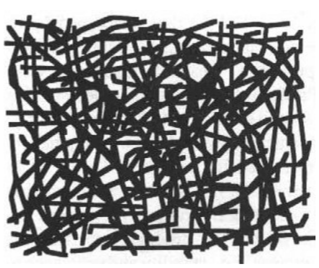
Tab. 4.1: Comparison between woven and knitted fabrics, machine and process.

Sr. #	Parameter	Woven Fabric	Knitted Fabric
1	Process requirement	Fabric requires two sets of yarn for interlacement, one is warp and other is weft yarn.	Fabric can be produced from a single end or a cone of a yarn in case of weft knitting.
2	Dimensional stability	More stable	Less stable. Careful handling is required for knitted fabric during wet processing and stitching.
3	Comfort	Less comfort due to tight structure	More open spaces that give better air permeability and moisture management
4	Shape retention properties	Woven garments retain their own shape	Knitted garments get the shape of the wearer's body, hence, best for undergarments
5	Crease resistant	Poor crease resistance	High crease resistance
6	Development route	Yarn preparation requires like warping, sizing drawing, etc.	Fabric can be produced from yarn package. So process route is very short
7	Conversion cost	Conversion from yarn to fabric involves various processes. The conversion cost is higher.	Conversion requires no preparation, so conversion cost is low
8	Environmental effect	Preparation includes a sizing of warp yarn that has to remove before color application, that may cause environmental pollution	The yarn is just waxed. No need to size the yarn, so development cause less environmental hazards

3. Nonwoven

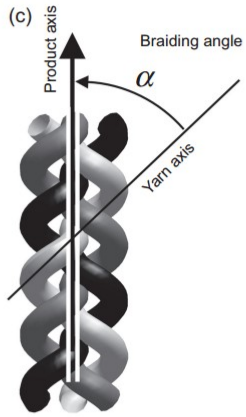
Nonwovens are made by **bonding and entangling of fibres** by means of mechanical, thermal or chemical processes.

e.g. geotextiles, filtration, wipes, health and hygiene products, surgical gowns, face masks, automotive textiles.



4. Braiding

Braiding generally produces tubular or narrow fabrics by **intertwining** three or more strands of yarns, threads or filaments.



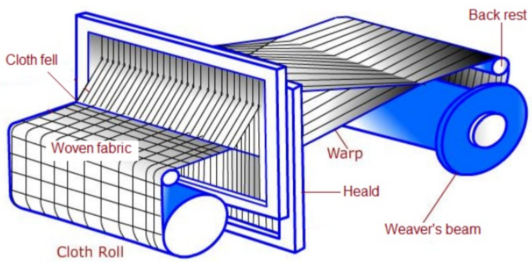
Commonly in ropes, shoe laces, composite preforms, etc

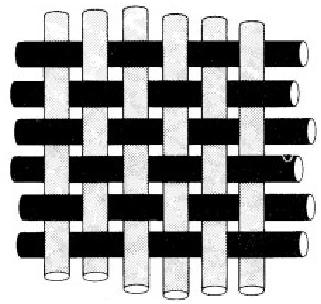
Comparison of production of fabric manufacturing methods

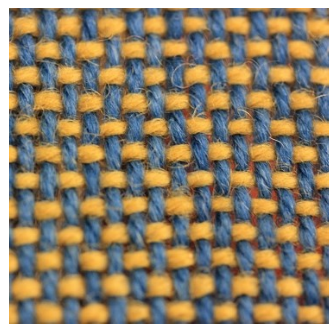
Tab. 4.4: Production comparison of woven, knitted and nonwoven fabrics (INDA).

Method	System	Production (m^2/ hour)
Weaving	Shuttle	15
Overall average 0.583 m^2/ min	Rapier	30
	Water jet	35
	Projectile	40
	Air jet	55
Knitting	Double knit	125
Overall average 8.5 m^2/ min	Rib	175
	Single jersey	250
	Raschel	800
	Tricot	1200
Nonwoven	Stitch bonded	450
Overall average 335.5 m^2/ min	Needle punched	7200
	Card bond	15000
	Wet laid	30000
	Spun laid	48000

1. WEAVING







Yarn preparation processes for weaving

Actual weaving process is preceded by yarn preparation processes, namely **winding, warping, sizing, drawing and denting.**

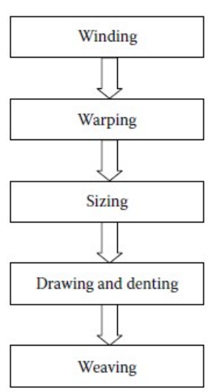


FIGURE 1.3 Steps of woven fabric manufacturing.

Yarn preparation processes for weaving

Winding converts smaller ringframe packages to bigger cheeses or cones while removing the objectionable yarn faults.

Pirn winding is performed to supply the weft yarns in shuttle looms.

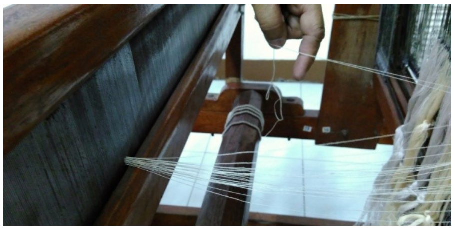
Yarn preparation processes for weaving

Warping is done to prepare a warper's beam which contains a large number of parallel warp yarns or ends in a double flanged beam.

Sizing is the process of applying a protective coating on the warp yarns so that they can withstand repeated abrasion, stress, strain and flexing during the weaving process.

Yarn preparation processes for weaving

Then the warp yarns are drawn through the heald wires and reed dents in **drawing and denting operations**, respectively.



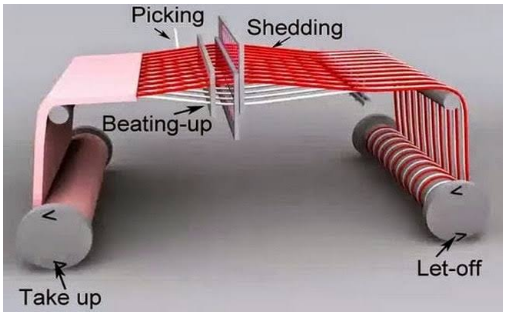
Finally the fabric is manufactured on looms which perform **several operations following a sequence** so that there is **interlacement** between warp and we yarns.

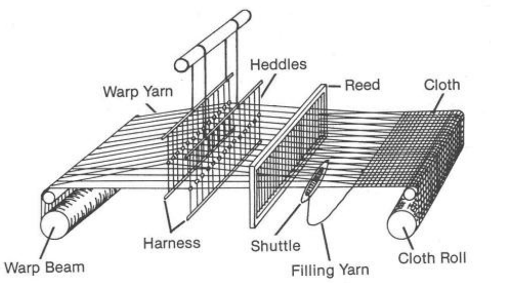
Weaving mechanism

Primary motions
1. Shedding
2. Picking
3. Beat up

Secondary motions
1. Take up
2. Let off

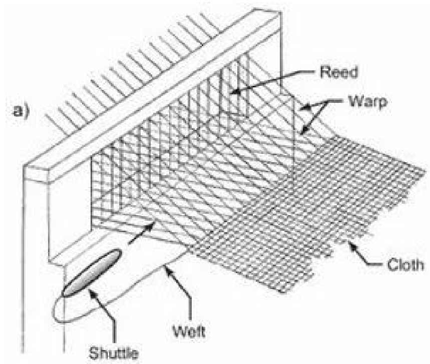
Auxiliary motions
1. Warp stop
2. Weft stop
3. Warp protector

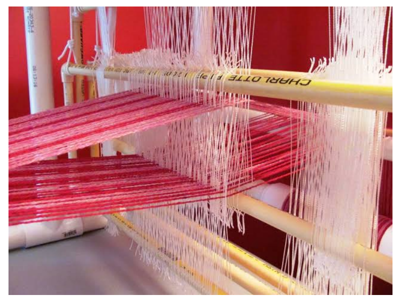




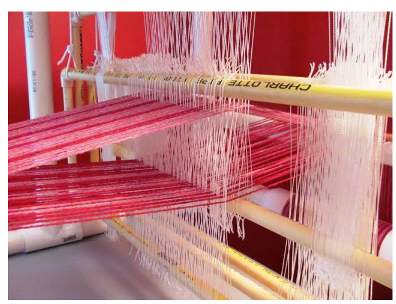
Shedding

Shedding is the process by which the warp sheet is **divided into two groups** so that a clear passage is created for the weft yarn to pass through it.



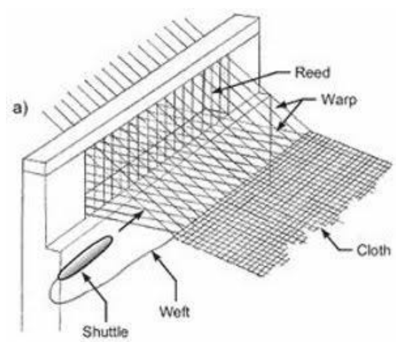


Shedding



One group of yarns either moves in the upward direction or stays in the up position, thus forming the top shed line.

Another group of yarns either moves in the downward direction or stays in the down position, thus forming the bottom shed line.

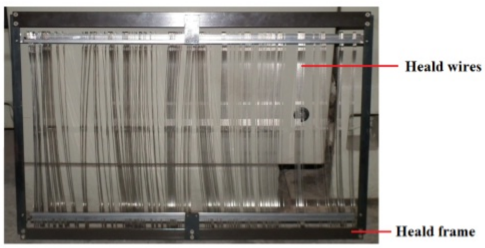


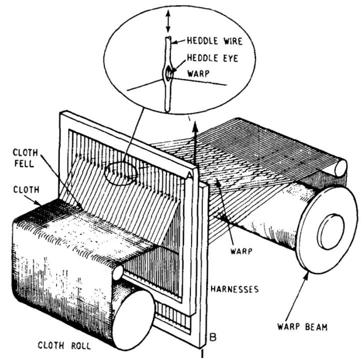
Shedding

Warp yarns are not controlled individually during the shedding operation (except Jacquard shedding)

Healds are used to control a large number of warp yarns.

The **heald frame** carries a large number of metallic wires known as **heald wires**.



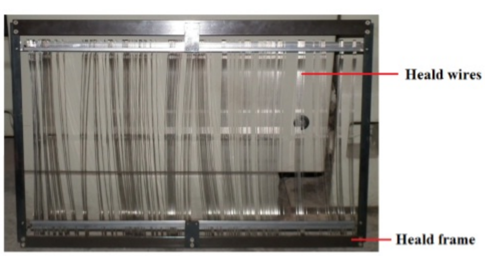


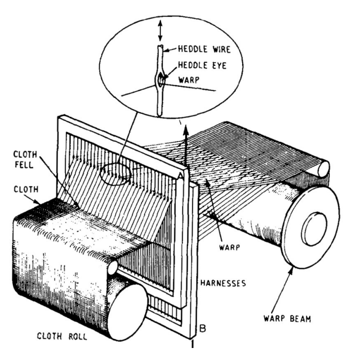
Shedding

Each heald wire has a hole, called **heald eye,** at the middle of its length.

The warp yarn actually passes through the heald eye.

Therefore, as the heald moves, all the warp yarns which are controlled by that heald also move.





Shedding

The upward and downward movements of healds are controlled either by cam or by dobby shedding mechanisms and associated heald reversing mechanism.

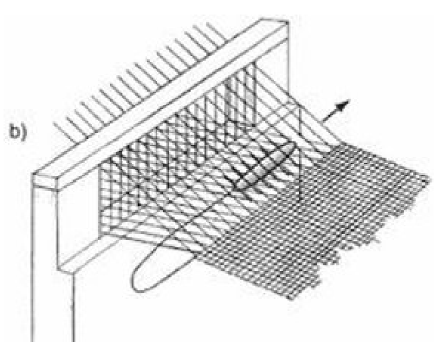
The movement of the healds is not continuous.

After reaching the topmost or lowest positions, the healds, in general, remain stationary for some duration. This known as ‘dwell’.

In general, the shed changes after every pick, that is the insertion of weft.

Picking

The insertion of weft or weft-carrying device (shuttle, projectile or rapier) through the shed is known as picking.



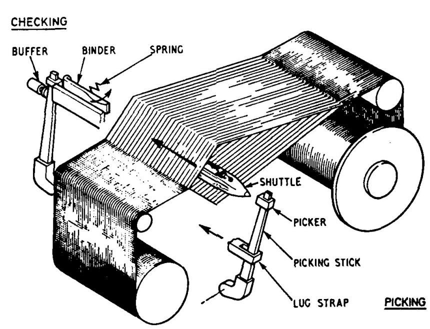


Fig. 2.9. Filling (weft) insertion.

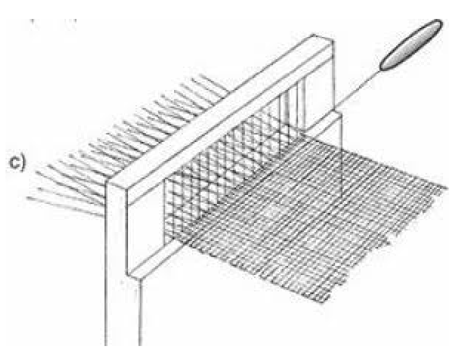
Picking

Shuttle loom: Weft package or pirn is carried by the wooden shuttle.
Rapier loom: Weft is inserted by flexible or rigid rapiers.
Projectile loom: Weft is carried by metallic or composite projectile.
Airjet loom: Weft is inserted by jet of compressed air.
Waterjet loom: Weft is inserted by water jet.

Beat-up

Beat-up is the action by which the newly inserted weft yarn or pick is pushed up to the cloth fell.

Cloth fell is the boundary up to which the fabric has been woven.



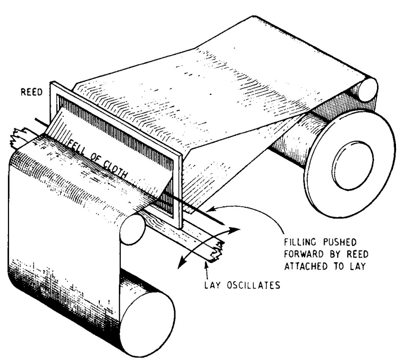
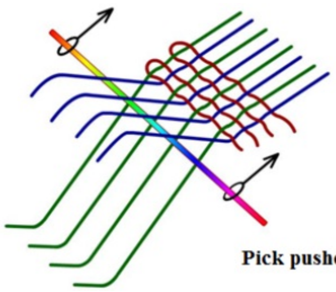


Fig. 2.10. Beat-up

Beat-up

The loom component responsible for the beat-up is called 'reed'.

The reed, which is like a metallic comb, can have different count. For example, 80s Stockport reed has 80 dents in 2 inches.



Pick pushed by reed

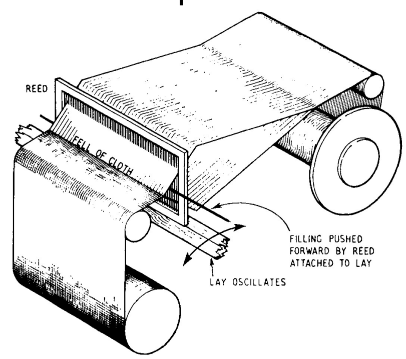
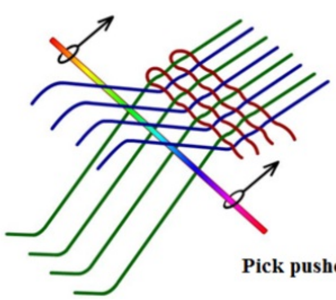


Fig. 2.10. Beat-up

Beat-up

Reed is carried by the sley, which sways forward and backward due to the crank connecting rod mechanism.

Generally, one beat-up is done after the insertion of one pick.



Pick pushed by reed

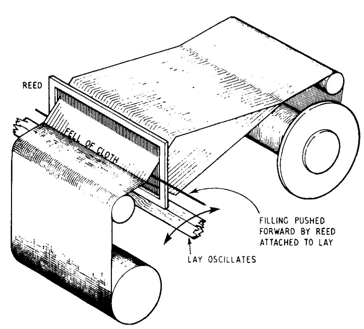
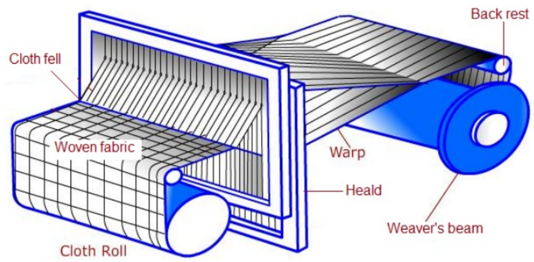


Fig. 2.10. Beat-up

Take-up motion

Take-up motion winds the newly formed fabric on the cloth roller either continuously or intermittently after the beat-up.

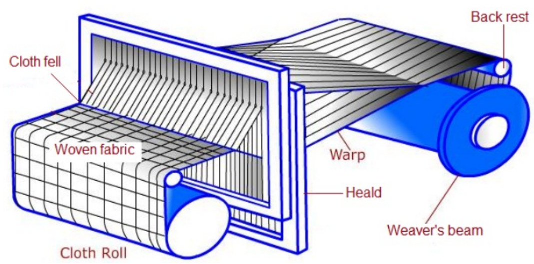
The take-up speed also determines the picks/cm value in the fabric at loom state.



Let-off mechanism

As the take-up motion winds the newly formed fabric, tension in the warp sheet increases.

To compensate this, the weaver's beam is rotated by the let-off mechanism so that adequate length of warp is released.



Auxiliary Motions

Activation of stop motions in case of any malfunctioning such as warp breakage, weft breakage or shuttle trapping within the shed.

1. Warp stop motion (in case of warp breakage)
2. Weft stop motion (in case of weft breakage)
3. Warp protector motion (in case of shuttle trapping inside the shed)

Types of weaving looms

1. Handloom
2. Power loom (non-automatic)
3. Automatic loom
4. Multiphase loom’
5. Shuttleless loom
6. Circular loom
7. Narrow loom

Hand loom

Mainly used in the unorganised sector.

Operations such as shedding and picking are done by using manual power.

major sources of employment generation in rural areas of India and many other countries.

Power loom (non-automatic):

All the operations of non-automatic power loom are driven by motor except pirn changing.

They have very limited use for the production of normal woven fabrics, specially in modern industries.

However, they are sometimes used for weaving industrial fabrics from very coarse weft

Automatic loom:

In this power loom, the exhausted pirn is replenished by the full one without stoppage.

Multiphase loom:

Multiple sheds can be formed simultaneously in this looms and thus productivity can be increased by a great extent.

However, it has failed to attain commercial success.

Shuttleless loom:

Weft is carried by projectiles, rapiers or fluids in case of shuttleless looms.

The rate of fabric production is much higher for these looms.

Besides, the quality of products is also better, and the product range is much broader compared to those of power looms.

Most of the modern mills are equipped with different types of shuttleless looms based on the product range.

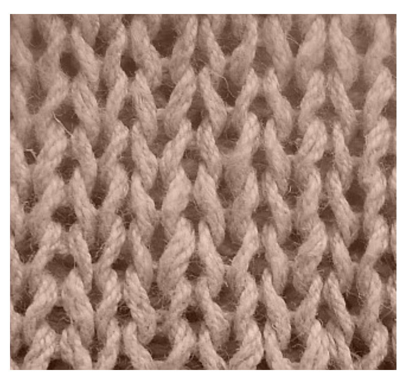
Circular loom:

Tubular fabrics such as hosepipes and sacks are manufactured by circular looms.

Narrow loom:

These looms are also known as needle looms and are used to manufacture narrow-width fabrics such as tapes, webbings, ribbons and zipper tapes.

Knitting

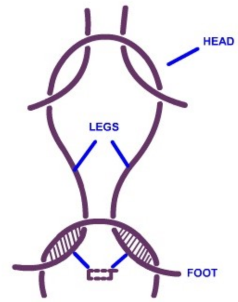


Knitting

Loops are the building blocks of knitted fabrics

The upper part of the loop is called 'head', whereas the two sides are called 'legs'.

The intermeshing of two loops happens through the 'foot'.



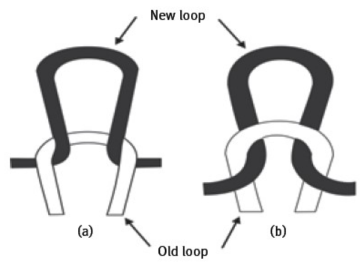


Fig. 4.19: Fabric sides: (a) Technical face, (b) Technical back.

Knitting

In general, the knitted fabrics are more stretchable than the woven fabrics.

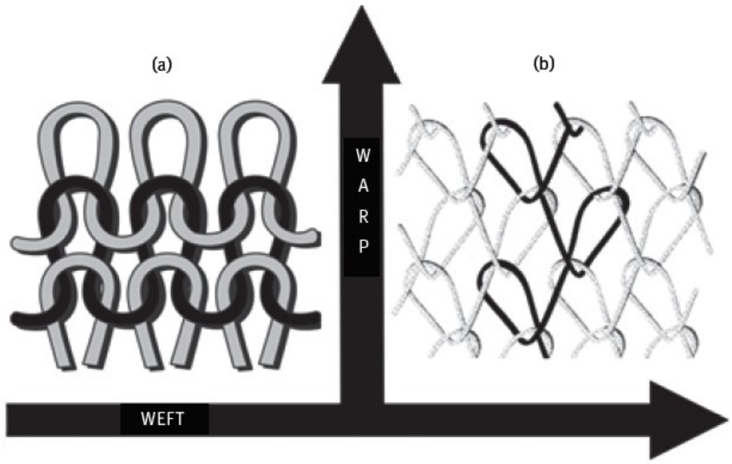
The open structure of knitted fabrics also facilitates better moisture vapour transmission, making it suitable for sports garments and high-activity clothing.

Besides, the knitted fabrics have more porosity than the woven fabrics.

Therefore, knitted fabrics can trap more air, resulting in lower thermal conductivity and higher thermal resistance.

Knitting

There are two types of knitting: warp knitting and weft knitting.



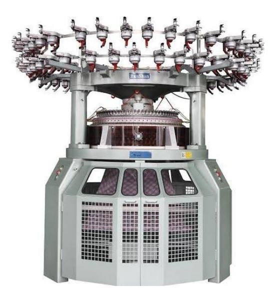
Weft knitting

In weft knitting loops are made by the supplied yarns across the width of the fabric

Weft knitted fabric can be made even from one supply package. The weft knitting machines are of two types:

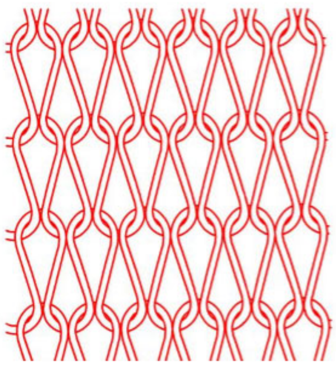
1. Flatbed machine
a. Single bed
b. Double bed or V bed

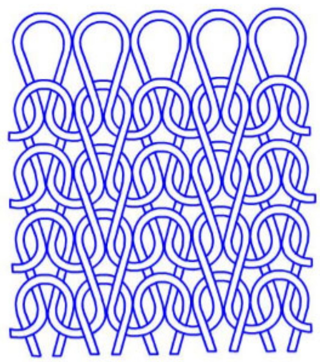
2. Circular bed machine



Weft knitting

Single bed machines produce plain or single jersey structure, whereas double bed machines produce rib (1 × 1, 2 × 2 etc.) and purl structures.



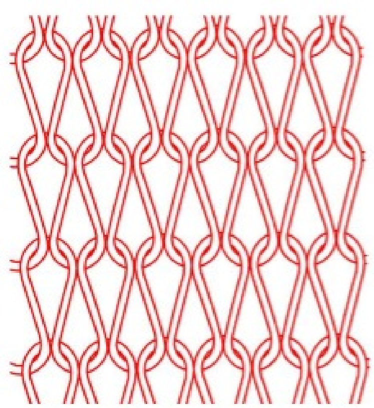


Single jersey fabrics

All the heads of the loops either face the viewer or are away from the viewer.

In Figure, all the heads of the loops are hidden from the viewer while the feet are prominently visible, so it is the technical face side of the fabric.

Single jersey fabrics tend to curl at the edges.

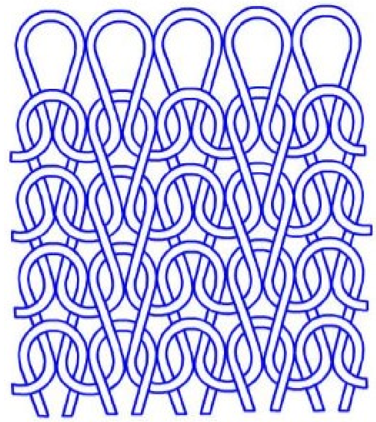


Double jersey fabrics

In case of rib (double jersey) fabrics, in some of the wales, heads of the loops face the viewer and vice versa

There is no technical face or back in double jersey fabric.

Thicker and more stretchable in course direction than the single jersey fabrics.

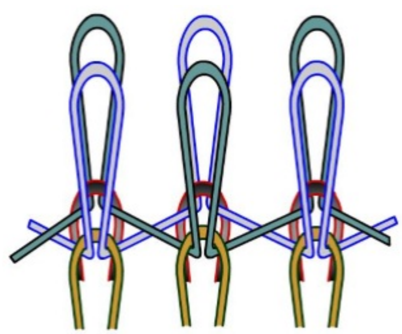


Interlock fabrics

It is basically a combination of two rib structures

The interlocking of two rib structures is responsible for lower stretchability of interlock fabrics as compared to the original rib structure.

Interlock fabrics are generally heavy and demonstrate least porosity among the three knitted structures (single jersey, rib and interlock).



Warp knitting

In warp knitting, loops are made from each warp yarn along the length of the fabric

The yarns are supplied in the form of a sheet made by parallel warp yarns coming out from a single or multiple warp beams.

The loop formation mechanism is more complex for warp knitting than that of weft knitting.

Types of needles used for knitting

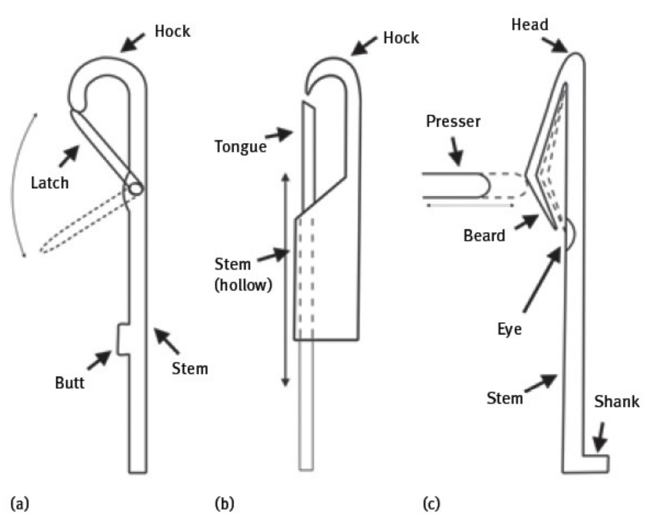


Fig. 4.14: Needle types and their parts: (a) Latch needle, (b) Compound, (c) Bearded needle.

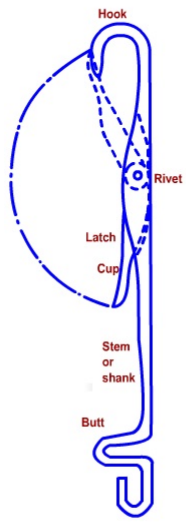
Latch needle for knitting

Needle helps in loop formation

Latch, bearded and compound needles are used

Latch needle is most popularly used in weft knitting and Raschel warp knitting machine.

The upward and downward movements (at butt) are caused by a set of cams in weft knitting and by movement of bars in warp knitting.

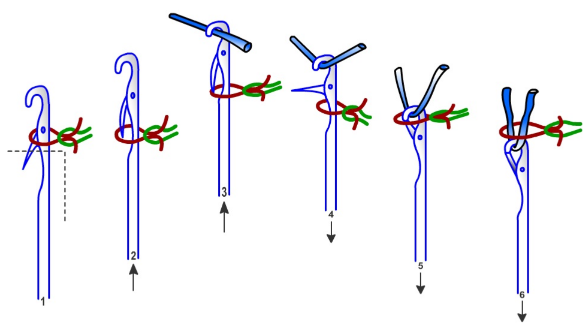


Loop Formation in Knitting

When the needle moves up, the old loop forces the latch to open (‘tuck’ position) (1 in Figure).

Then the needle moves up further and the old loop slides down the latch and rests on the stem of the needle (‘clearing’ position) (2 in Figure).

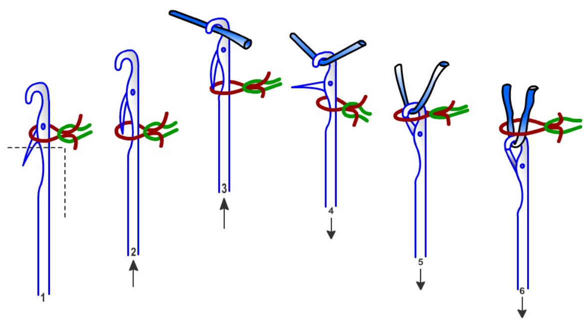
The needle attains its highest position at 3 in Figure.



Loop Formation in Knitting

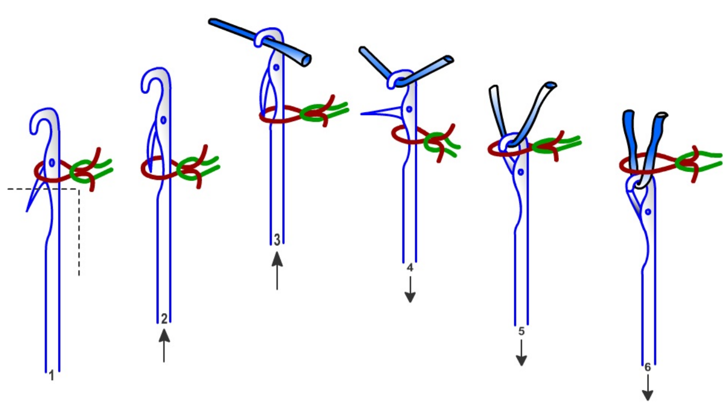
Then it starts to descend and the hook catches the yarn, the yarn bends in the form of a loop (‘U’ shape).

The old loop now helps close the latch by pushing it in upward direction so that the newly formed loop is about to be caught between the hook and latch (4 in Figure).



Loop Formation in Knitting

The needle continues to descend and new loop is ‘cast on’ (5 in Figure) and finally ‘knocked over’ (6 in Figure) through the old one.

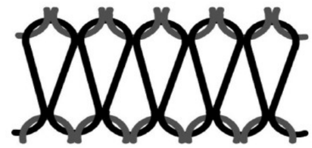


Knitted fabric structure

The horizontal row of loops is called ‘course’.

The vertical column of loops is called ‘wale’

The wales per inch (wpi) and courses per inch (cpi) of knitted fabrics are analogous to ends per inch (epi) and picks per inch (ppi) of woven fabrics.



Knitted fabric structure

For a fully relaxed knitted fabric, the wpi and cpi values are determined by the loop length.

Smaller loop length leads to higher values of wpi and cpi.

As a result, the stitch density or loop density, which is a product of wpi and cpi, also increases with the reduction in loop length.

The ratio of cpi and wpi is known as loop shape factor.

For a fully relaxed single jersey fabric, the loop shape factor is around 1.3.

Knitted fabric structure

Let the loop length be l inch.

Wales per inch $(wpi) = \frac{k_w}{l}$ and courses per inch $(cpi) = \frac{k_c}{l}$

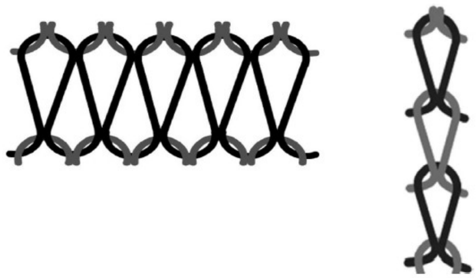


FIGURE 1.18 Course and wale.

Stitch density $(\text{inch}^{-2}) = wpi \times cpi = \frac{k_w}{l} \times \frac{k_c}{l} = \frac{k_w k_c}{l^2} = \frac{k_s}{l^2}$

where *kw, kc and ks are wale constant, course constant and stitch constant,* respectively.

Knitted fabric structure

Tightness factor implies the relative tightness or looseness of a single jersey knitted fabric

Indicated by ratio of fabric area covered by the yarn to the total fabric area corresponding to one loop.

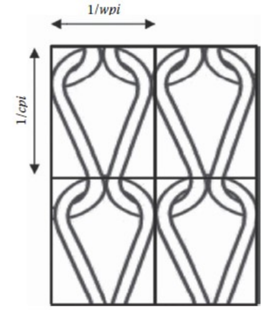
It is analogous to the cover factor of woven fabric.

$$\text{Tightness factor} = \frac{\text{Area covered by the yarn within the repeat unit}}{\text{Area of the repeat unit}}$$

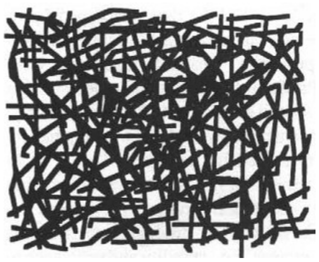
$$= \frac{l \times d}{\frac{1}{cpi} \times \frac{1}{wpi}} = \frac{l \times d}{\frac{l}{k_c} \times \frac{l}{k_w}} = \frac{k_c \times k_w \times d}{l} = \frac{k_s \times d}{l}$$

Yarn diameter (d) is proportionate with $(\text{tex})^{0.5}$.
Therefore,

$$\text{Tightness factor} \propto \frac{k_s \times \sqrt{\text{tex}}}{l}$$



Nonwoven



Nonwoven

The two major stages of nonwoven manufacturing are web formation and web bonding.

The major nonwoven technologies can be listed as follows:

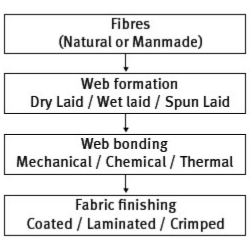


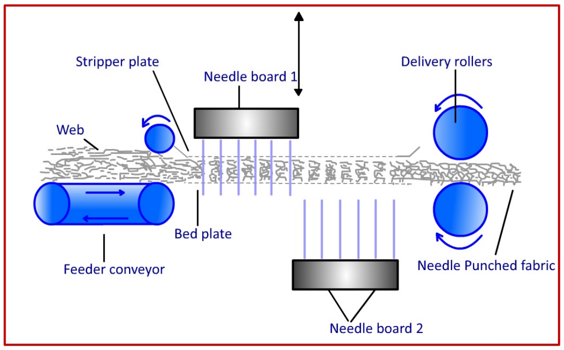
Fig. 4.24: Nonwoven production steps.

Web Formation	Web Bonding
Mechanically formed fibre webs (Drylaid)	Needle punching
Aerodynamically formed fibre webs (Drylaid)	Hydro-entanglement
Hydrodynamically formed fibre webs (Wetlaid)	Thermal bonding
Polymer-laid (Spunmelt nonwovens)	Chemical bonding

Needlepunch Nonwoven

It is the method of consolidation of fibrous webs by repeated insertion of barbed needles into the web

This process consolidates the structure of fibrous web by interlocking of fibres in the third or 'Z' dimension without using any binder.



Needlepunch Nonwoven

The needling can be done either from one side or from both (top and bottom) sides of the web.

Continuous filaments or short staple fibres are initially arranged in the form of a fibrous web in various orientations (random, cross, parallel or composite).

The degree of compaction of the fibrous web is largely dependent on punch density (PD), which is defined as the number of needle penetrations received by the fibrous web per unit area (punches/cm2).

Needlepunch Nonwoven

If the stroke frequency (cycles/min) of the needle board is *N and the number of needles per* linear cm width of the needle board is *n and the delivery speed of the fabric is v cm/min, then punch density can be calculated by the following expression.*

$$\text{Punch density } PD = \frac{N \times n}{v}\ \text{cm}^{-2}$$

Higher punch density creates more fibre entanglement in the web, thus increasing the compactness of the web.

Needlepunch Nonwoven

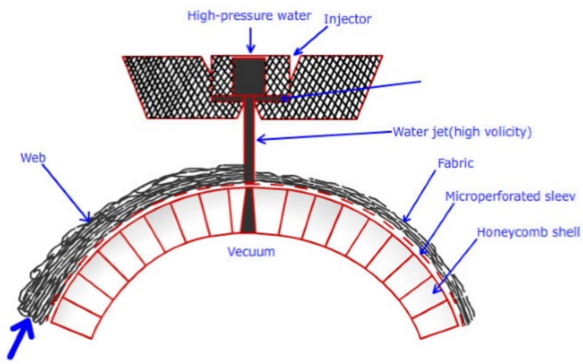
Needle-punched nonwoven geotextiles are extensively used in civil engineering applications

The properties of needle-punched nonwoven fabric depend on parameters such as fibre type, web aerial density, needle penetration depth, punch density (number of punches/cm2) and the number of needling passages.

Hydro-entanglement, or spunlace nonwoven

Hydro-entanglement, or spunlacing, is a versatile method of bonding the fibrous web using high-pressure water jets.

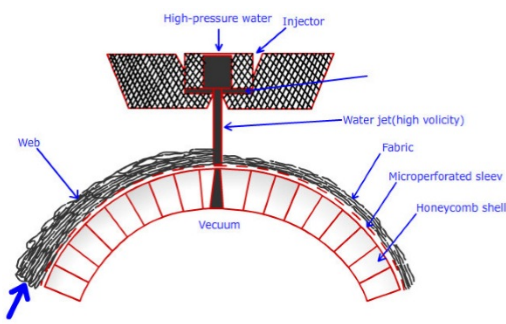
Fabric is produced by subjecting a web of loose fibres to high-pressure fine water jets.



Hydro-entanglement, or spunlace nonwoven

The fibre web is supported by either regularly spaced woven wires or a surface with randomly distributed holes

As a result of the impact of high-pressure jets, the fibres bend and curl around each other, forming an integrated web where fibres are held together by frictional forces.



Hydro-entanglement, or spunlace nonwoven

Hydro-entangled nonwovens have an extensive range of applications, including wipes, carpet backing, filters, sanitary, medical dressings and composites.

Among these applications, personal care and household wipes form the fastest growing sector.

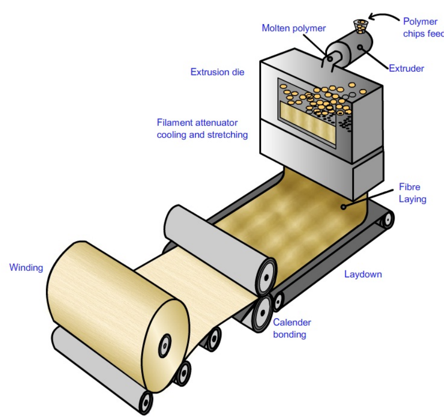
Spunbond Nonwoven

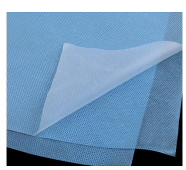
Polymer melt is first extruded into filaments and then formed into web.

The web is then subjected to the bonding process which can be done by chemical and/or thermal process.

Polypropylene and polyester are commonly used

Spun-bonded nonwovens have high strength but lower flexibility.



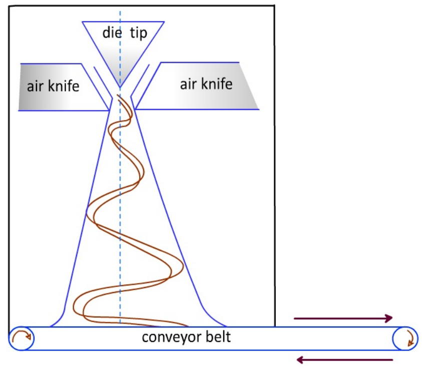


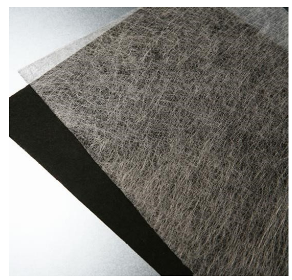
Meltblown Nonwoven

Meltblown technology is unique as web is very fine along with very small pore sizes

The polymer is fed into the die tip and the resulting fibre is attenuated by hot air, which is blown near the die tip.

The ability to form a web directly from a molten polymer without controlled stretching gives meltblown technology a distinct cost advantage





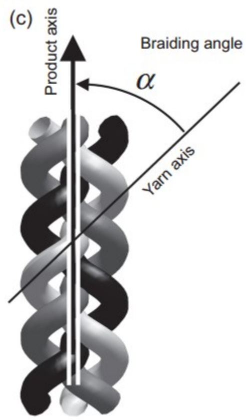
Meltblown Nonwoven

Meltblown webs offer random fibre orientation, very fine fibre and low to moderate web strength.

The major end-uses are filtration media (surgical mask filters, liquid and gas filtration), surgical disposable gown, sterilisation wrap, disposable absorbent products and oil absorbents.

The laminated SMS (spunbond-meltblown-spunbond) structures are ideal for gradient filtration as the material shows excellent barrier properties combined with mechanical strength.

Braiding



Braiding

The yarn packages move on serpentine path

In simple machines, half of the packages move in clockwise direction, whereas the remaining packages move in anticlockwise direction.

Shoelaces and ropes