LECTURE NOTE

SUB: FABRIC MANUFACTURE - III

BRANCH: - TEXTILE ENGG.

SEMESTER: 5TH

GOVERNMENT POLYTECHNIC, BHADRAK

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SYLLABUS

1. Introduction to Knitting

1.1 Define knitting, Courses & Wales, Explain types of Knitting.
1.2 Compare between Weaving and Knitting.
1.3 Compare between warp and weft knitting.

2. Weft Knitting

2.1 State the types of basic weft knitted structures.
2.2 State the representation of basic knitted structures in the form of loop diagrams and in the form of stitch notations.
2.3 Characteristics basic knitted structures and end uses.
2.4 Define float and luck stitches, Explain effects of luck and float stitches.
2.5 State the passage of material through circular weft knitting machine.
2.6 State the function of the machinery parts: Creels, stop motions, positive feeders, yarn guides, take-up and winding mechanism.
2.7 Explain the arrangement of knitting elements, State the knitting action of stitch forming elements in single jersey and double jersey knitting machines (rib, inter lock and purl machines)

3. Warp Knitting

3.1 Define Warp Knitting loop structures.
3.2 Differentiate warp knitting machines –Tricot & Rasset.

4. Knitting Calculation

4.1 Define machine gauge, tightness factor and yarn number.
4.2 Calculate weft knitting machine production, Calculate loop length, fabric widths, weigh per square yard

5. Non-Woven

5.1 Introduction to non-woven technology.
5.2 Types of fibres used and end uses of nonwovens.
5.3 Methods of web preparation & Orientation of fibres in the web.
5.4 Methods of bonding of web, Brief idea on non-woven fabrics by needle punching, stitch bonding, spun bonding, thermal bonding, Adhesive bonding techniques etc.

MODULE – I
INTRODUCTION TO KNITTING

1.1 Definition of knitting, Courses & Wales, Types of Knitting

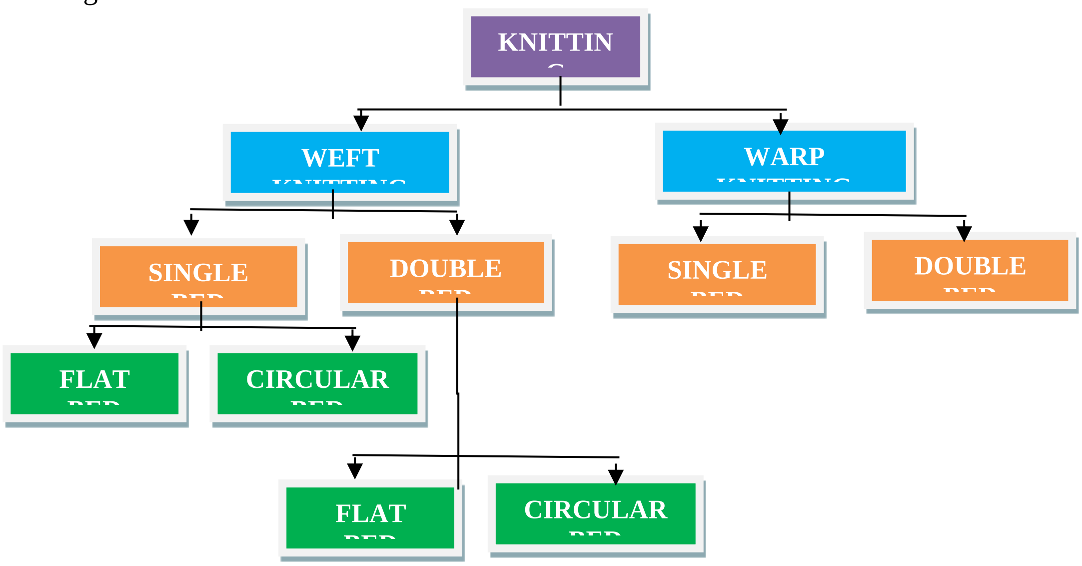
Definition of knitting

Knitting is a process of fabric forming by the intermeshing of loops of yarns.

Types of Knitting

The two main forms of knitting are:

1. Weft knitting, and
2. Warp knitting



1. Weft knitting

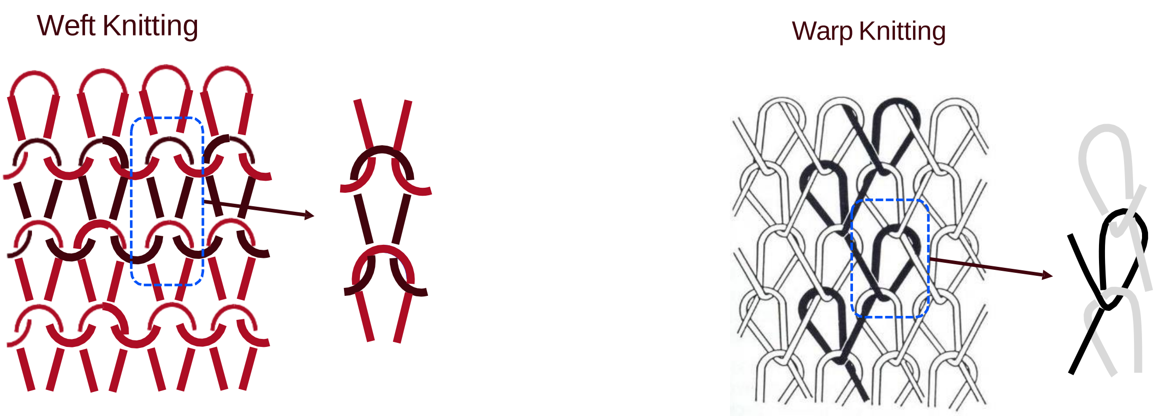
Weft knitting is a method of forming a fabric in which the loops are made in horizontal way from a single yarn and intermeshing of loops take place in a circular or flat form on acrosswise basis.

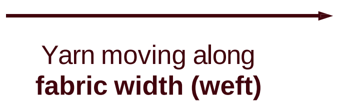
In this method, feeding is one yarn at a time, to a multiplicity of fashion. Most of the weft knitting is of tubular form.

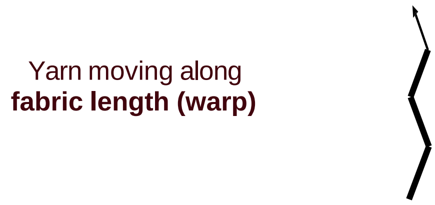
2. Warp knitting

Warp knitting is a method of fabric forming in which the loops are made in a vertical way along the length of the fabric from each warp yarns and intermeshing of loops takes place in a flat form of lengthwise basis.

Here, numerous ends of yarns are being fed simultaneously to individual needles placed in a lateral fashion. Most of the knitted structures are flat or open width form.







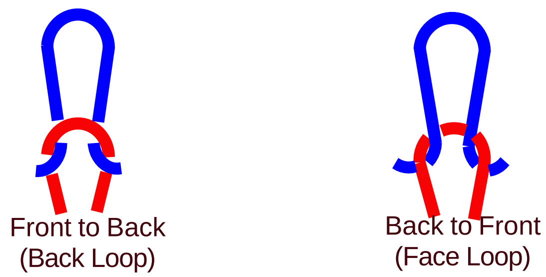
TERMS OF KNITTING

Open Loop: The open loop is one in which the loop forming yarns does not cross at the bottom of the loop.

Closed Loop: In Closed loop, the legs of the loop cross so that the loop closing takes place.

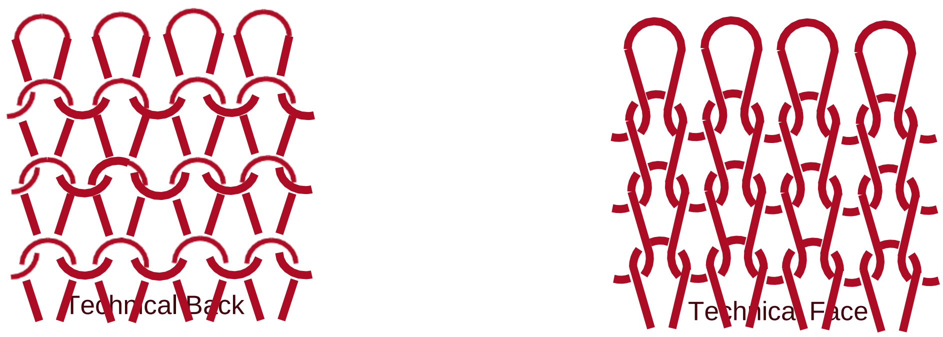
Face Loop: During loop formation, when the new loop emerges through the old loop from back to the face (or front) side, it is called as face loop or weft knit loop.

Back Loop: If the new loop passes from the face side to the back side of old loop, it is called as back loop or weft purl loop.



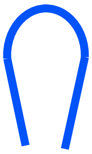
Technical Face: The side of the knitted fabric that consists all of face or knit loops, is called technical face of the fabric.

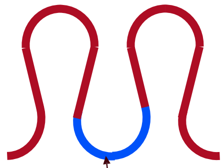
Technical Back: The side of the knitted fabric having full of back or purl loops is called technical back of the fabric. Normally the reverse side of the technical face is the technical back.



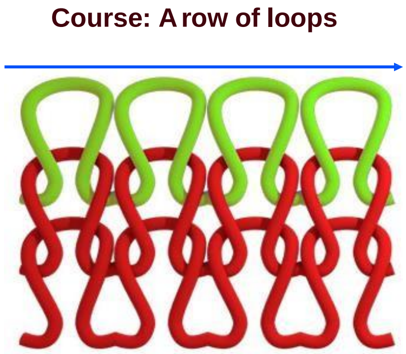
Needle Loop: The upper part of the loop produced by the needle drawing the yarn is called as needle loop.

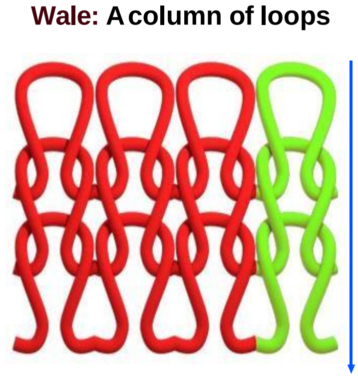
Sinker Loop: The lower part of the knitted loop is technically referred as sinker loop. It is the connection of two legs belonging to the neighbouring stitches lying laterally.





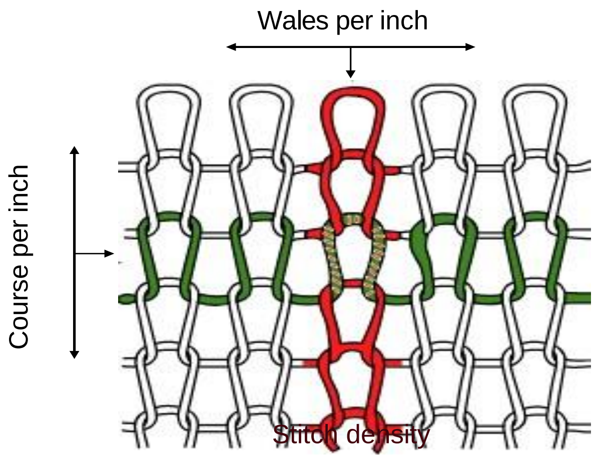
Course: The series of loops those are connected horizontally, continuously are called as courses.
Wales: The series of loops that intermeshes vertically are known as wales.



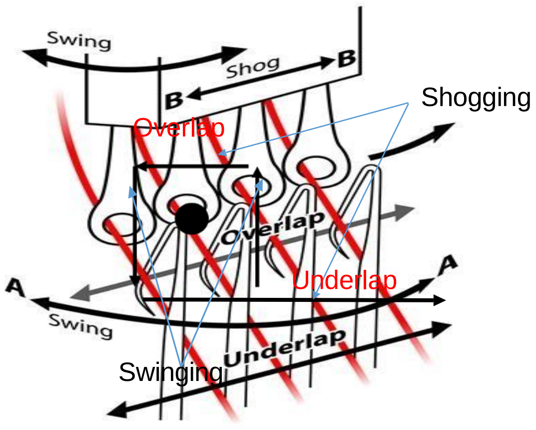


Stitch density: It is the number of stitches per unit area of a knitted fabric. It determines the area of the fabric.

Stitch density = Course per inch or cm × Wales per inch or cm



Over lap: This term refers mainly to warp knitting. Lateral movements of the guide bars on the front side (or hook side) of the needle is called over lap. This movement is normally restricted to one needle space.
Under lap: This term also refers to warp knitting. Lateral movements of the guide bars at the backside of the needles are called under lap. This movement related to the needle space is variable according to the construction of the fabric.

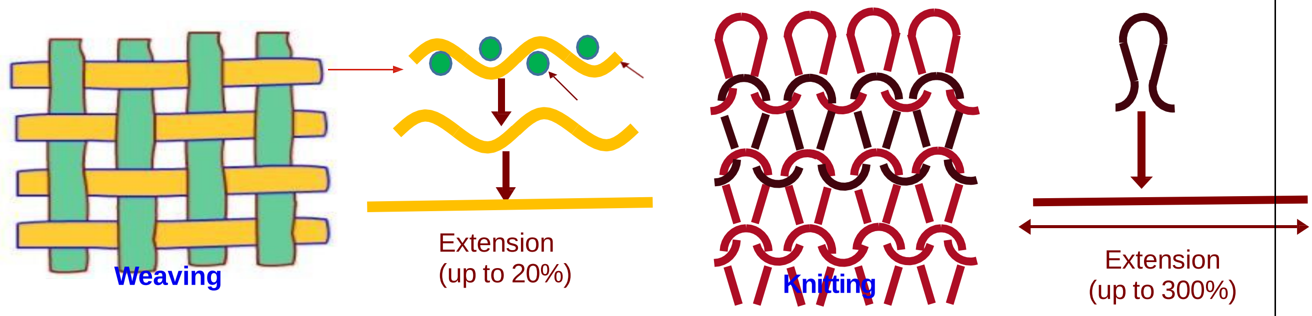


Guide bar movement

Single Jersey: The weft knitted fabrics produced with one set of needles (both in tubular or flat forms) are called as single jersey or plain knitted fabrics.

Double Jersey: Weft knitted fabrics (tubular/flat) produced with two sets of needles mounted in two needle beds are called as double jersey or double-knit fabrics.

1.2 Comparison between Weaving and Knitting



Sl.No.	Weaving	Knitting
1.	In weaving fabric is made by interlacement of yarns.	In knitting fabric is made by inter-looping of yarns.
2.	Two set of yarns – warp and weft are used in making the fabric	One or one set of yarns – either warp or weft is used in making the fabric.
3.	Weaving requires more number of preparatory processes.	Knitting requires less number of preparatory processes.
4.	Machines are mostly flat	Machines are flat as well as circular
5.	Fabric is comparatively more rigid	Fabric is comparatively less rigid
6.	Fabric is less stretchable	Fabric is more stretchable
7.	Fabric does not bend easily and results less comfort and form fitting property	Fabric bends easily and results good comfort and form fitting property
8.	It is easy to tear the fabric	It is difficult to tear the fabric
9.	For same GSM the fabric is less thicker	For same GSM the fabric is more thicker
10.	Fabric has low wrinkle (crease) resistance	Fabric has high wrinkle (crease) resistance
11.	Fabric is stiffer and has harsh feel	Fabric is less stiffer and has soft feel
12.	Fabric is less porous and air permeable	Fabric is more porous and air permeable
13.	Fabric is stronger and durable	Fabric is comparatively weaker and less durable
14.	Lesser inherent tensions cause minimum shrinkage and loss of size	During conversion of yarn into loop, tension development is high which results high shrinkage
15.	Moisture absorption power is less due to compact structure	Moisture absorption is more because of comparatively loose and voluminous structure
16.	Fabrics are more dimensionally stable due to tighter construction and intersecting of warp and weft in right angle	Because of loose structure and inability of yarn to return to original position, the dimensional stability is poor.

1.3 Comparison between warp and weft knitting

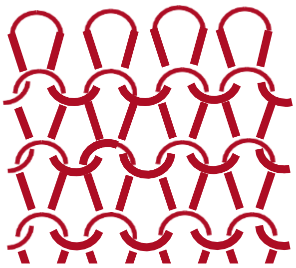
Sl.No.	Weft Knitting	Warp Knitting
1.	Loop formation takes place course wise in horizontal direction	Loop formation takes place wale wise in vertical direction
2.	Needles knit sequentially in a knitting cycle	Needles knit altogether in a knitting cycle
3.	Yarn is supplied generally in the form of cone hold in a creel	Yarn is supplied generally in the form of warp beam
4.	Less preparatory processes are required before knitting	More preparatory processes are required before knitting
5.	Latch needles are used in all machines	Bearded needles are mostly used but latch needles can also be used in some cases
6.	Less variety of structure can be made in a machine	Wide variety of structure can be made in a machine
7.	Change in pattern reduces the machine speed	Change in pattern does not reduce the machine speed
8.	Fabrics have less aesthetic value	Fabrics have more aesthetic value
9.	Fabrics are more resilient and suitable for inner garments	Fabrics are less resilient and not suitable for inner garments
10.	Fabrics have stretchability in both directions, comparatively higher in width direction	Fabrics have lower stretchability in both directions, comparatively higher in width direction
11.	Dimensional stability of the fabrics are lower	Dimensional stability of the fabrics are higher
12.	Wide range of semi or full garment length machines are available	Limited range of garment length machines are available
13.	Machines may be flat or circular	Machines are generally flat
14.	Weft insertion during loop formation is not possible for producing highly dimensional stable technical textiles	Weft insertion during loop formation is possible for producing highly dimensional stable technical textiles
15.	Tailoring is difficult	Tailoring is easy
16.	Machines as well as the fabrics produced are comparatively cheaper	Machines as well as the fabrics produced are comparatively costlier

MODULE – II
WEFT KNITTING

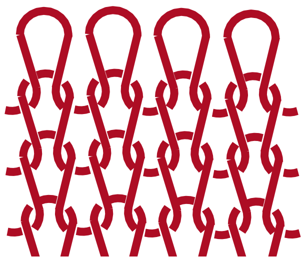
2.1 Types of basic weft knitted structures

Single jersey

It is a plain single knit structure with face loops on one side and back loops on the other. The structure is produced when all the needles of a single bed machine knit at each feed. This structure can be of technical face or technical back.



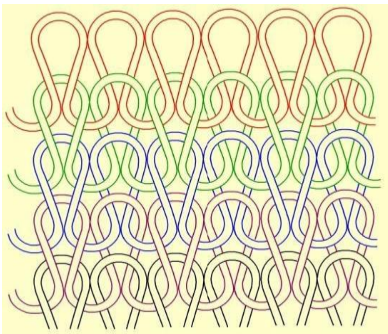
Single Jersey (Technical



Single Jersey (Technical

Rib

In rib structure, each courses having one face and one back loop, with succeeding courses identical to the first one, having alternating wales of face and back loops.

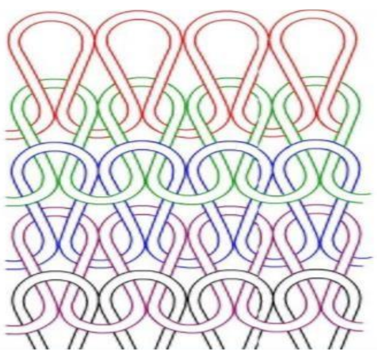


X	O	X	O
X	O	X	O
X	O	X	O
X	O	X	O

Rib (1 x 1)

Purl

In purl structure, each wales having one face and one back loop, with succeeding wales identical to that first one, having alternating courses of face and back loops.

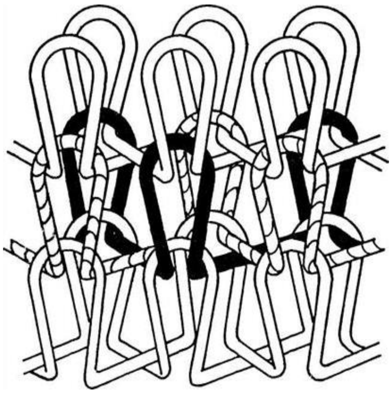


X	X	X	X
O	O	O	O
X	X	X	X
O	O	O	O

Purl (1 x 1)

Interlock

The structure essentially consists of two separate 1x1 rib fabrics intimately combined into one complete fabric. Interlock structure is made up of rib structures, which are of knitted alternately, first a course of one, then a course of the second so that the two individual structures are intermeshed in single composite structure. Unlike the other structures, a course is completed by knitting with two feeders in interlock knitting.



0	X	0
X	0	X
0	X	0
X	0	X

Interlock

2.2 Representation of basic knitted structures in the form of loop diagrams and in the form of stitch notations.

The weft knitted structures can be represented by the following four methods of notations:

1. Verbal notation
2. Graphic or line diagram notation
3. Symbolic notation
4. Diagrammatic notation

Verbal Notation

It describes the structure in a definition form and hence it essentially requires the technical knowledge of knitting. For example, 1x1 rib structure is represented by consisting of face and back loops disposed in an alternate wale lines.

Graphic or Line Diagram Notation

This method is only useful for simple structures and could be easily understood by a beginner with a little knowledge of knitting. For complex structures, by means of line diagram and graphic methods, it is very difficult to represent. It is time consuming as well as confusing.

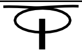
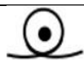
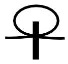
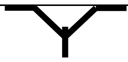
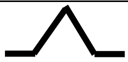
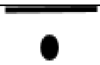
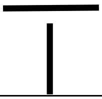
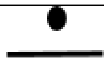
Symbolic Notation.

Here the knowledge of principal stitches those used for weft knitted structures is essential. Knit or purl stitches are ordinary loop forming stitches and are formed by needles, as they rise to feed position. A tuck stitch is formed when a needle receives new yarn, but does not "cast off" its old loop.

In float stitch, the needle does not receive the new yarn to form a loop, but instead, the yarn passes behind the previously held loops i.e., it floats on the reverse side of the fabric.

Diagrammatic Notation

Whenever the face and back loops are involved in the same structure, then two sets of needles, one called the cylinder needle responsible for face loops and the other called the dial needle responsible for back loops are required. A dot represents a needle, either cylinder or dial. A knit stitch is represented by encircling a dot, the circle facing down.

Stitch	Technical Front			Technical Back		
	Diagramatic Notation	Symbolic Notation	Bar Notation	Diagramati cNotation	Symbolic Notation	Bar Notation
Loop/Knit	X			o		
Tuck	•			•		
Float						

2.3 Characteristics of basic knitted structures and end uses.

Characteristics of Single jersey fabrics

1. Appearance of face and back are different
2. Extensibility in width wise is approximately twice than lengthwise
3. Curl or roll of fabrics at edges occur
4. Unravelling of fabric course by course, from either side is possible
5. Thickness of fabric is approximately, twice the diameter of yarn used
6. Run (collapse of wale) will occur if a cut or exposed loop is stressed. The direction of collapse can be either from top to bottom or vice versa.

End uses

T-shirts, baby clothing, Childrens leggings, pyjamas, women's and men's light casual wear, yoga clothing etc.

Characteristics of Rib fabrics

1. The appearance of face and back are identical.
2. Fabric width wise extensibility is approximately twice that of single jersey.
3. Fabric does not curl at edges.
4. Fabric thickness is approximately twice that of single jersey.
5. A run will develop if the exposed loop is cut and the direction of collapse will be from the top to bottom only.

End uses

Sleeve bands, neck bands, sweater waist bands etc.

Characteristics of Interlock fabrics

1. The appearance of face and back are same.
2. Width wise and length wise elongation are approximately the same as single jersey.
3. The fabric does not curl at the edges.
4. The fabric can be unravelled from the end kitted last.
5. Two yarns must be removed to unravel a complete knitted structure.

End uses

Used in all sorts of elastic garments, such as t-shirts, tops & sportswear.

Characteristics of Purl fabrics

1. Fabric has the same appearance in face and back.
2. Extension in all direction but length wise extension is more.
3. The fabric does not curl at the edges.
4. The fabric is two or three times thicker than single jersey.
5. The fabric will run in wale direction starting from either end.
6. The fabric may be unravelled course by course from either end.

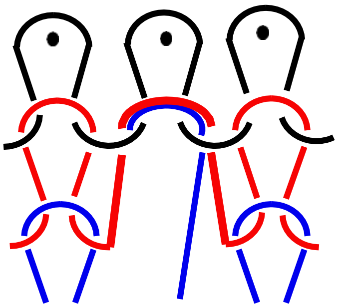
End uses

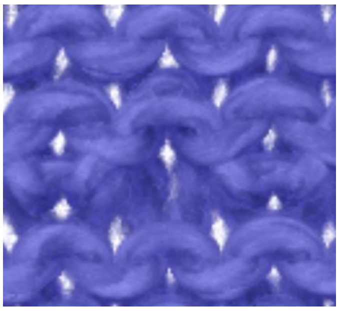
Used in manufacture of bulky sweaters, cardigans, pullovers and children's clothing.

2.4 Definition of float and tuck stitches, Effects of tuck and float stitches on fabric properties

Tuck Stitch

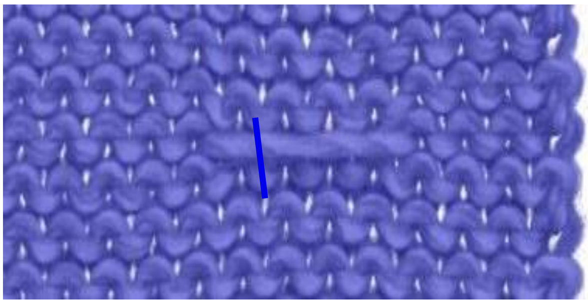
When the needle is raised by camming action to obtain yarn in the hook, but is not raised high enough to clear the previously formed loop below the latch, the needle will have two loops in the hook, and a tuck stitch will be formed when it knits at next course.

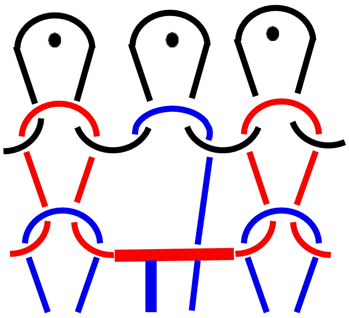


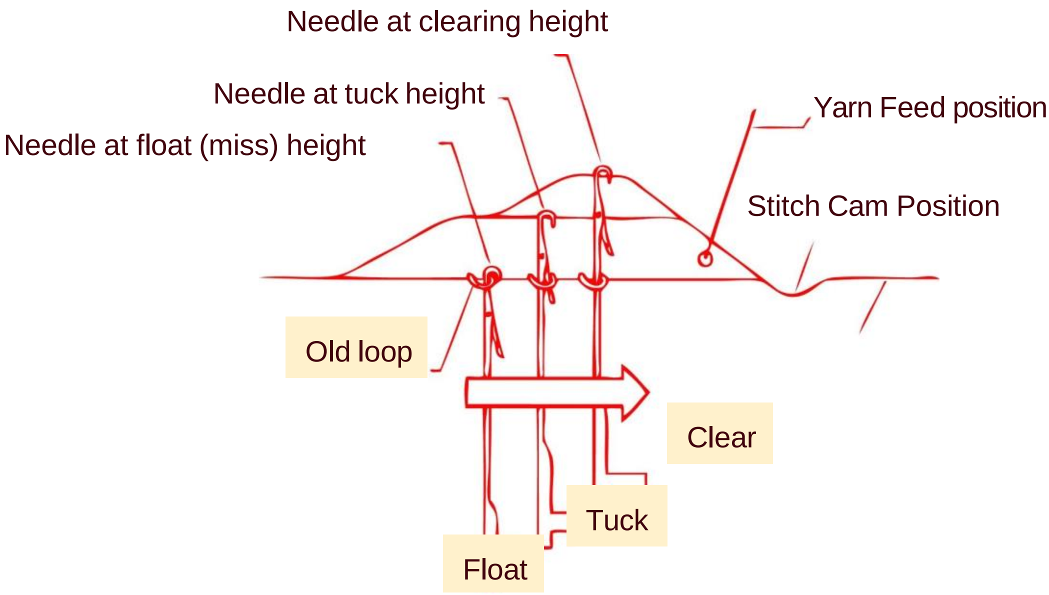


Float Stitch

A float stitch occurs only if the yarn is presented to the needle but is not taken by it. Here the needle is not activated upwards to receive the yarn that is presented to it and hence it will retain its old loop in the hook.







Effect of Tuck Stitches

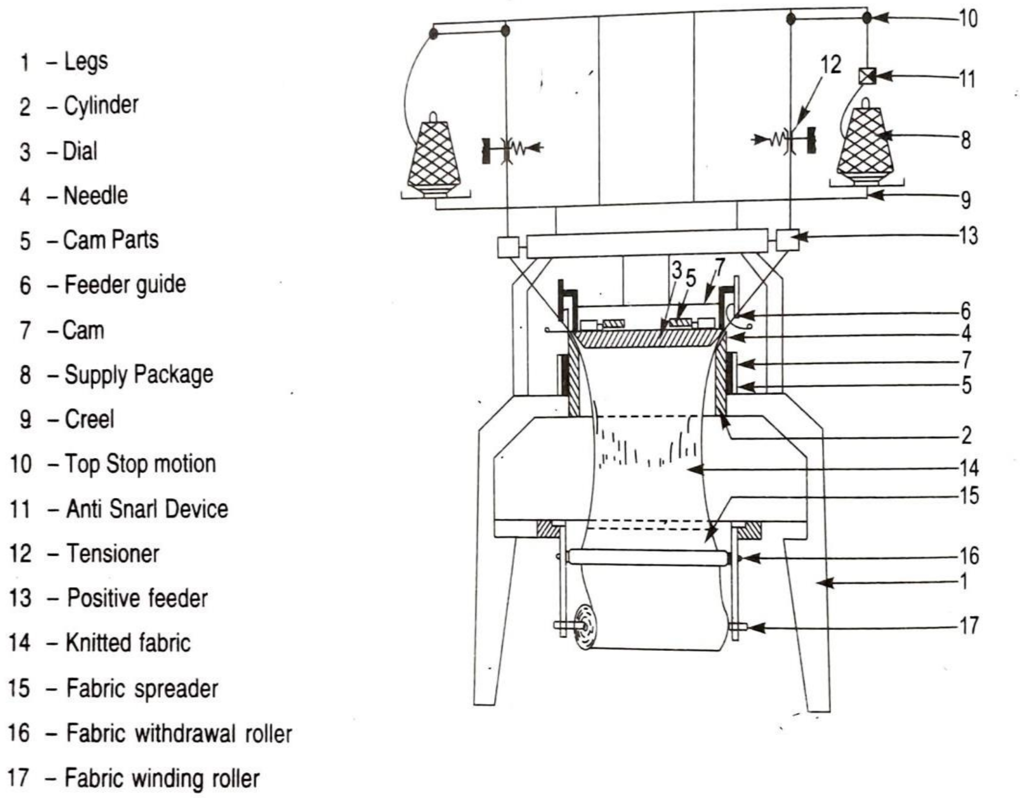
1. Fabric with tuck stitches is thicker than knit stitches due to accumulation of yarn in stitches at tucking places.
2. The structure with tuck stitches is wider than with knit stitches and the loop shape has a wider base at stitches.
3. Tuck stitch structure is less extensible because at every tuck stitch, the loop length is shortened.
4. Due to thicker in nature, the tuck stitched fabric is heavier in weight per unit area than the knit stitches.
5. Tuck stitched structure is more open and porous than the knit stitched fabric. Tuck stitch is also used to get fancy effects by using coloured yarns.

Effect of Float Stitches

It is used for designing, when an unwanted, coloured yarn is to be hidden completely from the surface, by allowing it to float at the back instead of tucking. By floating, uniform texture is obtained and the yarn can be saved.

1. Float stitch makes the fabric thinner than the tuck stitched one, as there is no yarn accumulation.
2. It makes the fabric narrower as there is no looped configuration and hence the whole structure is pulled to minimum width.
3. Less extensible than either knitted or tucked structures.
4. Fabric is lighter in weight due to minimum yarn used in construction.
5. Fabric is flimsy or less rigid compared to others.

2.5 Passage of material through circular weft knitting machine.



Circular Weft Knitting machine

Parts of Circular Weft Knitting Machine:

Circular **knitting** machine contains the following parts:

1. Creel
2. Cone holder
3. Aluminum Telescopic Tube
4. MPF Device
5. Winding Wheel & Driven Pulley
6. Yarn Tensioner
7. Stopper
8. Sensor
9. Lycra Attachment Device
10. Yarn Guide
11. Feeder Guide
12. Feeder Ring
13. Needle
14. VDQ Pulley
15. Pulley Belt
16. Cam

17. Cam Box
18. Sinker
19. Sinker Box
20. Sinker Ring
21. Cylinder
22. Body
23. Base Plate
24. Air Blow Gun
25. Automatic Needle Detector
26. Fabric Detector
27. Adjustable Fan
28. Lubricating Tube
29. Manual Jig
30. Gate
31. Spreader
32. Take-Down Motion Rollers
33. Winding Roller

2.6 Function of the machinery parts: Creels, stop motions, positive feeders, yarn guides, take-up and winding mechanism.

1. **Creel:** Creel is a vertical aluminium stick where creel is placed for holding the yarn cone. It also known as side creel.
2. **Cone Holder:** Cone holder is an inclined metallic stick where yarn cone is placed for feeding the yarn to the feeder easily. It is also known as cone carrier.
3. **Aluminum Telescopic Tube:** This is the tube through which yarn is passed. It reaches the yarn to the Memminger positive feeder. It works as a yarn cover. It protects the yarn from the excessive friction, dust and fly fiber.
4. **MPF Device:** MPF means **Memminger Positive Feed**. It receives yarn from aluminium telescopic tube. As this device gives a positive feed of yarn to the needles, so it is called Memminger Positive Feed device. MPF provides uniform tension to yarn, reduces machine stoppage, identify and remove yarn knot and give a signal if yarn breaks.
5. **Winding Wheel & Driven Pulley:** Some yarn is rolled on the winding wheel so that if the yarn is torn off, the whole yarn does not need to be replaced again. Driven Pulley controls the speed of MPF.
6. **Yarn Tensioner:** Yarn tensioner is a device that ensures the appropriate gripping of yarn.
7. **Stopper:** Stopper is a part of MPF. Yarn is passed through the stopper and it is connected with the sensor. If yarn breaks, then stopper gets upwards and the sensor receives a signal to stop the machine. At the same time, a light also flashes. Generally, a stopper is two types. Top stopper and bottom stopper.
8. **Sensor:** The sensor is located at MPF. If anyone of the stoppers gets upwards due to the breakage of yarn, the sensor automatically receives signal and stops the machine.
9. **Lycra Attachment Device:** Lycra yarn is feed by the following device.
10. **Yarn Guide:** Yarn guide receive yarn from the MPF. It is used to guide the yarn and sent yarn to the feeder guide. It maintains the smooth tension on the yarn.
11. **Feeder Guide:** Feeder guide receive yarn from yarn guide and feed yarn to the needle. It is the last device which releases yarn to the knit fabric.
12. **Feeder Ring:** This is a circular ring which holds all the feeder guide.
13. **Needle:** Needle is the master part of the knitting machine. Needle receive yarn from the feeder, create a loop as well as release old loop and finally produce the fabric.
14. **VDQ Pulley:** VDQ means Variable Dia for Quality. As this pulley controls the quality of knitted fabric by adjusting GSM & stitch length during the knitting process, so it is called VDQ pulley. To increase the fabric GSM the pulley is moved towards the positive direction and to decrease the fabric GSM the pulley is moved towards the reverse direction. This pulley also called quality adjustment pulley (QAP) or Quality adjustment Disk (QAD).
15. **Pulley Belt:** Pulley belt gives the motion to pulley

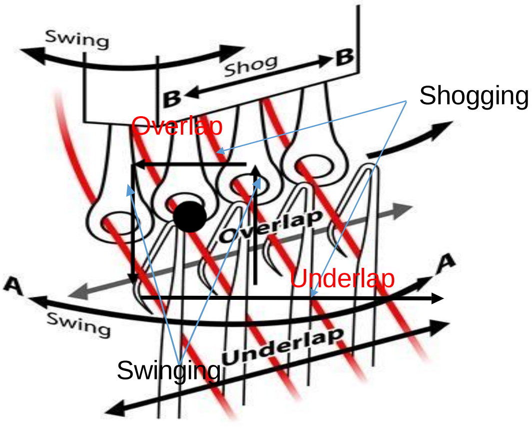
16. **Cam:** Cam is the device which converts the rotary motion into a definite reciprocating motion for the needles and some other devices.
17. **Cam Box:** Cam box holds and supports cam. Knit, truck and miss cam are arranged horizontally according to fabric design in the cam box.
18. **Sinker:** Sinker is another master part of the knitting machine. It supports yarn to form the desired loop. Sinker is located at each and every gap of the needle.
19. **Sinker Box:** Sinker box holds and supports the sinker.
20. **Sinker Ring:** This is a circular ring which holds all sinker box
21. **Cylinder:** Cylinder is another master part of the knitting machine. Cylinder adjustment is one of the most important technical work. The cylinder holds and carries needle, cam box, sinker, etc.
22. **Body:** The body of the knitting machine covers the whole area of the machine. It holds base plate, cylinder, etc.
23. **Base Plate:** Base plate is a plate that holds the cylinder. It located on the machine body.
24. **Air Blow Gun:** A device connected with high-velocity pressurized air. It blows air to feed the yarn through the aluminium tube. It also used for cleaning purposes.
25. **Automatic Needle Detector:** A device placed very close to the needle sets. It gives a signal if it found any broken or damaged needle.
26. **Fabric Detector:** If fabric torn off or fall down from the machine, fabric detector touches the cylinder and the machine becomes stopped. It also called fabric fault detector.
27. **Adjustable Fan:** Generally, two sets of running fans are continuously circulated from the center of machine dia. These fans are faced with the needle points that remove dust, hairy fiber as well as keep needle cool. Adjustable fans are rotated in the opposite motion of the cylinder.

MODULE – III
WARP KNITTING

3.1 Define Warp Knitting loop structures

Overlap: This term refers mainly to warp knitting. Lateral movements of the guide bars on the front side (or hook side) of the needle is called overlap. This movement is normally restricted to one needle space.

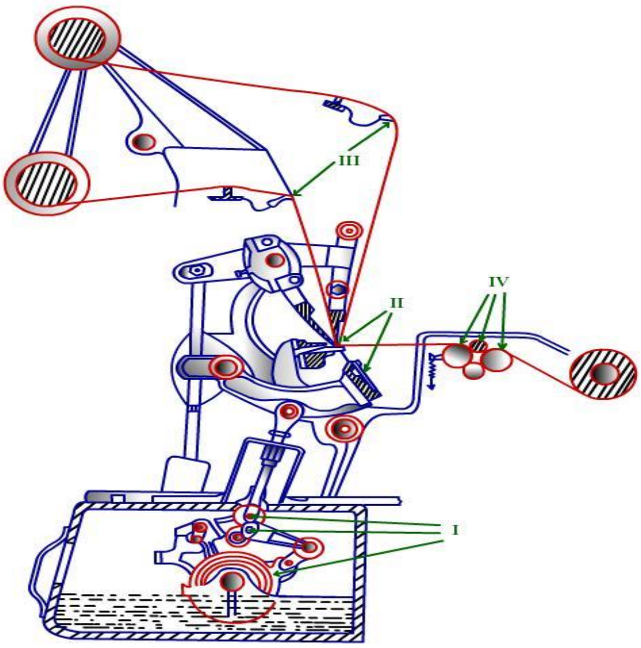
Under lap: This term also refers to warp knitting. Lateral movements of the guide bars at the backside of the needles are called under lap. This movement related to the needle space is variable according to the construction of the fabric.



Guide bar movement

3.2 Differentiate warp knitting machines –Tricot & Raschel

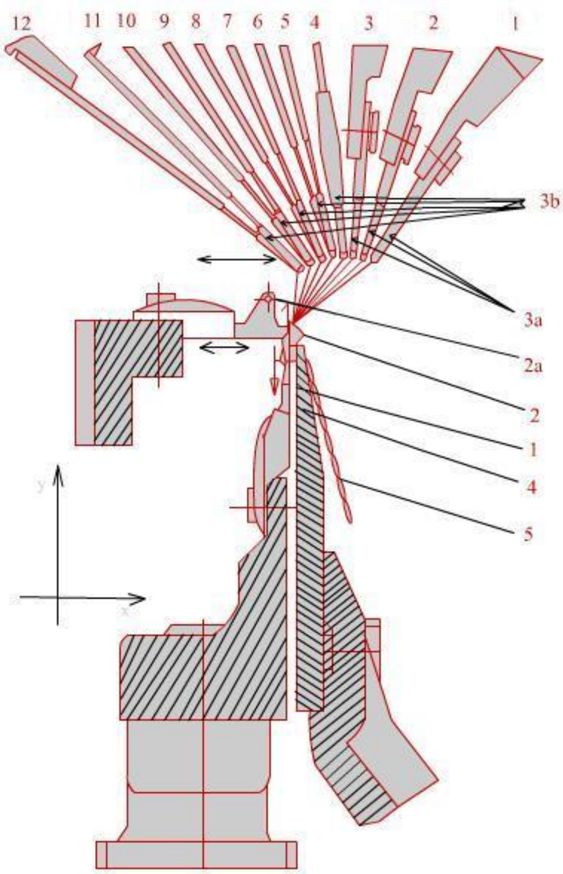
The tricot machine:



The machine can be broadly divided into four sections: The section I contains the central drive to the knitting elements, the section II represents the knitting zone where all the knitting elements converge and interact for converting the yarns into knitted fabric, the section III forms the yarn feeding zone and the section IV is the cloth take up zone.

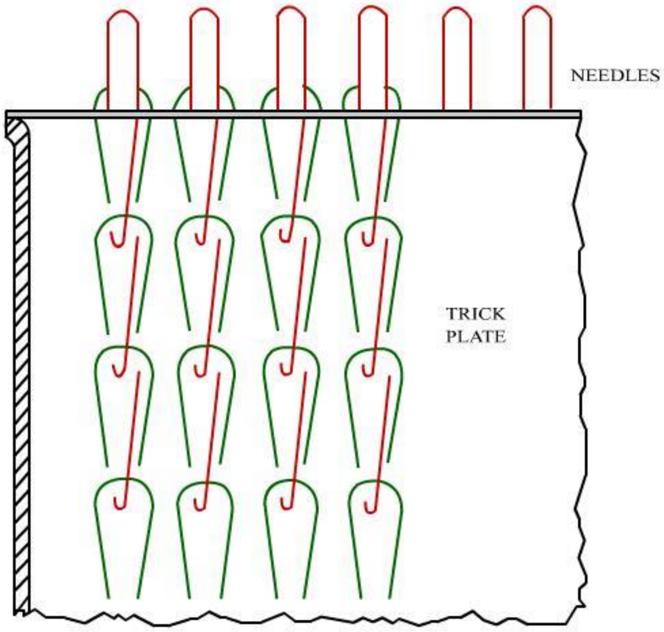
The driving mechanism is usually housed in an enclosure filled with machine oil. A central crank shaft, driven by the main motor is linked to reciprocating rods which jut out through the top plate of the enclosure. One set of rods is linked to the needle bar, one set to the sinker bar while another set is linked to the guide bars. The needle bar carries the needles and performs the function of the needle bed. The sinker and guide bars carry sinkers and guides.

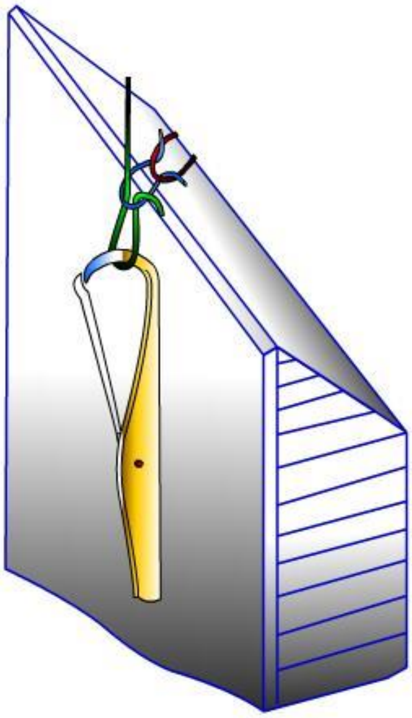
The Raschel machine:



In this figure, (1) is the needle, (2) is the sinker, (3) is the set of guide bars, (4) the trick plate and (5) the knitted fabric. Raschel machines employ latch needles (of late also compound needles) which are mounted on a bar and there may be one bar (single bed Raschel) or even two needle bars (double bed Raschel) in a machine. The sinker performs the function of holding down the fabric during the upward journey of the needles but play no role in the casting-off process. For assisting in casting-off, the trick plate is employed.

As can be observed from Fig., the fabric, coming out of the knitting zone, is taken down over the trick plate at a very low angle such that the fabric and needle axis are nearly parallel to each other. During the downward motion of needle, the new yarn is bent across the arms of the cast-off loop, because the loop just cast off is bodily supported by trick plate.





The trick plate **Casting-off with trick plate**

Each newly cast-off loop in the body of the fabric is thus supported by the top edge of the trick plate and resists as a group any movement of fabric in a direction along the downward motion of needle. Thus the supports/restrictions necessary for bending a yarn is provided by the rigidity acquired by the arms of loops just cast-off. This method permits production of wale lines devoid of sinker loops. Many networks showing large openings are therefore effectively produced on Raschel. Needless to mention, the manner of casting-off in tricot would not permit production of structures in which neighbouring wale lines are not connected by sinker loops. However, net like structures are effectively produced also on tricot.

Because the yarn sheet fed to the needles and the resultant knitted fabric are nearly in the same plane, a very high take down tension can be applied on the fabric without loading the needles excessively. This feature too permits maintaining very straight and rigid wale lines on the machine, a necessary condition for producing nets with large openings.

As the fabric is pulled in the downward direction by the take-up motion, it is conceivable that two sets of needle bed and trick plate can be easily arranged back-to-back (Video of double bed Raschel) for the production of a double layered knitted fabric.

MODULE – IV
KNITTING CALCULATION

4.1 Definition of machine gauge, tightness factor and yarn number

Machine gauge

It is the number of needles per inch arranged on the needle bed. Yarn number and machine gauge are related as

a. Yarn Tex = $(100/G)^2$
b. Worsted count = $G^2/10$ where G = Needles/Inch

Tightness factor

It is the ratio of the area covered by the yarn in one loop to the area occupied by that loop.

Tightness factor, $K = \sqrt{Tex} / l$ where l = loop length in centimetre.

4.2 Calculation of weft knitting machine production, Calculate loop length, fabric widths, weigh per square yard

Among the various factors those are to be considered in the manufacture of knitted fabrics, it is very important for the knitter to calculate the productivity of a machine in order to be able to schedule production and specify the delivery dates to the customer. Productivity in weft knitting terms refers to the length of the fabric that comes out of the machine, the width of the fabric both single and double width and the weight of the fabrics produced in unit time. The following are the important parameters which decide the production calculations of circular weft knitting.

Machine Parameters

a. Machine speed (rpm)
b. Machine diameter (inches)
c. Machine gauge (Needles/inch)
d. Number of feeders
e. Machine efficiency
f. Number of needles

Yarn and fabric parameters

a. Yarn count
b. Stitch length
c. Stitch density
d. Wales per inch
e. Courses per inch

Formula

The following simple formulae are used to calculate the knitting machine productivity:

I. Fabric production in Yards/Hour = s x f x 60 / CPI x 36
II. Fabric production in pounds/hour = S x f x N x l x 60 / 36 x 840 x Ne
III. Fabric weight per linear yard (lbs) = N x l x CPI x 36 / 36 x 840 × Ne
IV. Fabric width (in inches) = Number of Needles/WPI
   Or Number of needles x Wale spacing
   Where, Wale spacing = 4 × yarn diameter
V. Fabric weight (lbs) per square yard = Weight per linear yard × 36 / Fabric width in inches (for flat fabrics)

= Weight per linear yard × 36 / Fabric width in inches × 2

(for tubular fabrics)

Where,
S = Machine speed in rpm
f = Number of feeders in the machine
N = Number of needles in the machine
l = Stitch length in inches
CPI = Courses per inch
WPI = Wales per inch

Example

Calculation of the production of knitted fabrics in terms of (i) Yards per hour, (ii) pounds per hour, (iii) Fabric weight per linear yard, (iv) Fabric width and (v) Fabric weight per square yard of a knitting machine running with the following data:
Machine speed = 20 rpm
Number of needles = 490
Stitch length = 0.17 inches
Number of feeders = 12
Yarn count = 25's Ne
CPI = 24
WPI = 29

I. **Fabric production in Yards/Hour = s x f x 60 / CPI x 36**
= 20 x 12 x 60 / 24 x 36
= 16.67

II. **Fabric production in pounds/hour = S x f x N x l x 60 / 36 x 840 x Ne**
= 20 x 12 x 490 x 0.17 x 60 / 36 x 840 x 25
= 1.59

III. **Fabric weight per linear yard (lbs) = N x l x CPI x 36 / 36 x 840 × Ne**
= 490 x 0.17 x 24 x 36 / 36 x 840 x 25
= 0.095

IV. **Fabric width (in inches) = Number of Needles/WPI**
= 490 / 29
= 16.9 inches (open width)
= 8.45 inches (folded width)

V. **Fabric weight (lbs) per square yard = Weight per linear yard × 36 / Fabric width in inches**
= 0.095 / 16.9
= 0.0056 lbs

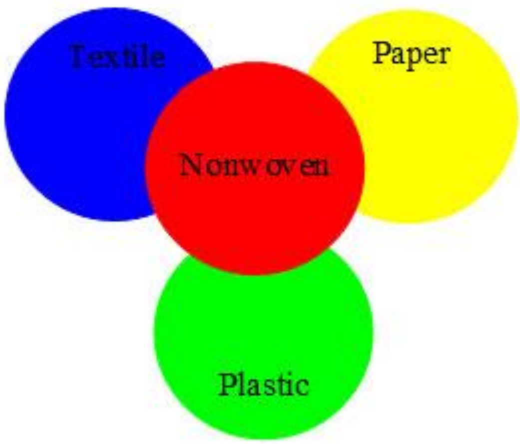
MODULE – V
NON - WOVEN

5.1 Introduction to non-woven technology

Nonwovens are known as engineered fabrics. They are created with a view to targeted structure and properties by applying a set of scientific principles for a variety of applications.

Nonwovens are manufactured by high-speed and low-cost processes. As compared to the traditional woven and knitting technology, a larger volume of materials can be produced at a lower cost by using nonwoven technology.

The manufacturing principles of nonwovens are manifested in a unique way based on the technologies of creation of textiles, papers, and plastics, as a result, the structure and properties of nonwovens resemble, to a great extent, to those of three materials.



Definitions of nonwovens

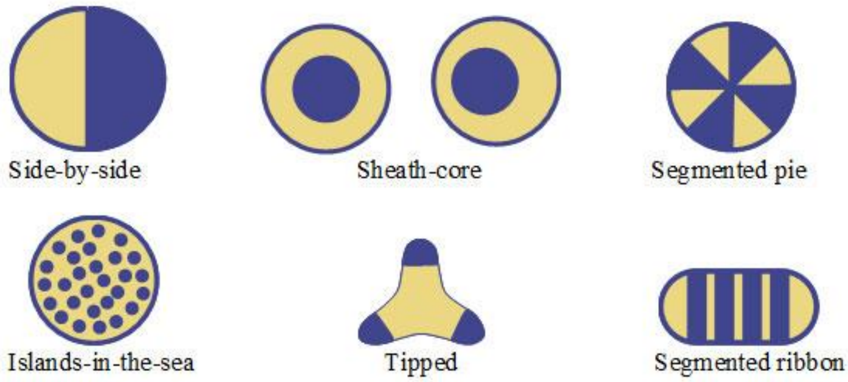
As per ISO 9092, nonwoven is defined as "manufactured sheet, web or batt of directionally or randomly oriented fibers, bonded by friction, and/or cohesion and/or adhesion, excluding paper and products which are woven, knitted, tufted, stitch-bonded incorporating binding yarns or filaments or felted by wet-milling, whether or not additionally needled. The fibers may be of natural or man-made origin. They may be staple or continuous filaments or be formed in situ.

5.2 Types of fibres used and end uses of nonwovens

The conventional man-made and natural staple fibres and bicomponent staple fibres are primarily used for preparation of carded nonwovens. The wood pulp is very popular for preparation of air-laid nonwovens.

Fiber	Density ($Kg.m^{-3}$)	Moisture regain (%)	Breaking force ($N.tex^{-1}$)	Breaking elongation (%)	Initial modulus ($N.tex^{-1}$)	Specific flexural rigidity ($mN.mm^2.tex^{-2}$)	Coefficient of static friction (1)
Polypropylene	910	0	0.65	17	7.1	0.51	-
Polyester	1390	0.4	0.47	37	8.8	0.30	0.58
Nylon 6	1140	4.1	0.29	46	0.6	-	0.47
Nylon 6, 6	1140	4.1	0.37	43	1.0	0.15-0.22	0.47
Acrylic	1190	1-2	0.27	25	6.2	0.33-0.48	-
Viscose rayon	1490	12-14	0.21	15.7	6.5	0.35	0.43
Glass	2500	0	0.75	2.5	29.4	0.89	-
Cotton	1520	7-8	0.19-0.45	5.6-7.1	3.9-7.3	0.53	0.22
Flax	1520	7	0.54	3	18.0	-	0.19
Jute	1520	12	0.31	1.8	17.2	-	0.46
Wool	1310	14	0.11-0.12	29.8-42.5	2.1-3	0.24	0.14
Silk	1340	10	0.38	23.4	7.3	0.60	0.52

In addition, the bicomponent fibres are also used for making carding and air-laid nonwovens. The bicomponent fibers are produced by having two polymers simultaneously form a fiber. They are used as binder fibers for thermal bonding. Some of the popular configurations of bicomponent fibres are shown in Fig.



Out of the six configurations shown, the sheath-core arrangement is mostly used. Three sheath-core bicomponent fibres are very popular. In the polyester core and polyester sheath bicomponent fibre, the core melts at 250 degree Celsius, but the sheath melts at 110 degree Celsius. In case of polyester core and polyethylene sheath bicomponent fibre, the core melts at 250 degree Celsius, but the sheath melts at 130 degree Celsius. In case of polypropylene core and polyethylene sheath bicomponent fibre, the core melts at 175 degree Celsius, but the sheath melts at 130 degree Celsius.

End uses of non-woven

a. Disposable nappies
b. Sanitary napkins and tampons
c. Sterile wraps, caps, gowns, masks, and curtains used in the medical field
d. Household and personal wipes
e. Laundry aids (fabric dryer-sheets)
f. Apparel interlinings
g. Carpeting and upholstery fabrics, padding and backing

h. Wall coverings
i. Agricultural coverings and seed strips
j. Automotive headliners and upholstery
k. Filters
l. Envelops
m. Tags
n. Labels
o. Insulation
p. House wraps
q. Roofing products
r. Civil engineering fabrics/geotextiles

5.3 Methods of web preparation & Orientation of fibres in the web

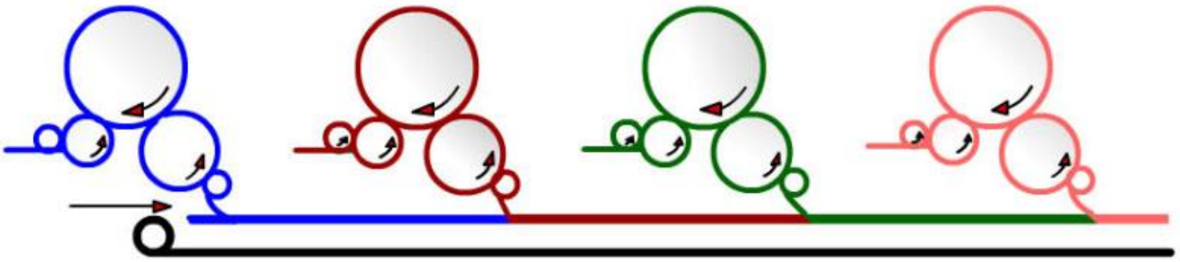
Web stacking processes

There exist three web stacking processes, namely

Parallel-lay process (parallel-laid)
Cross-lay process (cross-laid)
Perpendicular-lay process (perpendicular-laid)

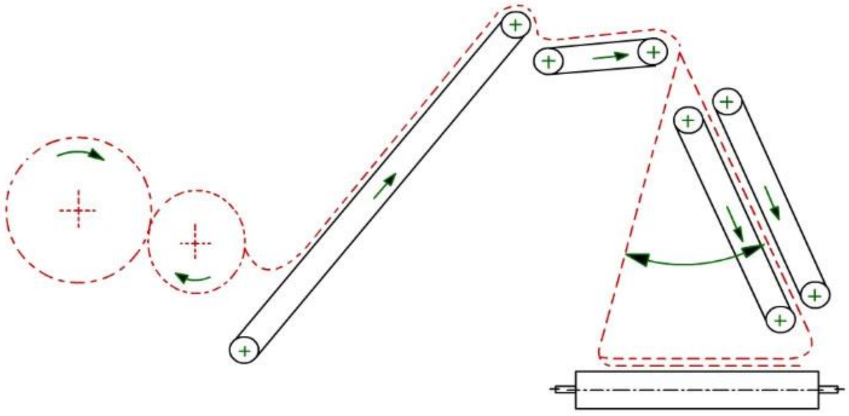
Parallel-lay process

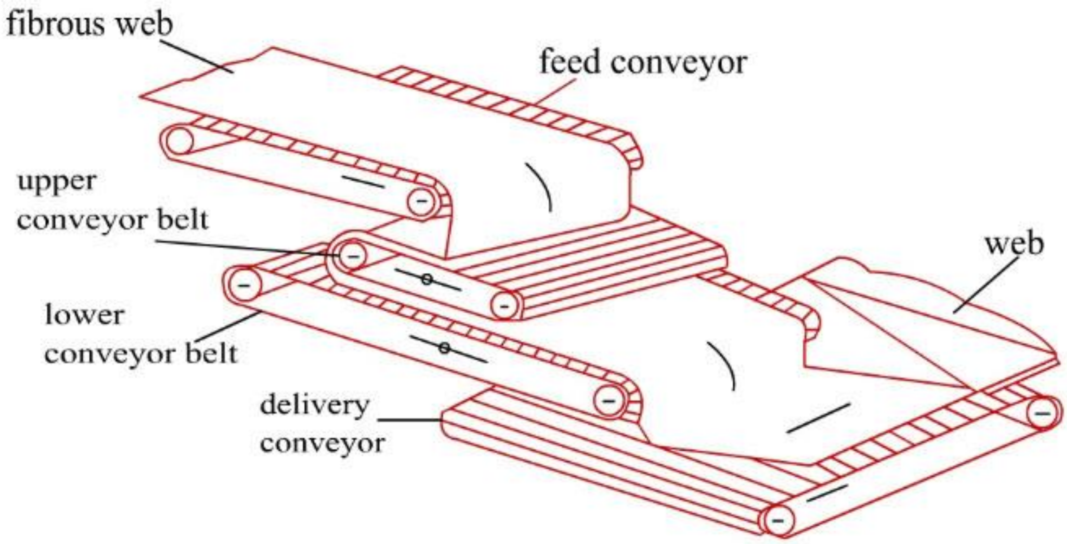
In parallel-lay process, the carded webs supplied by sequentially arranged parallel-cards are doubled on a common conveyor belt to form parallel-laid batt. This is shown in Figure. The fibers in the parallel-laid batt are preferentially oriented in the carding machine direction. The width of the parallel-laid batt is the same as that of the carded web. It produces batt with layered structure, each layer of carded web can be made up of different fibers or different basis weight, etc.



Cross-lay process

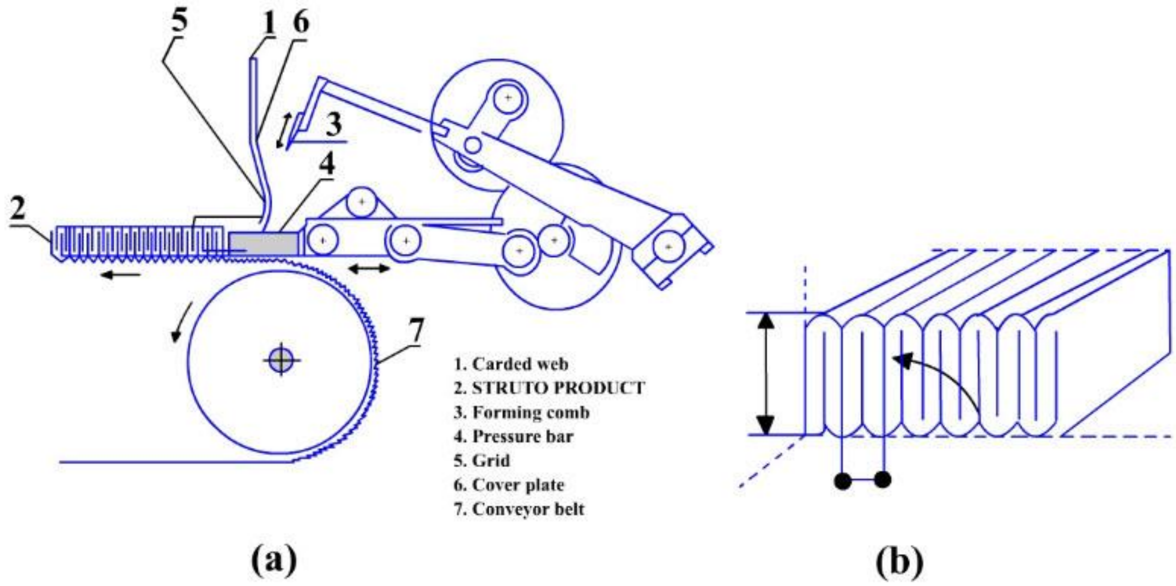
The cross-lay process is very popular among the nonwoven industries. The functions of cross-lay process are as follows.
To obtain batt with higher basis weight than that of card web
To obtain batt with higher width than that of card web
To obtain batt with fibers preferentially oriented along the transverse direction of it
To obtain batt with layered structure
There exist two types of cross-laying, camel back laying and horizontal laying. The camel back laying is shown in Figure. It is so termed because of the shape of the web path used by this machine. In camel back laying, a conveyor transports the emerging web from a card, upwards to a pivot point from which the conveyor system reciprocates to layer the web onto a cross conveyor. Such systems utilized simple harmonic motion to reciprocate the web layering conveyor and as such, produced heavy edges at the end of each traverse due to overfeed of the web as the mechanism decelerated and then accelerated at the sides. Here, the laying width can be changed and it depends on machine height and the machine throughput is constant.





Perpendicular-lay process

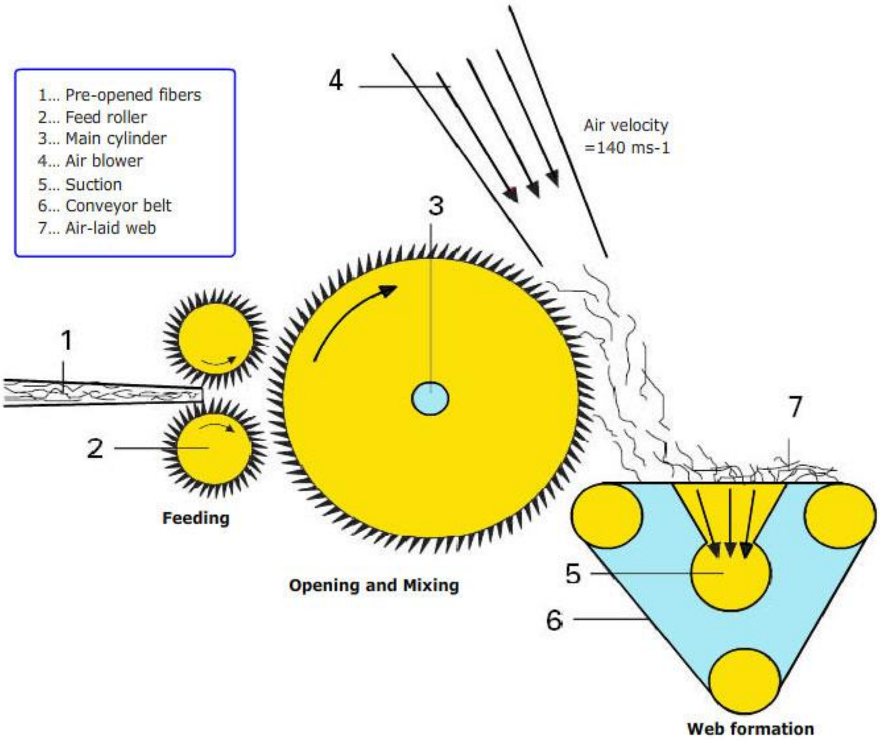
The perpendicular-lay process is considered as a special laying process to obtain



significant z-directional orientation of fibres in the batt. The resulting batt, often thermally bonded, offers excellent compression-recovery properties that make them suitable for automobile seat squab and sound insulation applications.

Air-lay process

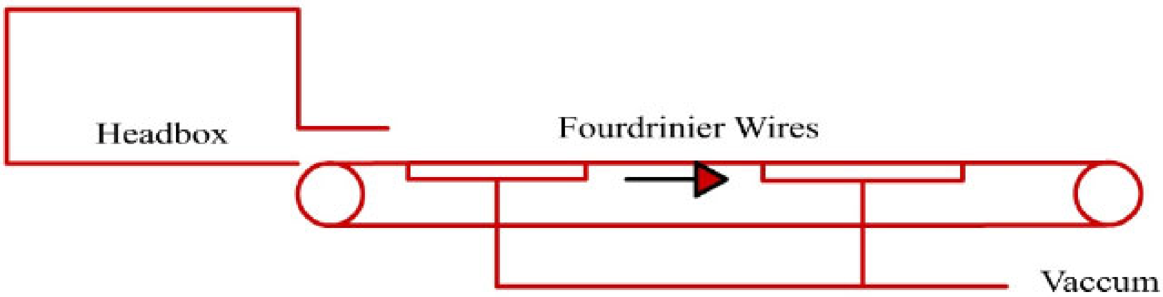
The air-lay process was invented during 1940s with an aim to overcome the high degree of anisotropy of fibre direction in the nonwoven fabrics prepared from carded webs. In this process, the fibres are dispersed in air and then deposited from a suspended state onto a perforated screen to form a web. Figure displays the schematic diagram of air-lay system.

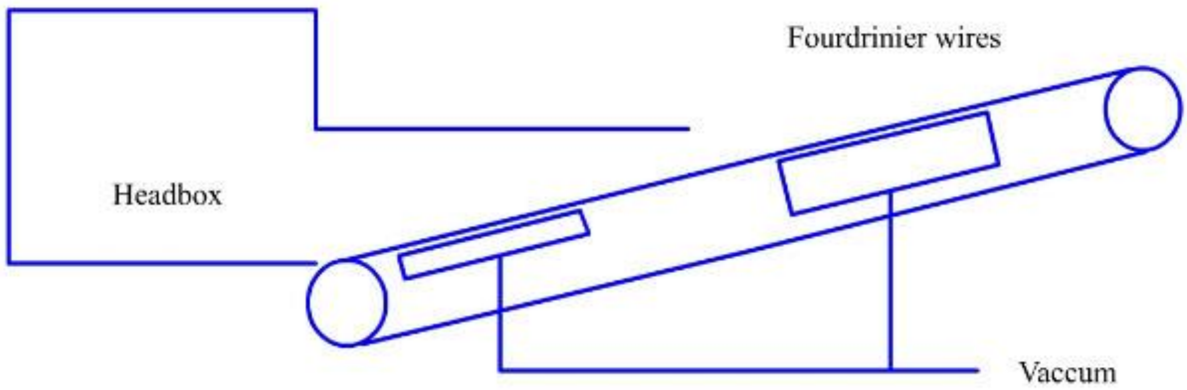


It consists of three units: feeding, opening and mixing, and web formation. The fibres are fed to an opening roller by a pair of feed rollers. The fibres are gripped by the feed rollers and opened by the opening roller. The fibres are then transported by hooking around the wire teeth on the roller and are subsequently removed by a high-velocity airstream directed over the wire teeth surface. In this way, the fibres are mixed with air and transported with it to a perforated conveyor where the air is separated and fibres are deposited to form a web.

Wet-lay Process

The wet-lay nonwoven process is known to be derived from the wet-laid paper making process. H. Fourdrinier developed a papermaking machine that has been the basis for the most modern papermaking machines employing very short fibers. The schematic diagram of this machine is shown in Figure.

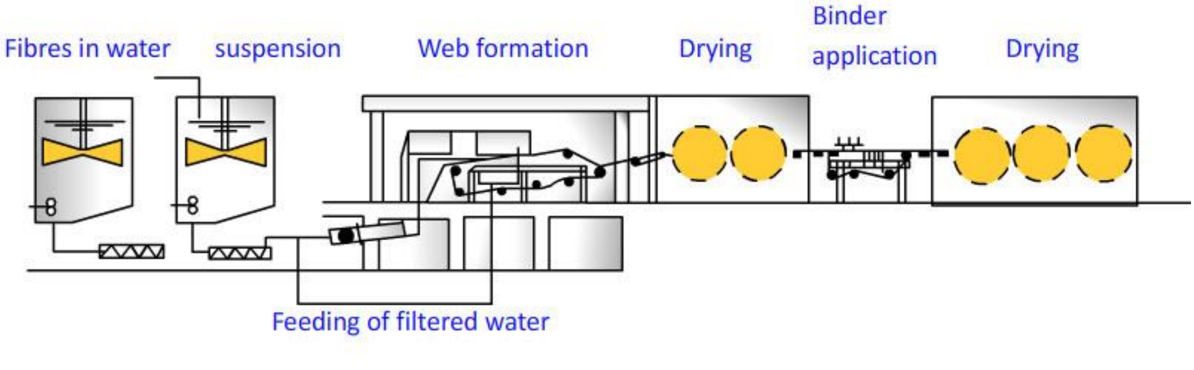




The wood pulp and water in the ratio of 0.003-0.007 (w/w) are mixed to make a good quality suspension of fibres and water. The suspension is then pumped to the headbox which has a small opening, often called as slice. Through the slice, the fibre-water suspension is dropped onto the moving perforated Fourdeinier wires. These wires contain a lot of perforations through which the water gets drained to the vacuum and the fibres, deposited on the moving wires, formed a web. In this way, the wet-laid paper is formed. But, by using this machine it was not possible to process relatively long fibers as the mentioned dilution ratio results in inadequate fiber dispersion in water. In this regard, F. Osborne and C. H. Dexter proposed a solution. According to them, in order to process longer fibres, the ratio of weight of fiber pulp and weight of water should be around 0.0005-0.00005 and in order to handle such a huge quantity of water, the inclination of the forming wire to the base is required to be equal to 20°. The modified machine had a large headbox (slice) opening with inclined wire machine is shown in Figure. This machine has been used to make papers from long fibres and subsequently the basis for making nonwovens also.

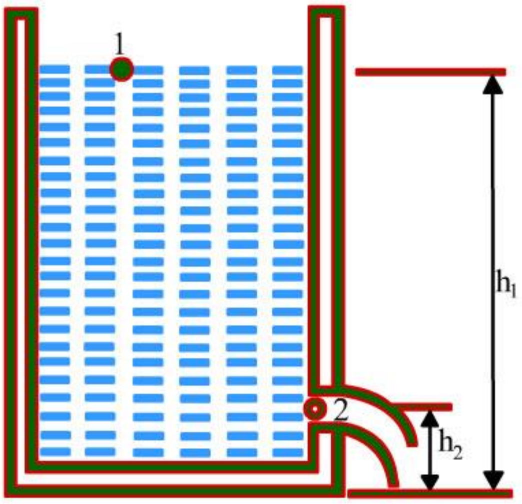
Process description

The schematic diagram of a typical wet-lay process for making nonwovens is shown in Figure. The fibres are mixed with water and it forms fibre-water suspension. It shows two mixing tanks for preparation of better fibre-water suspension. This suspension is then pumped through the headbox to the perforated wire. The water is drained through the perforations and the fibres are laid on the moving wire to form a web. The wet-laid web is then dried and bonded by using binder. It is again dried and finally wound on a roll.



Process model

It is often necessary to calculate process parameters in advance with an aim to obtain a specific structure of wet-laid nonwovens. Because of this, it is often necessary to model the wet- lay process. The following section deals with a simple model of wet-lay process. Figure displays the schematic diagram of a headbox of a wet-lay nonwoven machine.



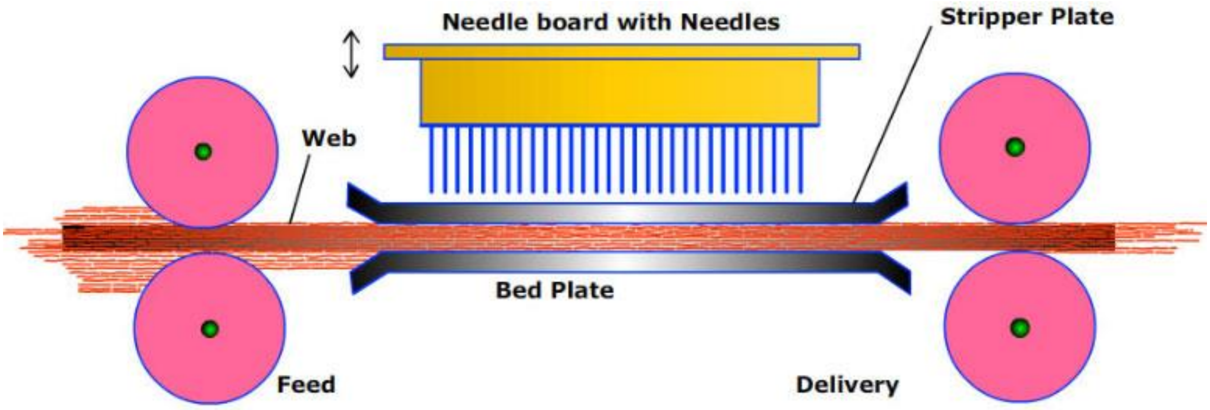
The velocity of water in relation to the velocity of wire determines the structure of the web. When both the velocities are equal then the fibre lay-down is found to be practically random. When the velocity of wire is higher than the velocity of water then fibres are found to be preferentially orientated in the machine direction, but when the velocity of wire is lower than the velocity of water then fibres are found to be preferentially orientated in the cross direction.
Fabric defects

5.4 Methods of bonding of web, Brief idea on non-woven fabrics by needle punching, stitch bonding, spun bonding, thermal bonding, Adhesive bonding techniques etc.

Needle punching process

Principle

Needle punching is a nonwoven process by which the fibres are mechanically entangled to produce a nonwoven fabric by repeated penetration of barbed needles through a preformed dry fibrous web. The machine which accomplishes this process is known as needle loom. Figure 3.1 displays the schematic diagram of a needle loom. The fibrous web, which is unbonded and therefore thick and voluminous, is fed to the machine by a pair of feed rollers.

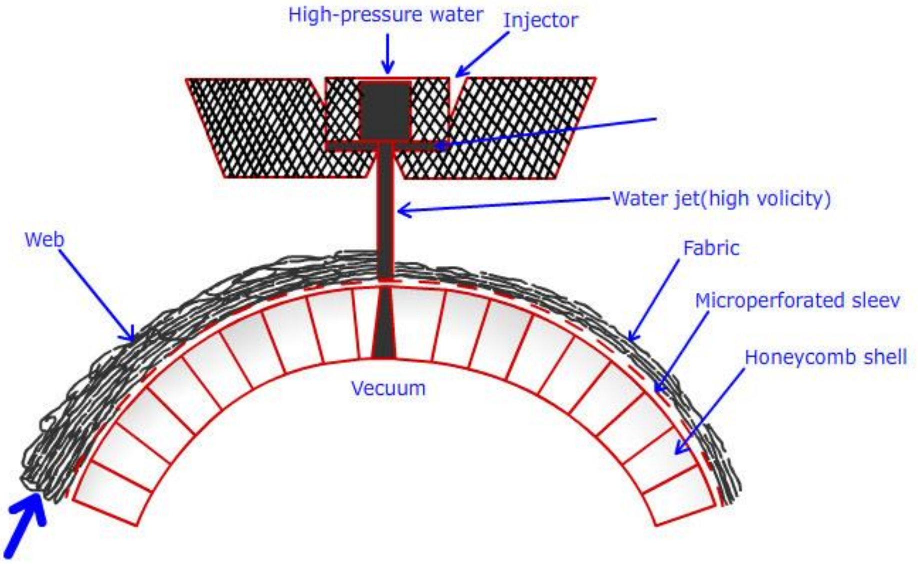


It then goes to the working zone of the machine and passes in-between a pair of perforated bed plates. The needles are arranged in a needle board in width-wise rows. The needle board is mounted on a beam which is given an up and down reciprocating motion by means of an eccentric crank mechanism. In the down stroke mode, the needles descend through the perforations of the top bed plate, through the web, and through the perforations of the bottom bed plate. During the upstroke, the barbed needles withdraw upwards and the bed plate strips the web off the needles. As a result, the fibres are mechanically interlocked, thereby providing the mechanical strength. The needle bonded nonwoven is delivered by a pair of delivery rollers.

Hydroentanglement process

Principle

Hydroentanglement, spun lacing, hydraulic entanglement, and water jet needling are synonymous terms describing the process of mechanically bonding the fibres in a web by means of high energy water jets. The machine which accomplishes this is known as hydroentanglement or spunlace machine. The basic elements of this machine are shown in Figure 3.10. A series of multiple high pressure columnar water jets is produced by pumping water through a series of fine nozzles in a jet strip clamped into an injector (manifold). The high velocity water jets are directed to the unbonded web, which is supported on a moving perforated conveyor. The conveyor may have a flatbed surface or cylindrical surface. The entanglement among the fibres is introduced by the combined effects of the incident water jets and the turbulent water created in the web which intertwines neighbouring fibres. The conveyor sleeve being permeable enables most of the de-energised water to be drawn into the vacuum box for recycling and reuse.



Thermal Bonding Processes

It is known that the fibres in the webs can be bonded thermally in order to have sufficient resistance to mechanical deformation. The basic concept of thermal bonding was introduced by Reed in 1942. He described a process in which a web consisting of thermoplastic and non-thermoplastic fibres was made and then heated to the melting or softening temperature of the constituent thermoplastic fibres followed by cooling or solidify the bonding area. Since then many developments have been made in thermal bonding processes. Today the thermal bonding processes include calender bonding, through-air bonding, infrared bonding, and ultrasonic bonding. Thermal bonding requires a thermoplastic component to be present in the web in the form of homofil fibre, powder, film, hot melt or as a part (sheath) of bicomponent fibre. The thermoplastic component becomes viscous under the application of thermal energy. The polymer flows to fibre-to-fibre crossover points where bonding regions are formed. The bonding regions are fixed by subsequent cooling. The thermal bonding process is environmental-friendly, as no latex binder is required. The thermal bonding process consumes less energy compared to foam bonding or hydroentanglement bonding.

Principle of thermal bonding

The formation of a bond during thermal bonding follows in sequence through three critical steps:

(1) heating the web to partially melt the crystalline region,
(2) repetition of the newly released chain segments across the fibre-fibre interface, and
(3) subsequent cooling of the web to re-solidify it and to trap the chain segments that diffused across the fibre-fibre interface.

Raw materials

The thermal bonding processes utilize either thermoplastic fibres alone or blends containing fibres that are not intended to soften or flow on heating. The non-binder fibre components may be referred to as the base fibres or sometimes, carrier fibres. Commercially, a variety of base fibres are used. The binder fibre component normally ranges from 5-50 % on weight of the fibre depending on the targeted properties of the final product made thereupon.

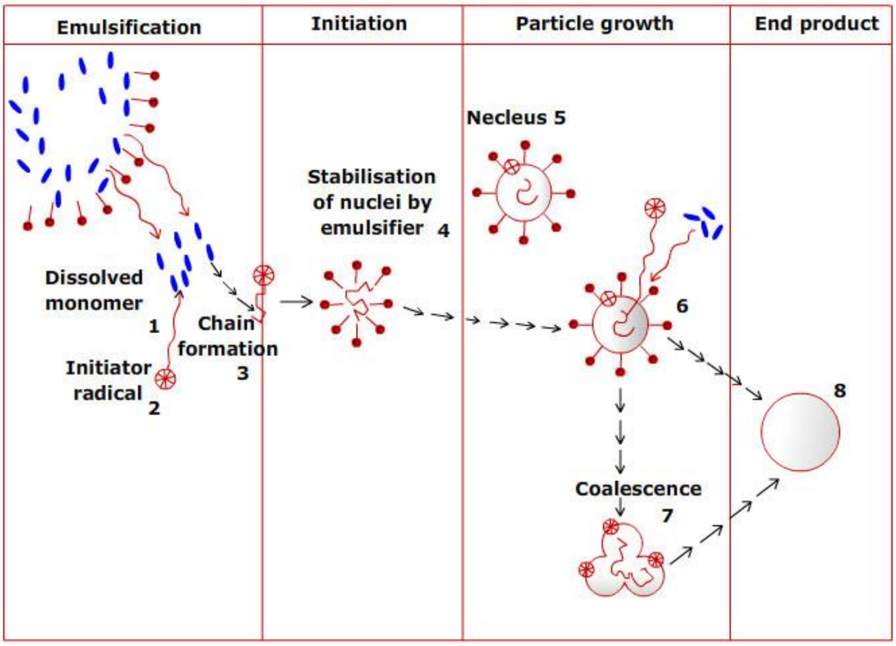
Chemical Bonding Processes

In chemical bonding, chemical binders (adhesive materials) are used to hold the fibers together in a nonwoven fabric. Chemical binders are polymers that are formed by emulsion polymerization. The mostly used binders today are water-borne latexes. They are applied in a number of different ways to nonwovens and because of their viscosity is close to that of water they can easily penetrate into nonwoven structure by emulsion. After application of binder by, for example, immersion, they are dried and the water evaporates. The binder then forms an adhesive film across or between fibre intersections and fibre bonding takes place.

Chemical binders

There are various chemical binder polymers used including vinyl polymers and copolymers, acrylic ester polymers and copolymers, rubber and synthetic rubber, and natural binders, principally starch. These are usually applied in aqueous dispersions but can be supplied as polymer solutions providing, they have sufficiently low viscosity to allow penetration into the web.

Commercially, latex polymers are the most commonly encountered binder because of their availability, variety, versatility, ease of application, and cost-effectiveness. The latex polymers are prepared by emulsion polymerization by controlled addition of several components. These components include monomers (building block), water (medium), initiator (decomposes to form free radicals to start the polymerization process), surfactant (to prevent particle attraction and thus stabilize the emulsion particles) and chain transfer agent (to control the final polymer molecular weight). The process of latex formation starts with a distribution of monomer droplets in water, stabilized by emulsifiers that have accumulated at the interface to the water phase. The emulsifier molecules have the hydrophilic heads and hydrophobic tails. In Figure, the dot indicates the hydrophilic head and the line represents the hydrophobic tail of emulsifier molecule. If the concentration of the emulsifier is above a critical value, a spheroidal collection of them is formed. This is called micelle and it typically contains about a hundred emulsifier molecules.



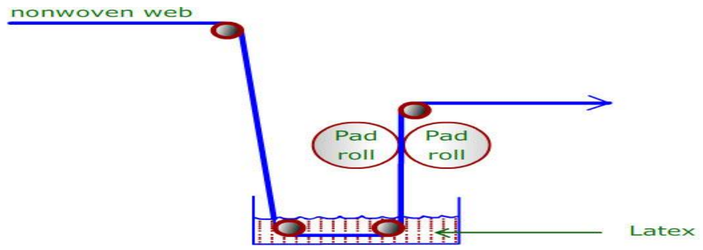
The initiator added is decomposed to form water-soluble free radicals. When a free radical encounters monomer molecules dissolved in water, it reacts successively with several to form a short polymer chain. This short chain, called oligomer radical, is no longer soluble in water. It precipitates and is stabilized by the emulsifier, which accumulates at the newly formed interface. This is now called a latex particle. When there are enough oligomer radicals formed they grow into latex particles. Also, it is possible for a growing oligomer radical to meet a monomer droplet and initiate polymerization to form a latex particle. In this case, the latex particle would be large. In addition, when the oligomer radical meets an emulsifier micelle where monomer molecules are diffused in, the monomers polymerize and form another latex particle. This can occur only if the concentration of emulsifier is enough high, that is, above the critical micelle concentration. Once the formation of latex particles is completed, their growth starts. The monomers flow from water to the latex particles where the polymerization occurs. The latex particle grows larger and contains hundreds or thousands of closely packed molecules in one particle. As propagation proceeds more latex particles are added in layers to form a larger latex particle. Sometimes it is desirable to limit the molecular weight of the polymer by introducing a chain transfer agent. The growing polymer radical combines with the chain transfer agent to stop the chain growth.

Methods of binder application

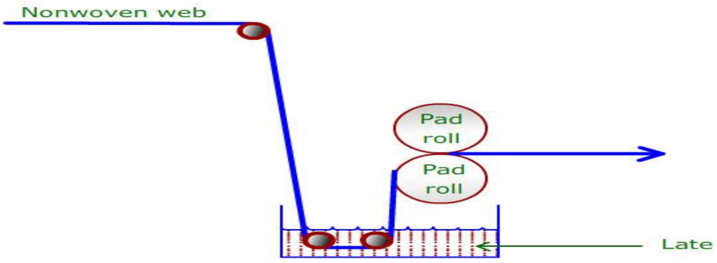
The most common methods of applying a binder to a dry-laid web are saturation, foam, spray, and print bonding methods. For wet-laid nonwovens, most of the same methods can be used but bonding must be applied after partial drying. For printing, the web must be dry.

Saturation bonding process

Saturation chemical bonding involves complete immersion of the nonwoven web in a bath containing binder. The excess binder can be removed by a pair of nip rolls. Figure shows the basic methods of saturation using horizontal padding (a) and vertical padding (b). The nonwoven web is guided through the saturation bath by rollers and then presses between a pair of nip rolls to squeeze out excess liquid. The amount of binder taken up by the nonwoven depends on the basis weight of the nonwoven, length of time spent in the bath, wettability of the fibres and nip pressure. This method can provide higher binder to fibre levels uniformly throughout the nonwoven. But as it includes short wetting time, the method is more suitable for lightweight and highly permeable nonwovens.



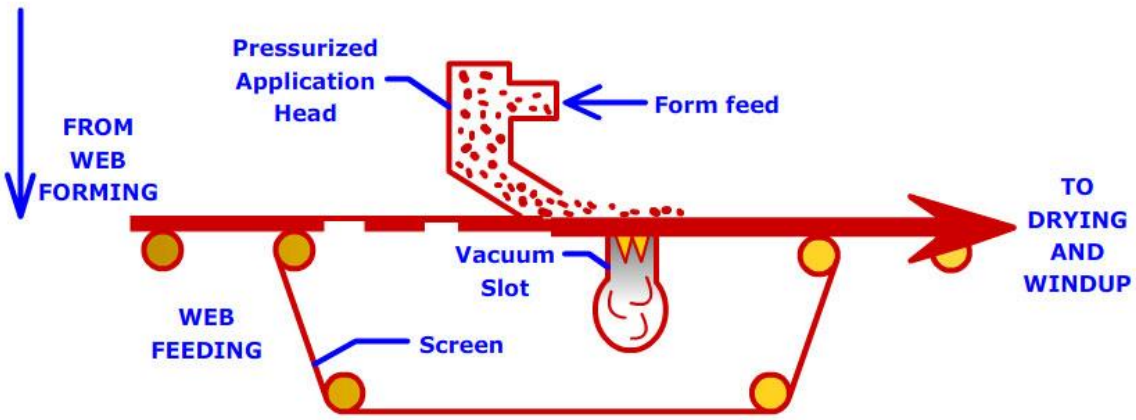
(a) Horizontal padder



(b) Vertical padder

Foam bonding process

Figure illustrates the foam bonding process. Here, air or water is used to dilute the binder and as a mean to carry the binder to the fibres. One advantage of diluting binder with air rather than with water is that drying is faster and energy cost is reduced remarkably. Foam is generated mechanically and can be stabilized with a stabilizing agent to prevent collapse during application.

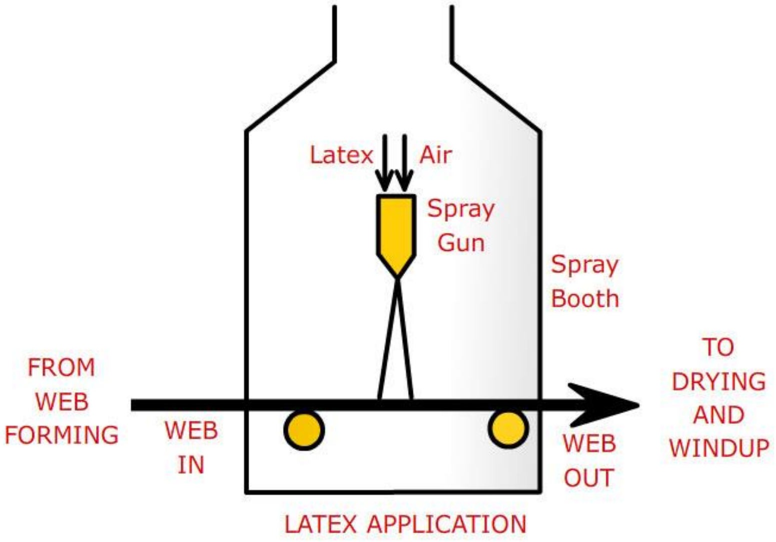


FOAM APPLICATION

Foam can be applied so as to remain at the surface or can be made to penetrate all the way through the fabric cross-section. One or two reciprocating foam spreaders are commonly used to distribute the foam across the width of the fabric. The excess foam is sucked through the porous portion of the fabric and the perforations of the web carrying medium to the vacuum extractor as shown in Figure 3.27 The key advantage of foam bonding is more efficiency drying and the ability to control fabric softness. The disadvantages include the difficulty in achieving adequate foaming and in controlling the process to give a uniform binder distribution. Sometimes, non-stabilized foams, called froths, are formed.

Spray bonding process

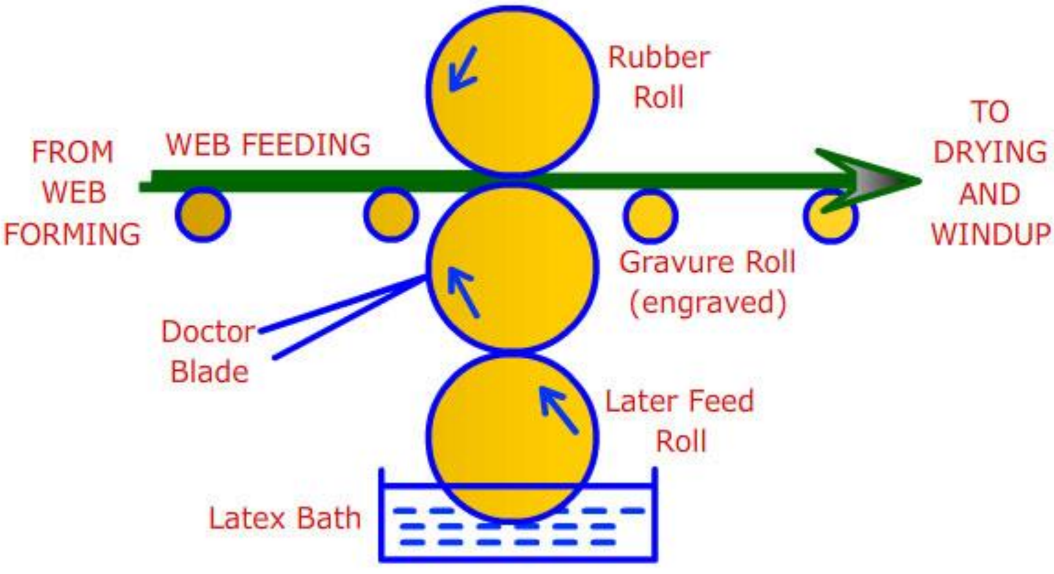
Figure illustrates a typical spray bonding process. Here the binder is sprayed onto a moving web in fine droplet form through a system of nozzles, which can be statically mounted across the machine or transverse from one side to the other side of the machine. It is used to make highly porous and bulky products. This is possible because the substrate does not need to pass between nip rollers.



The liquid is atomised by air pressure, hydraulic pressure, or centrifugal force and is applied to the upper surfaces of the web. The depth of penetration of the binder into the substrate depends on the wettability of the fibres, permeability of the web, and amount of binder. The main advantage of this method is that the nonwoven is not compressed and the original bulk and structure is retained. The disadvantages include lack of control of the uniformity of spraying, poor binder penetration, high level of overspray and waste, and possible lack of shear stability of the binder.

Print bonding process

The print bonding process applies the binder only in predetermined areas as dictated by the pattern of the printing surfaces. Figure 3.29 displays the print bonding process where the latex is transferred to the web via feed roll and engraved roll. As the web passes the engraved roll, it is pressed against the surface by a rubber roll, transferring binder to the fabric.



The excess latex is removed by a doctor blade. This method is suitable only for applying low levels of binder to the surface where a textile-like handle is needled.

Applications

The chemical bonding process is used to develop nonwovens used as wipes, interlinings, hygiene and medical products, footwear, automotives, and home furnishing products.