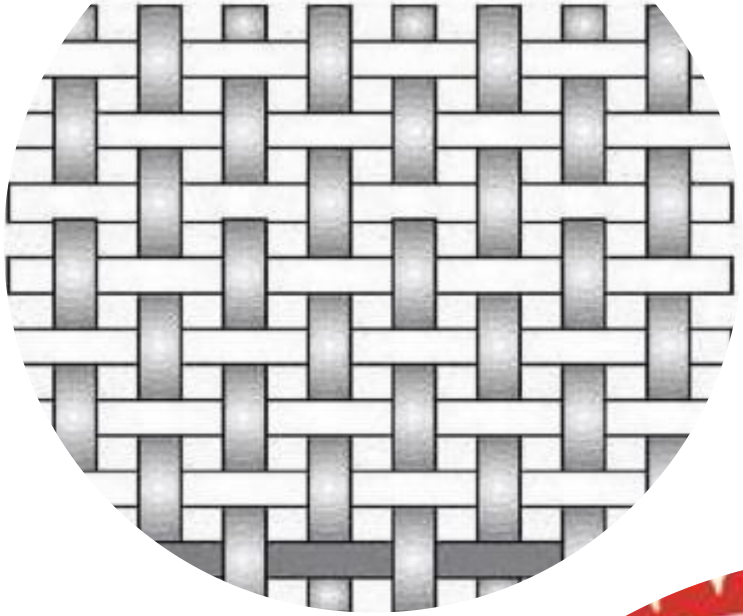
Fabric Manufacturing I (TXL231)



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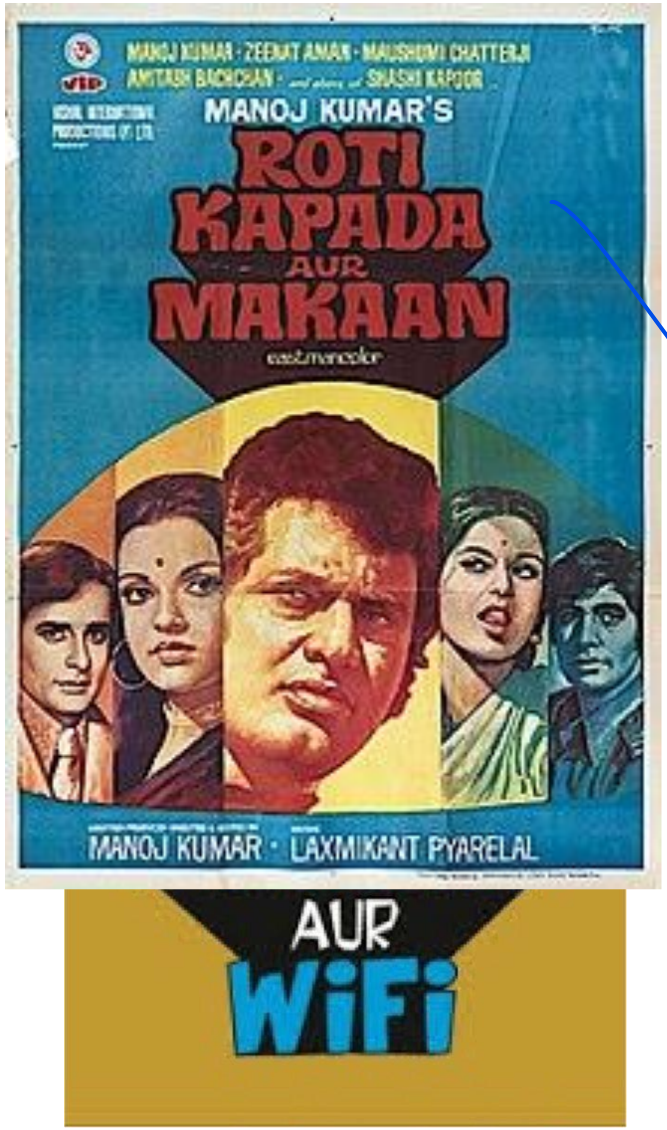
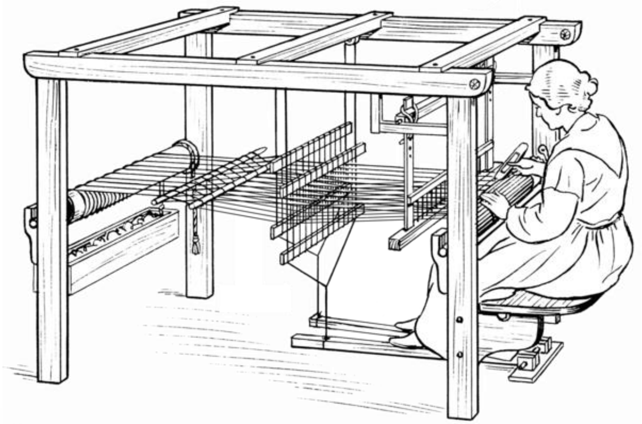
Introduction to Fabric Manufacturing

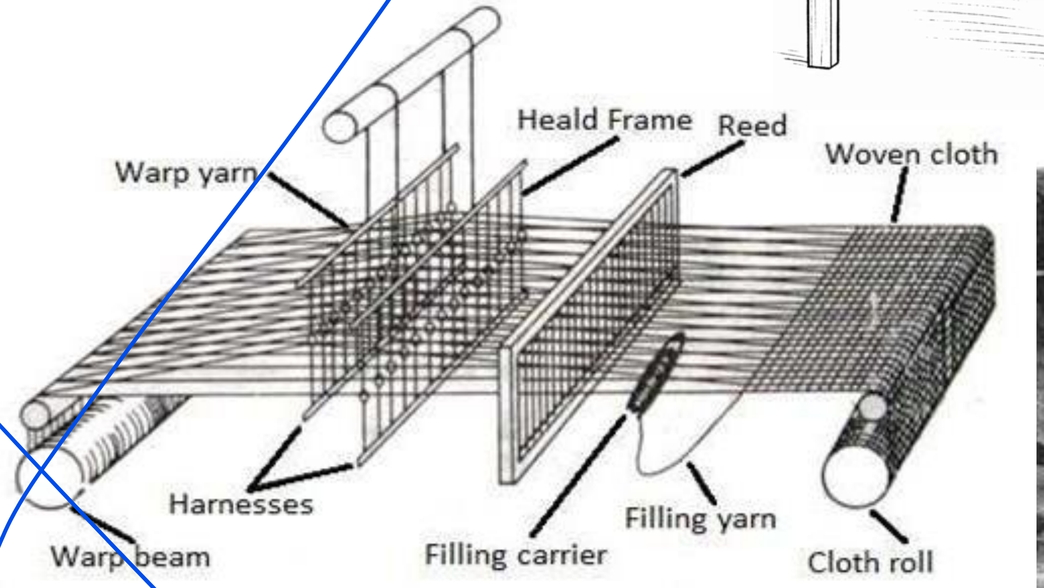


Clothing is our one of basic needs. Fabric formation is general and probably as old as human history, at least in terms of the real historical evidence that we have.

Egyptian flax linen remnants



Shuttleless weaving machine



Artist's imagination of Dhaka Muslin weaving

Gujrat weaver using power loom

History of Weaving

- The tradition of weaving traces back to Neolithic times – approximately 12,000 years ago. Even before the actual process of weaving was discovered, the basic principle of weaving was applied to interlace branches and twigs to create fences, shelters and baskets for protection
- The oldest known textiles found in the Americas are remnants of six finely woven textiles and cordage found in Guitarrero Cave, Peru. The weavings, made from plant fibres, are dated between 10,100 and 9080 BCE

John Kay (1733) invented the flying shuttle, used to pull thread horizontally (weft) across longitudinal threads (warp) on a weaving frame

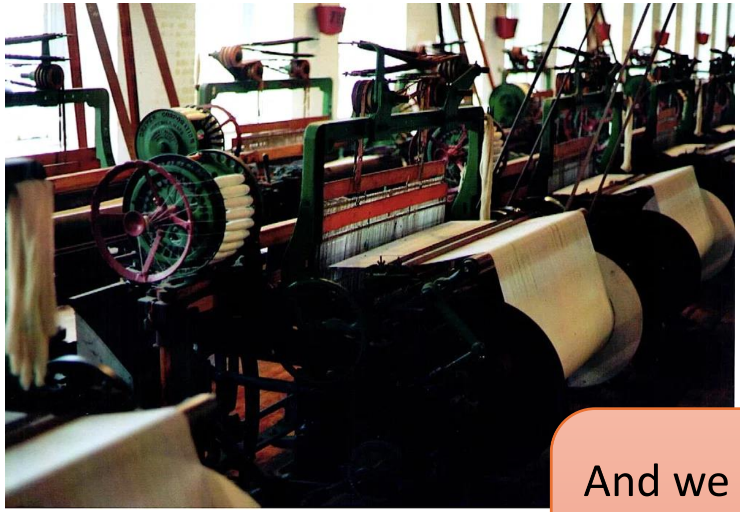
The production increased, but the weavers needed more yarn. The traditional spinning wheel was an efficient machine but could only spin one thread at a time

James Hargreaves invented the spinning jenny (machine) in Lancashire in 1764 (patented in 1770) that could spin eight cotton threads at the same time.

And undoubtedly, we entered our first Industrial Revolution (~1760-1820)

History of Weaving

❖ Then came Edmund Cartwright who invented Power Loom (1785)



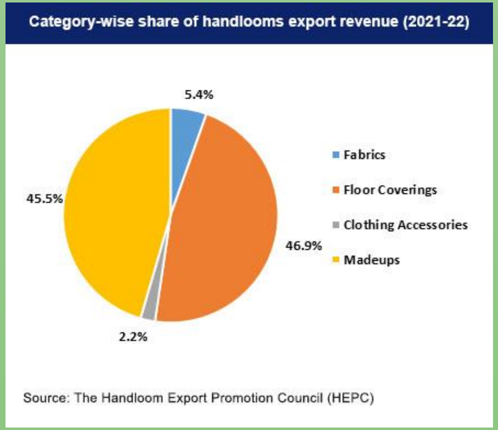
And we all know the down spiral fate of Indian weavers by end of the 18th century (a part of colonization)

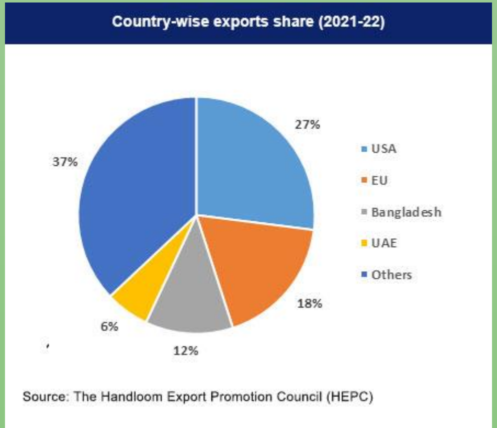
❖ Joseph Marie Jacquard, from Lyon, invented Jacquard loom (1801) to control each thread, as per design

❖ In mid 1900s, projectile weaving machines came as a part of shuttleless looms line up and the weaving industry didn't look back

Modern India and Weaving

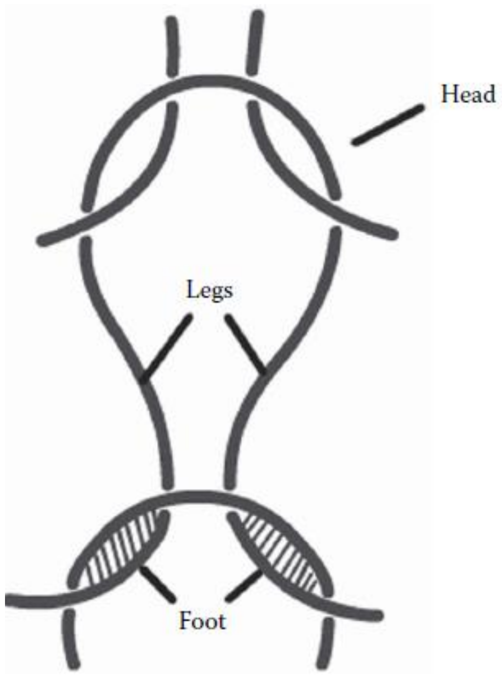
- The handloom sector of India is one of the biggest unorganized economic activities
- It is the rural region's second-largest employment provider, employing more than 3 million people in direct and allied activities
- The sector employs 43.31 lakh weavers directly and indirectly throughout the country with 77% of them being women





Knitting

- Knitting is a process of fabric formation by producing series of intermeshed loops
- Thee upper part of the loop is called ‘head’, whereas the two sides are called ‘legs’. The intermeshing of two loops happens through the ‘foot’
- The knitted fabrics are more stretchable than the woven fabrics. It also facilitates better moisture vapour transmission, making it suitable for sports garments and high-activity

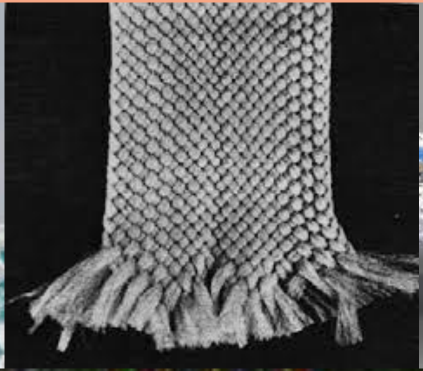


Knitting is as old as >1000 years; the first set of knitted components was found to be socks from Egyptian socks

Madonna Knitting, by Bertram of Minden 1400-1410.
Source: Wikipedia

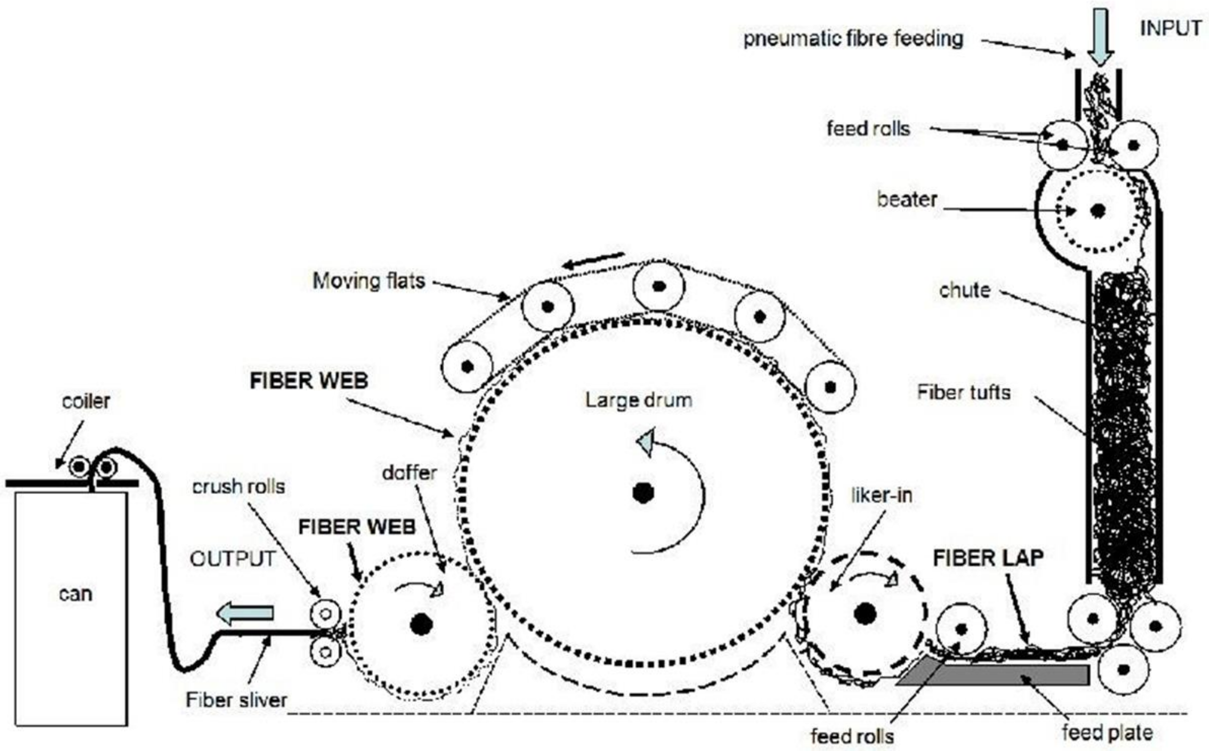
Braiding

- Traditionally used as decorative trimmings and functional elastic components in apparel goods
- Demanding technical applications, like- in shielding wires from electromagnetic interference
- Absorbing very high impactful energy in the form of ropes, fishing lines, parachute cords
- Fairly modest and less demanding functions in household goods in the form of draw threads for curtains, wash lines
- And of course, shoelaces (the most ubiquitous one)

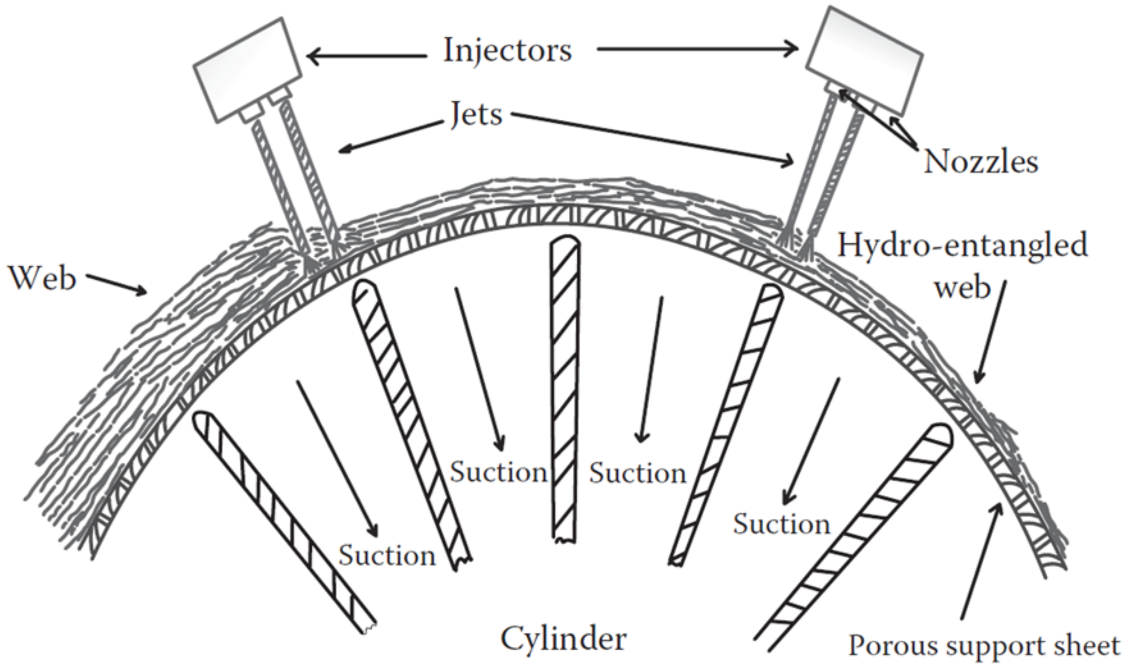



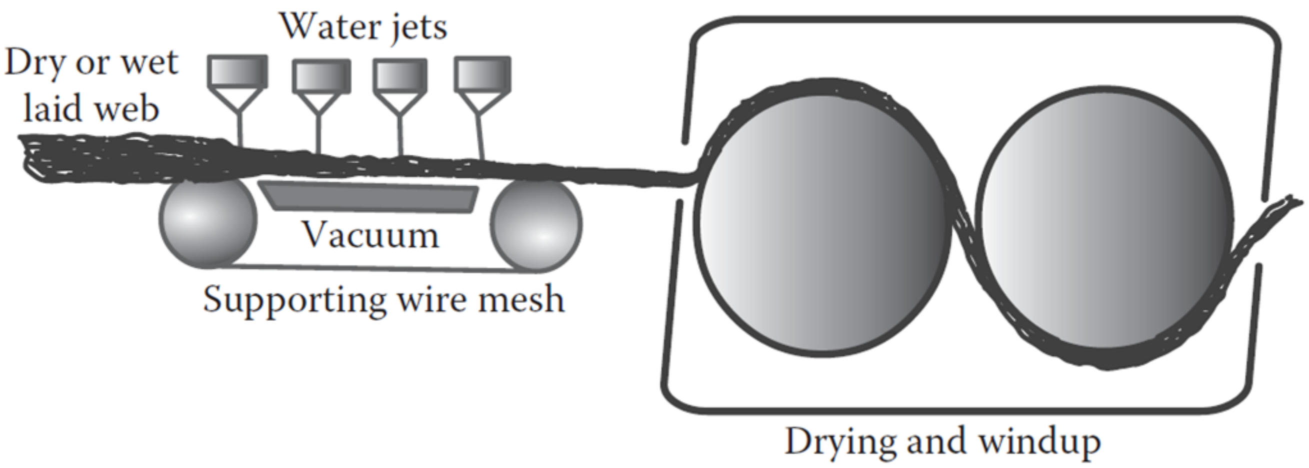


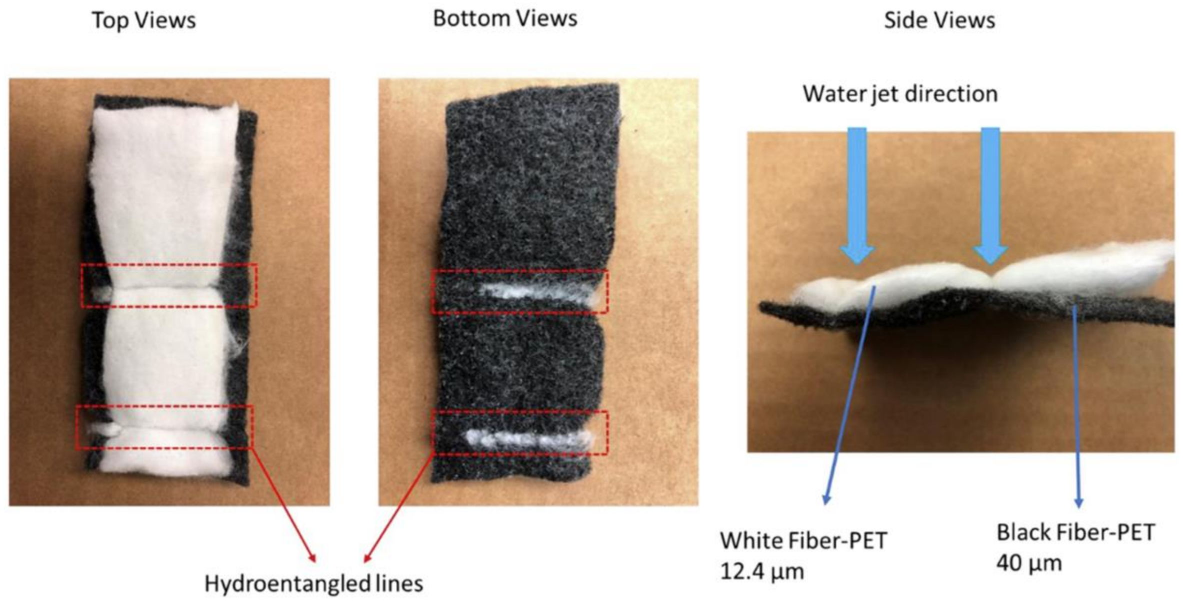

Nonwoven: Needle Punching



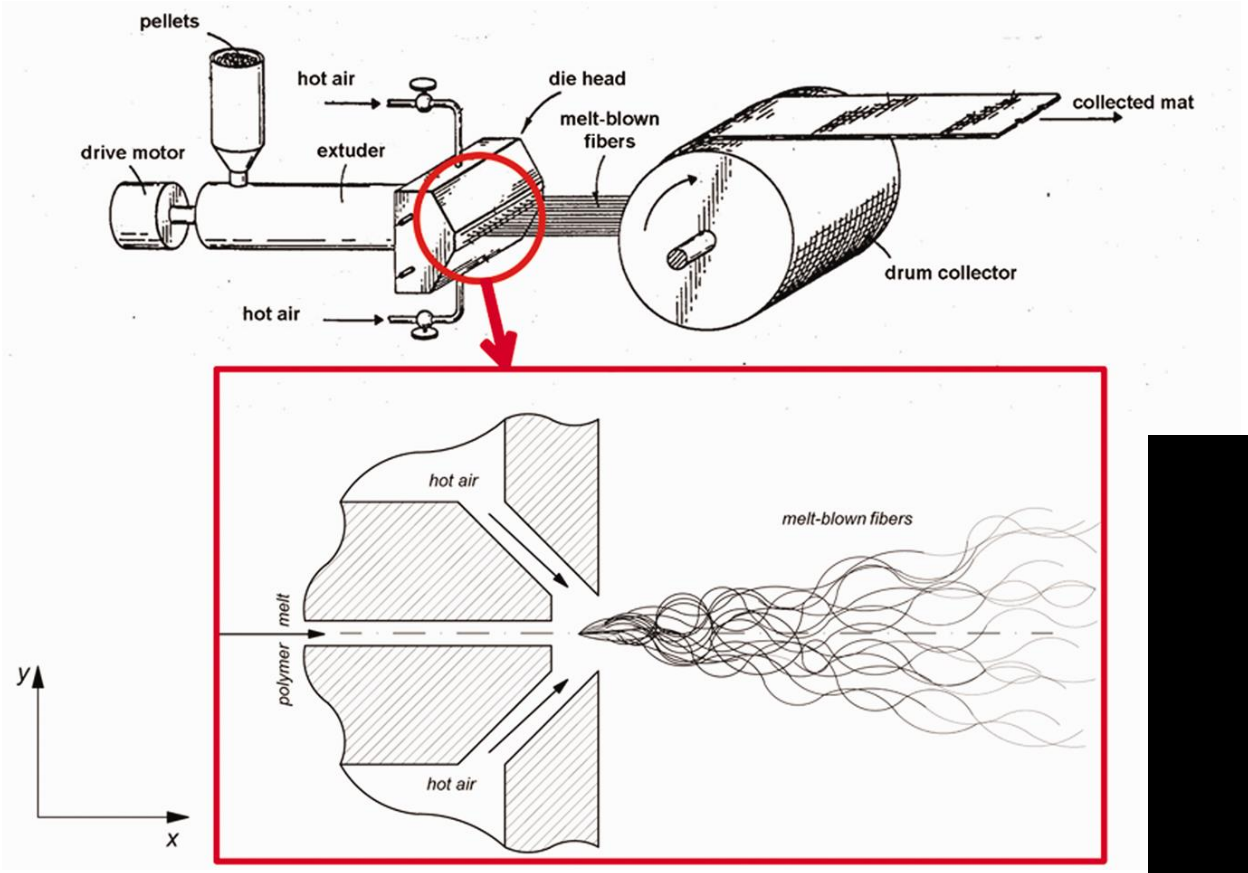
Nonwoven: Hydroentanglement



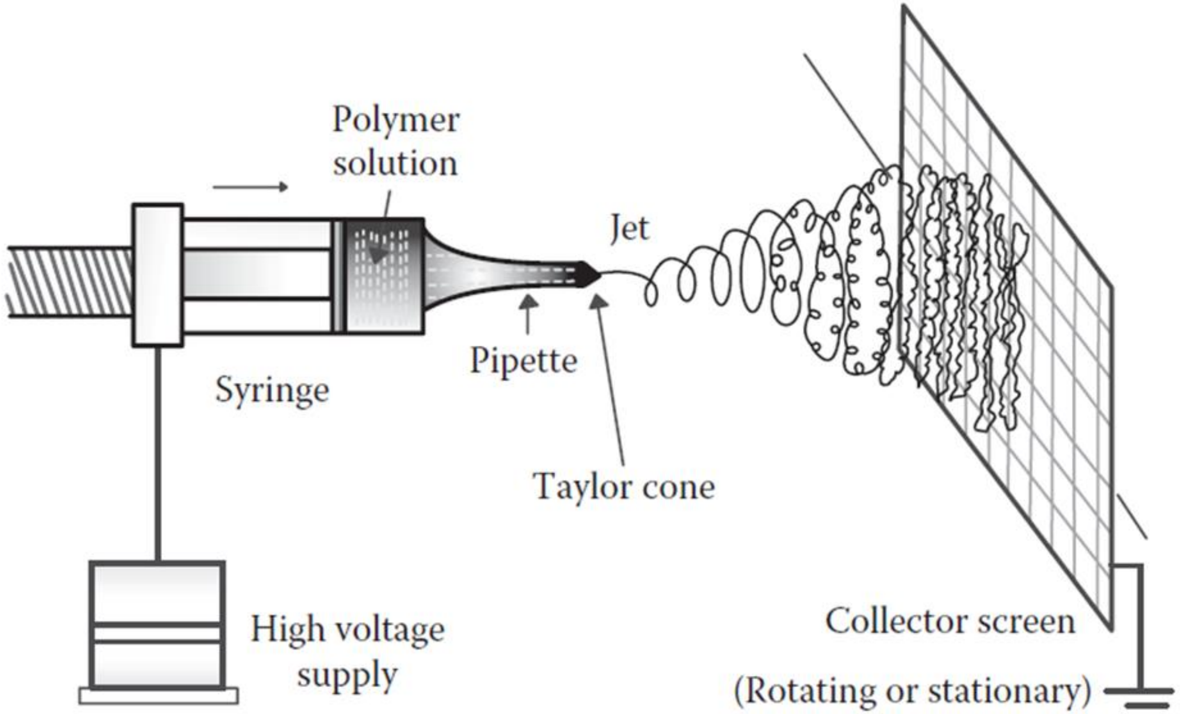


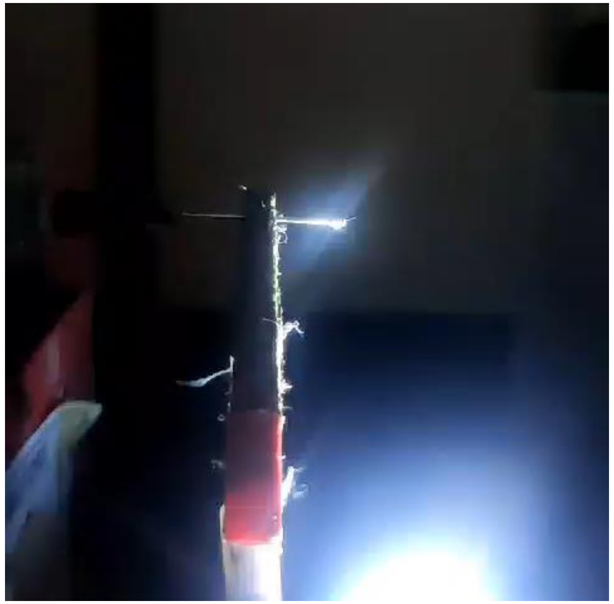


Nonwoven: Meltblowing

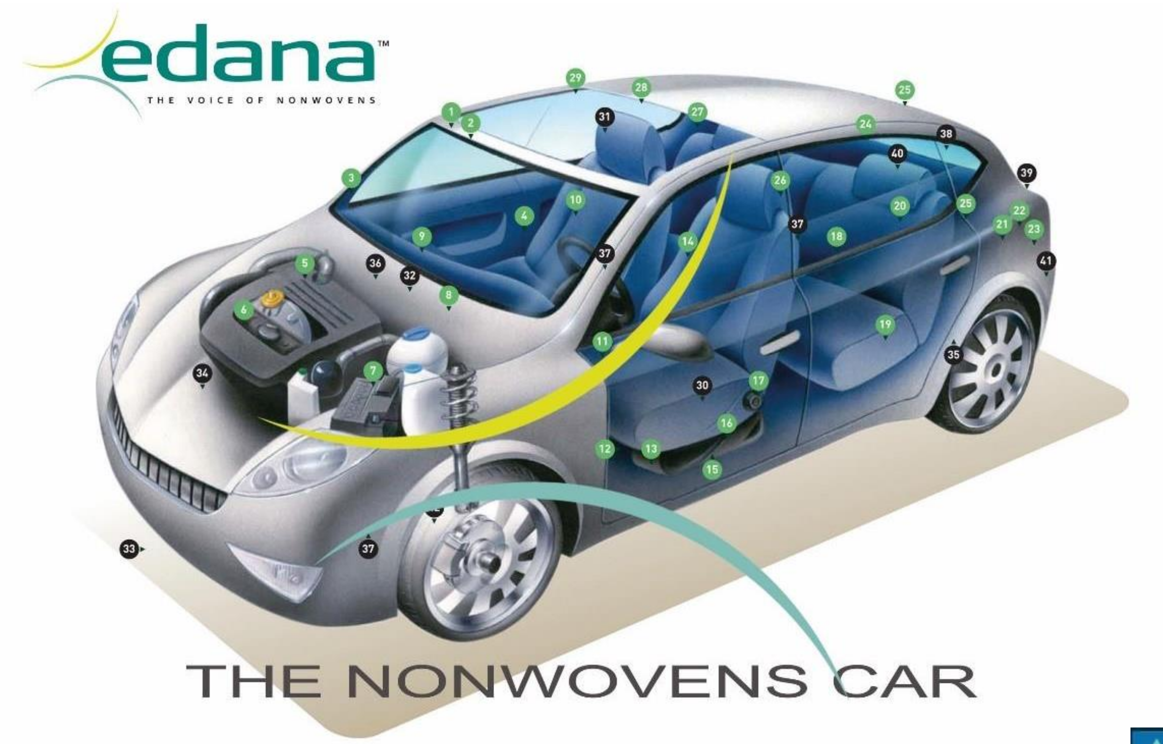


Nonwoven: Electrospinning





Vast World of Nonwoven

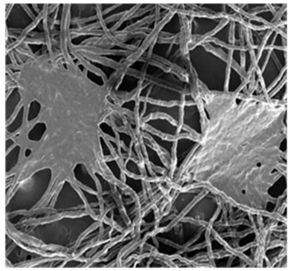


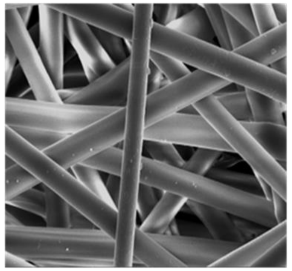
1 Covering material for sun-visors
2 Padding for sun-visors
3 A, B, C, column padding
4 Door trim pads
5 Fuel filters
6 Oil filters
7 Battery separators
8 Cabin air filters
9 Loudspeaker cover
10 Covering for moulded seats
11 Transmission tunnel
12 Carpet & carpet reinforcement
13 Car mats
14 Vinyl backing for seat covers
15 Backing for tufted carpeting
16 Covering for seat belt anchorage
17 Covering for seat belt
18 Decorative fabric
19 Polyurethane coated backing
20 Seat slip agents
21 Boot (trunk) liners
22 Moulded fuel tanks
23 Bodywork parts
24 Window frames
25 Headliner facings
26 Upholstery backing
27 Loudspeaker housing
28 Sunroof
29 Saloon roof

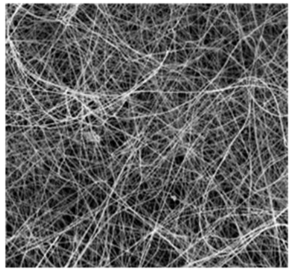
Acoustic absorber applications

30 Doors
31 Headliner
32 Inner & outer dashboard insulation
33 Under engine shield
34 Moulded bonnet liner
35 Rear wheel arch liner
36 Cowl
37 Pillar trim panels
38 Parcel shelf
39 Trunk trims
40 Rear seat strainer
41 Air extractor
42 Wheel arch liners

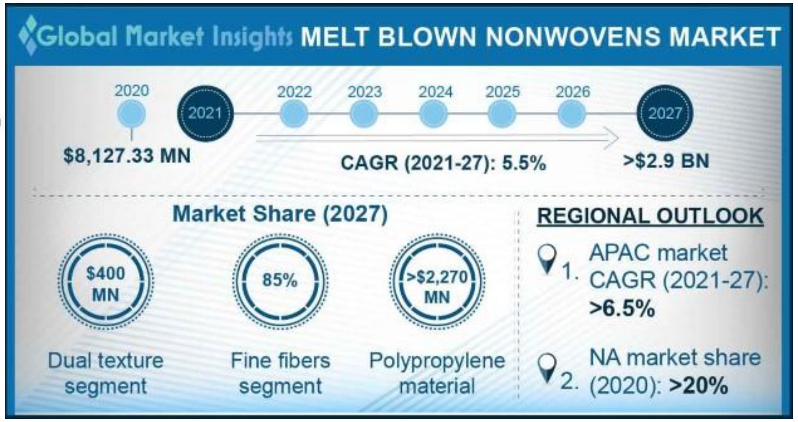

Needle punched

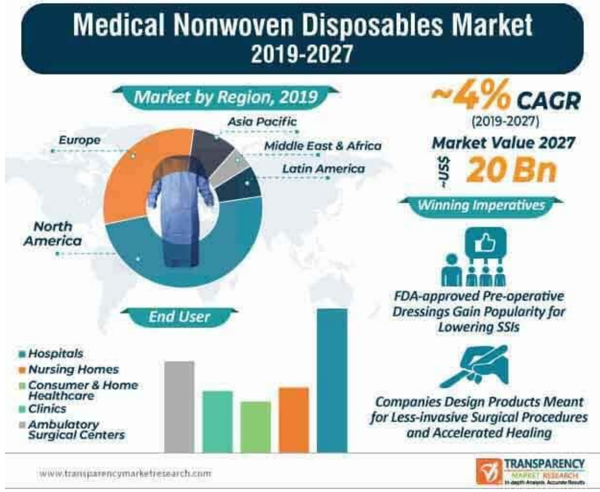

Spunbond


Meltblown


Electrospun

Where do you see the differences?





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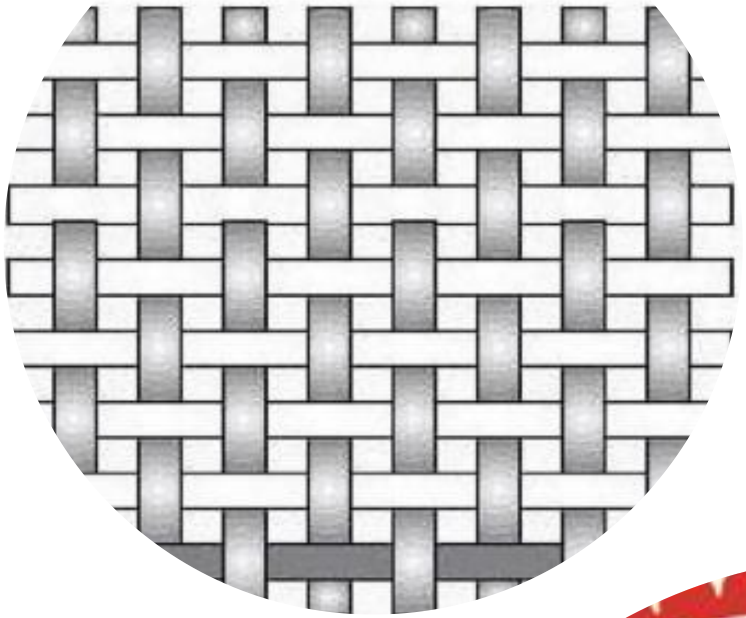
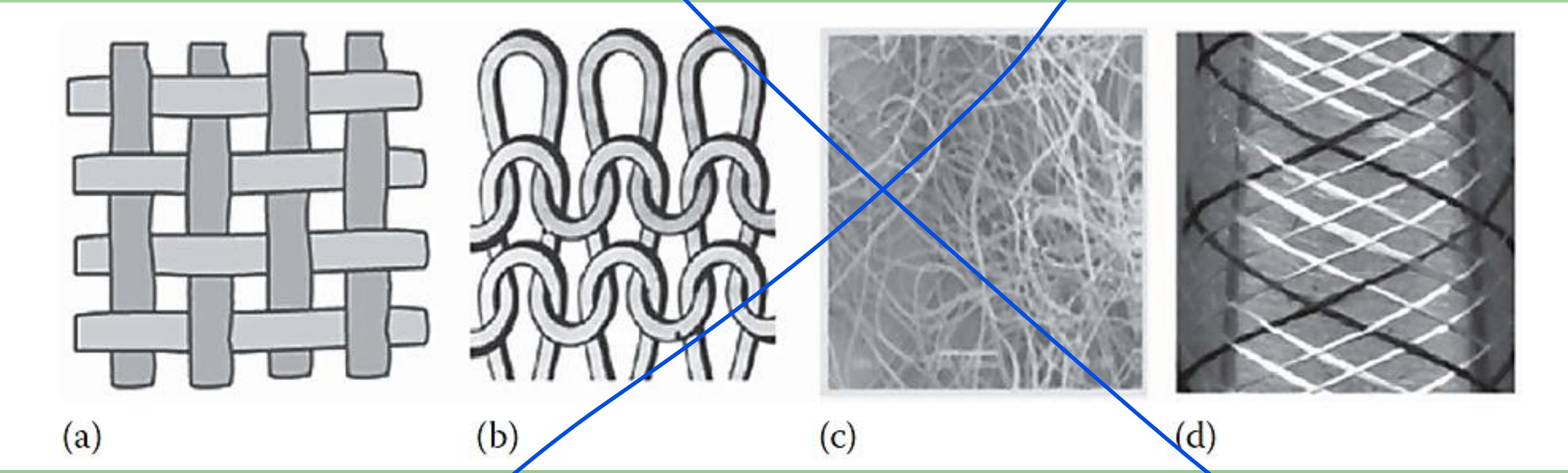


Recap of Previous Class

❖ We talked about the ab initio weaving and its modernization

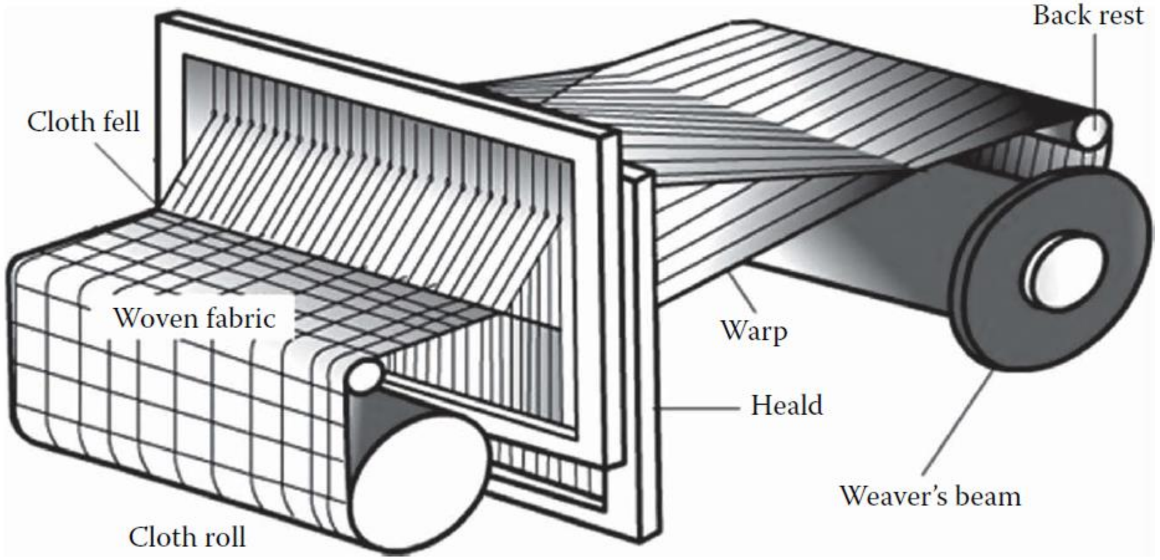
❖ Methods of fabric formation-

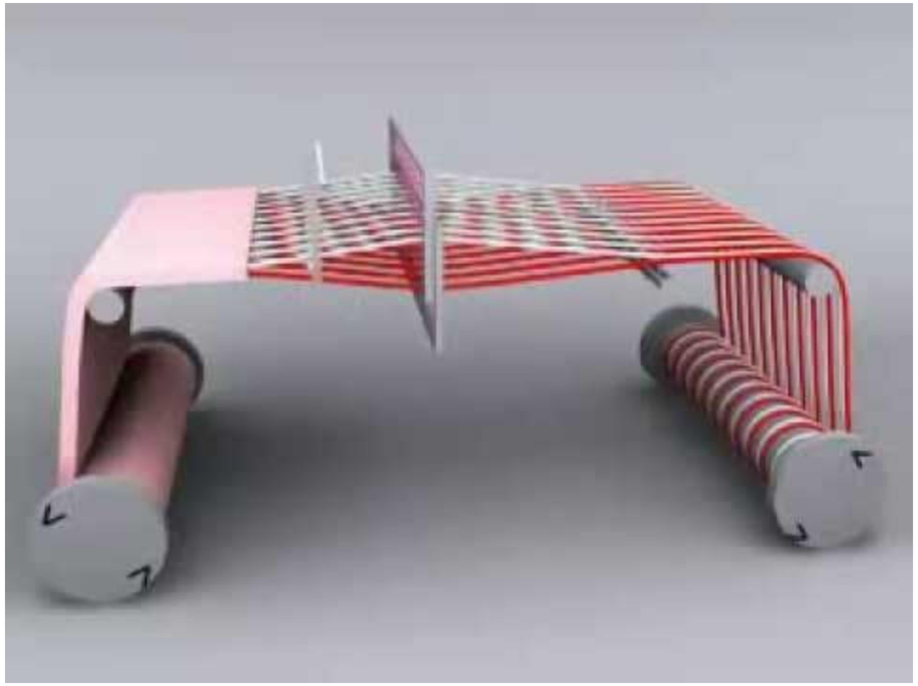


Woven **Knitted** **Nonwoven** **Braided**

❖ Economic impacts of different fabric manufacturing industries and their growth scenario

Stages of Weaving





https://www.youtube.com/watch?v=worKmsWZqYE

A few motions to consider:

a) Primary
b) Secondary
c) Auxiliary

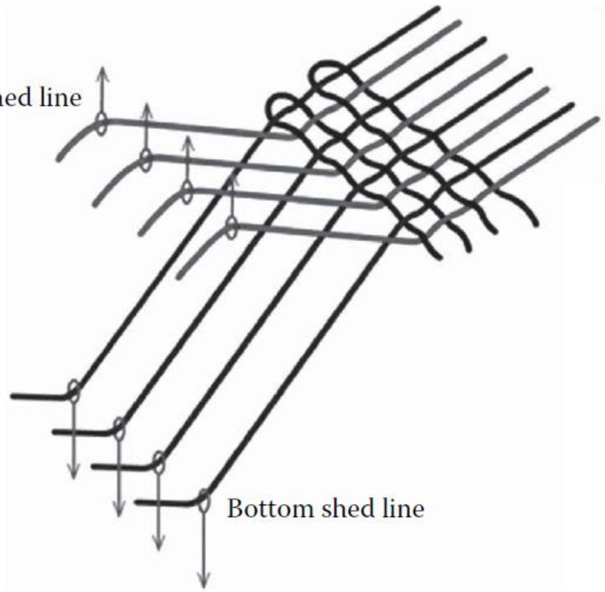
- **Motions**
  - **Primary**
    - Shedding
    - Picking
    - Beat-up
  - **Secondary**
    - Take-up
    - Let-off
  - **Auxiliary**
    - Warp stop
    - Weft stop
    - Warp protector

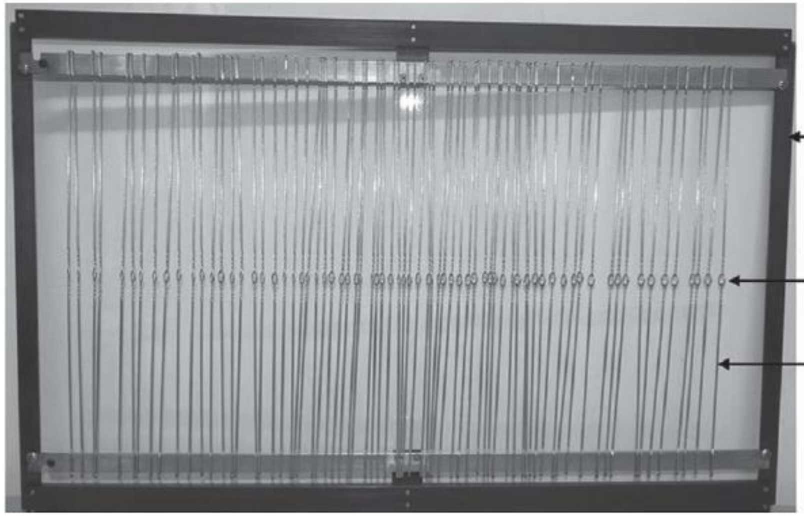
Types of Looms

- Hand loom: This is mainly used in the unorganized sector. Operations such as shedding and picking are done by using manual power. This is one of the 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
- Automatic loom: In this power loom, the exhausted pirn is replenished by the full one without stoppage. This is possible only in under-pick system
- 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.

Primary Motion: 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 or for the weft-carrying device to pass through it. One group of yarns either moves in the upward direction or stays in the up position (if they are already in that position), thus forming the top shed line. Another group of yarns either moves in the downward direction or stays in the down position (if they are already in that position), thus forming the bottom shed line.

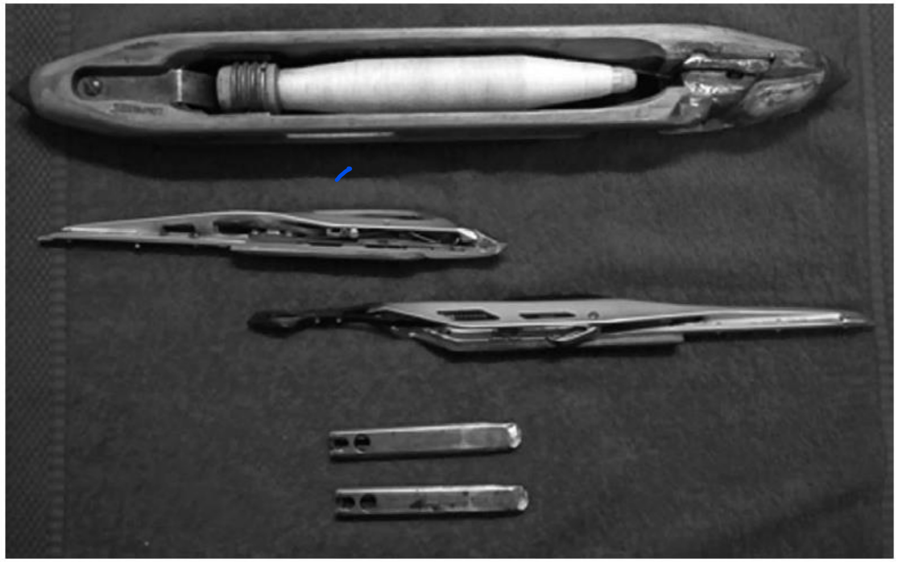




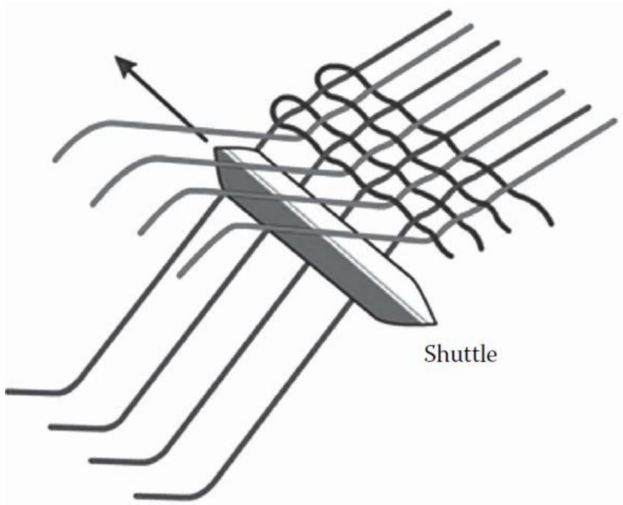
Healds are used to control a large number of warp yarns. The warp yarn actually passes through the heald eye. Therefore, as the heald moves, all the warp yarns which are controlled by that head also move

Primary Motion: Picking

- The insertion of weft or weft-carrying device (shuttle, projectile or rapier) through the shed is known as picking. Based on the picking system, looms can be classified as- Shuttle, Projectile, Rapier, Air jet, Water jet loom. With the exception of shuttle loom, weft is always inserted from only one side of the loom. The timing of picking is extremely important, especially in case of shuttle loom.

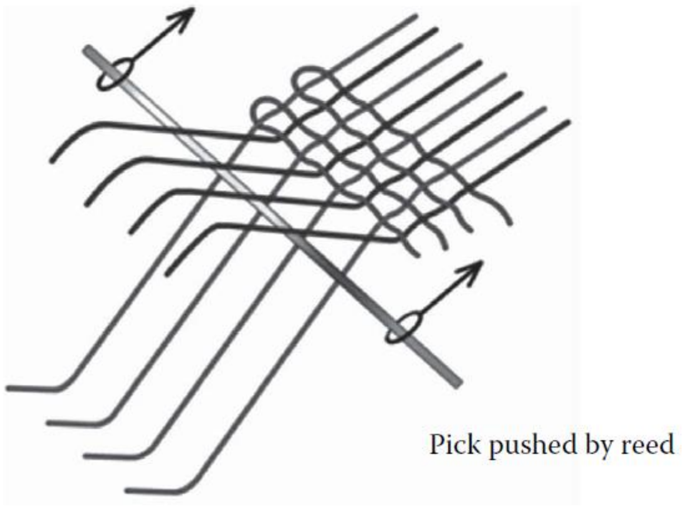


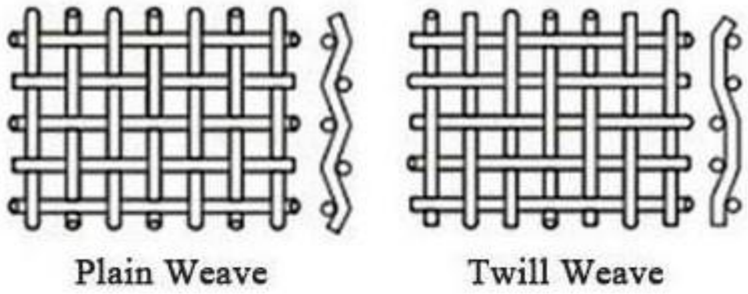
Shuttle, rapier heads and projectile (from top to bottom)



Primary Motion: 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. The loom component responsible for the beat-up is called ‘reed’





Reed is like a metallic comb. It can have different count. For example, 80s Stockport reed has 80 dents in 2 inches. Generally, one or two warp yarns are passed through a single dent, and these are called ‘one in a dent’ or ‘two in a dent’, respectively

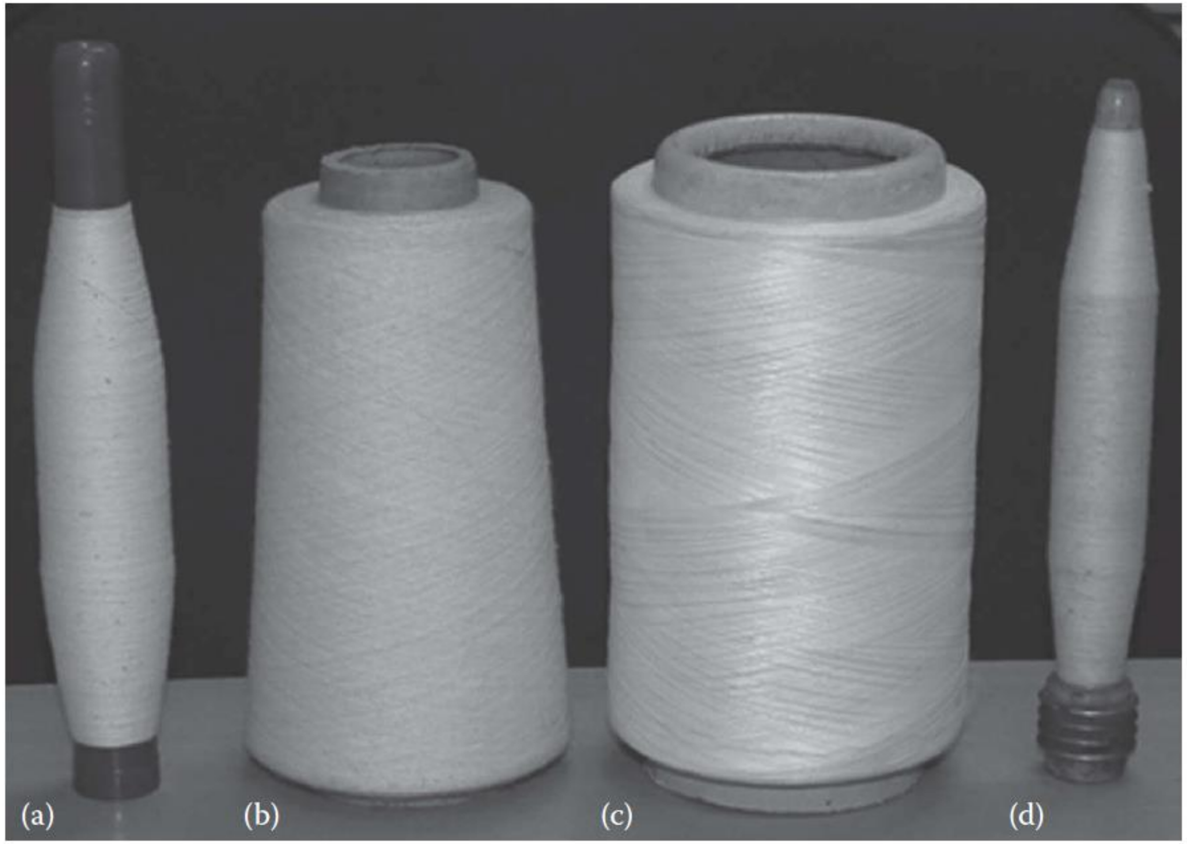
Secondary and Auxiliary Motions

- **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. 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 are mainly related to the activation of stop motions in case of any malfunctioning such as warp breakage (Warp Stop), weft breakage (Weft Stop) or shuttle trapping within the shed (Warp Protector)

However, before all of these, comes the most important part- the raw material (Yarn- Fibres)

Before Weaving

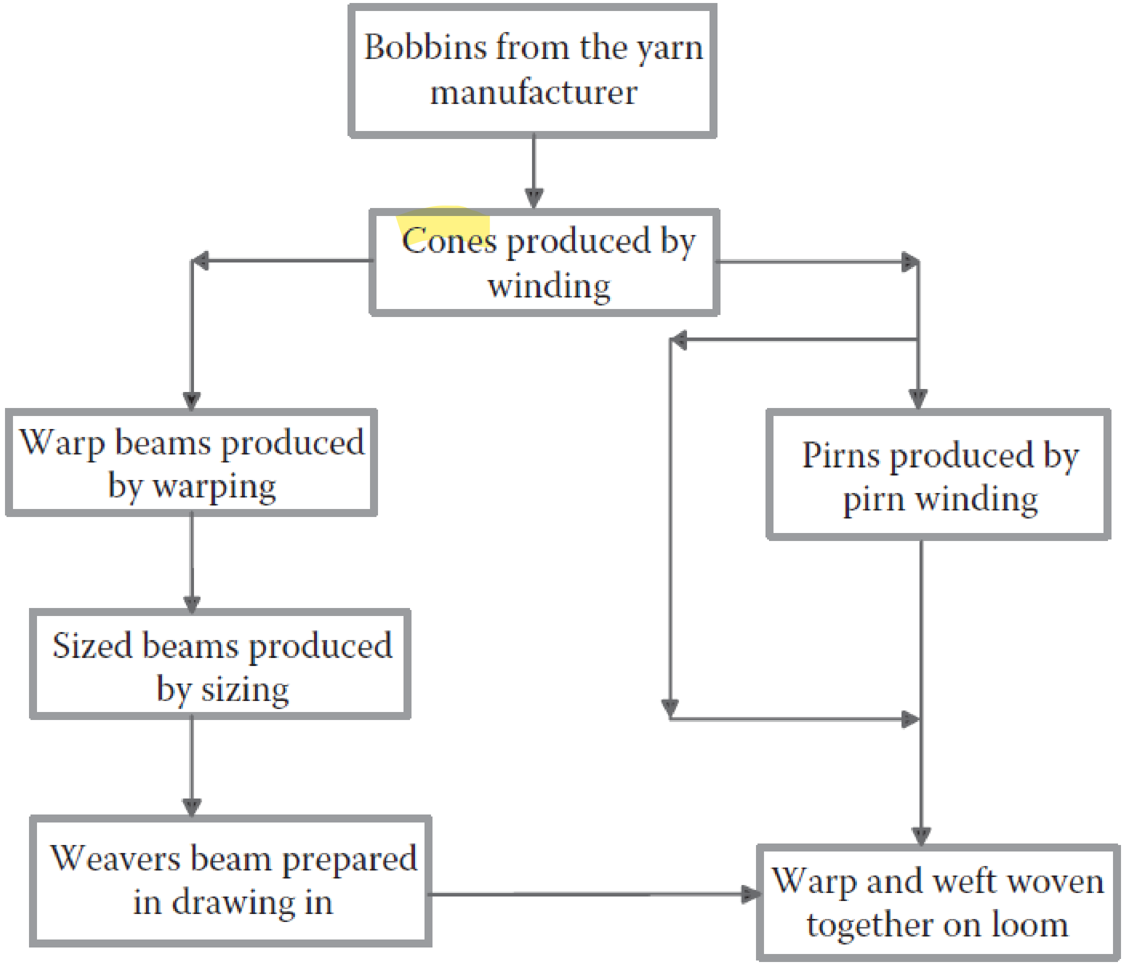


(a) Ringframe bobbin or cop, (b) cone, (c)cheese and (d) pirn

- During yarn formation such bobbins (~2000 m), contain many objectionable faults. Such faults need to be removed, and the resultant clean yarns from the supply bobbins need to be joined together to form a package of suitable dimension containing a sufficiently long length of yarn.

Before weaving comes 'Preparatory Stages'- Winding, Warping, Sizing, and *drawing, denting*

Before Weaving



The yarn itself is, in several instances, assembled from discontinuous fibres in a still more elaborate yarn-formation process. Thus, a large lag time is inherent in this textile system of conversion of fibres to yarns first followed by conversion of yarns to fabric.

Some Necessary Definitions: Knowing the Yarn

Yarn Count:

1. Direct systems (example: Tex, Denier)
2. Indirect systems (example: new English, i.e. Ne, Metric, i.e. Nm)

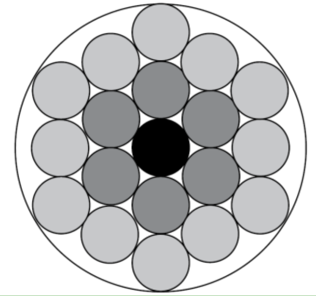
Direct systems revolve around expressing the mass of yarn per unit length. In contrast, indirect system expresses the length of yarn per unit mass. 10 tex yarn implies that a piece of 1000 m long yarn will have a mass of 10 g. Similarly, for 10 denier, a piece of 9000 m long yarn will have a mass of 10 g. 10 Ne implies that a 1-pound yarn will have a length of 10 × 840 yards

$$\text{Tex} = \frac{590.5}{\text{Ne}}, \quad \text{Denier} = 9 \times \text{Tex} \quad \text{and} \quad \text{Denier} = \frac{5315}{\text{Ne}}$$

Packing Factor or Packing Coefficient:

Packing factor or packing coefficient represents the extent of closeness of fibres within the yarn structure. For the same yarn linear density, if the fibres are closely packed, then yarn diameter will be less.

$$\text{Packing factor} = \frac{\text{Cumulative area of all fibres}}{\text{Area of yarn cross section}} = \frac{\text{Yarn density}}{\text{Fibre density}}$$



For spun yarns, packing factor generally lies between 0.55 and 0.65. Yarns with lower packing factor are expected to be bulkier and softer.

Some Necessary Definitions: Knowing the Yarn

Crimp:

Once the warp and weft are interlaced, both assume wavy or sinusoidal-like path. Thus the length of the yarn becomes more than that of the fabric within which the former is constrained. Crimp is a measure of the degree of waviness present in the yarns inside a woven fabric.

$$\text{Crimp \%} = \frac{\text{Length of yarn} - \text{Length of fabric}}{\text{Length of fabric}} \times 100$$

$$\text{Contraction \%} = \frac{\text{Length of yarn} - \text{Length of fabric}}{\text{Length of yarn}} \times 100$$

Fractional Cover and Cover Factor:

Fractional cover is the ratio of the area covered by the yarns to the total area of the fabric. If diameter of warp yarn is d_1 inch and spacing, that is gap between the two consecutive ends is p_1 inch, then fractional cover for warp (k_1) is d_1/p_1. For cotton yarns, having packing factor of 0.6, the relationship between yarn diameter (d) in inch and yarn count (Ne) is-

$$d = \frac{1}{28\sqrt{\text{Ne}}}$$

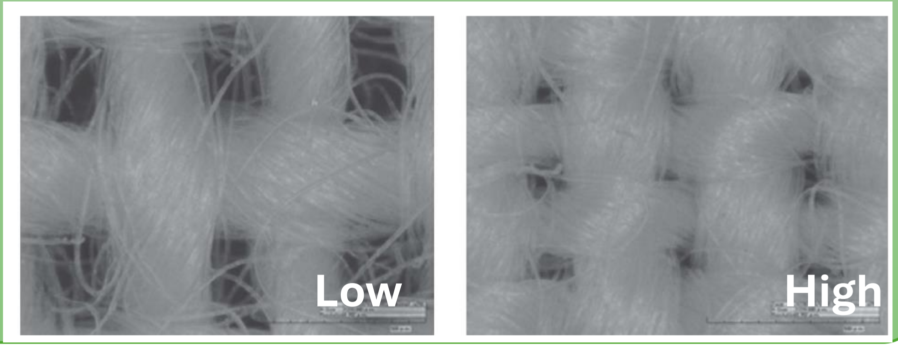
$$k_1 = \frac{n_1}{28\sqrt{\text{Ne}_1}}$$

The relationship between end spacing (p_1) and ends per inch (n_1) is-

$$n_1 = \frac{1}{p_1}$$

Cover factor is obtained by multiplying fractional cover with 28

$$\text{Warp cover factor} = k_w = 28 \times k_1 = \frac{n_1}{\sqrt{\text{Ne}_1}}$$



Some Necessary Definitions: Knowing the Yarn

Porosity:

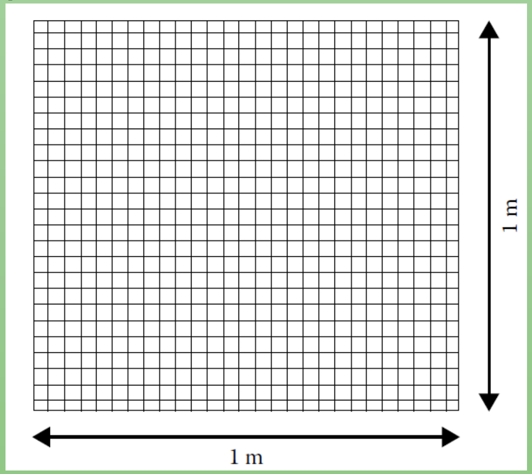
Porosity is a measure of presence of void or air inside the fabric or fibrous assemblies. It indicates the percentage of volume of fabric that has been occupied by the air. If, Fabric areal density or gram per square meter (GSM) = G (g/m^{2})
Thickness of fabric = T (m), Density of Fibre = ρ (g/m^{3}) , Porosity (%) = P

$$\text{porosity}(\%) = \left(1 - \frac{G}{T \times \rho}\right) \times 100$$

Areal Density:

Areal density is expressed by the mass of the fabric per unit area (g/m^{2}, popularly called GSM). Areal density of the fabric will depend on the following parameters-

- Warp yarn count (tex): T_1
- Weft yarn count (tex): T_2
- Ends per unit length (EPcm): N_1
- Picks per unit length (PPcm): N_2
- Crimp % in warp: C_1
- Crimp % in weft: C_2



Total length of ends (warp)

$$= \text{Total number of ends} \times \text{straightened length of one end}$$

$$= 100 N_1 \times \left(1 + \frac{C_1}{100}\right) \text{ m.}$$

$$\text{Mass of warp yarns (g)} = \frac{\text{Total length of ends in m}}{1000} \times \text{tex of warp}$$

$$= \frac{100 N_1 \times \left(1 + \frac{C_1}{100}\right)}{1000} \times T_1 = \frac{N_1 T_1}{10}\left(1 + \frac{C_1}{100}\right)$$

$$\text{The mass of weft yarns (g)} = \frac{N_2 T_2}{10}\left(1 + \frac{C_2}{100}\right)$$

$$\text{Areal density of fabric or GSM} = \frac{1}{10}\left[N_1 T_1\left(1 + \frac{C_1}{100}\right) + N_2 T_2\left(1 + \frac{C_2}{100}\right)\right]$$

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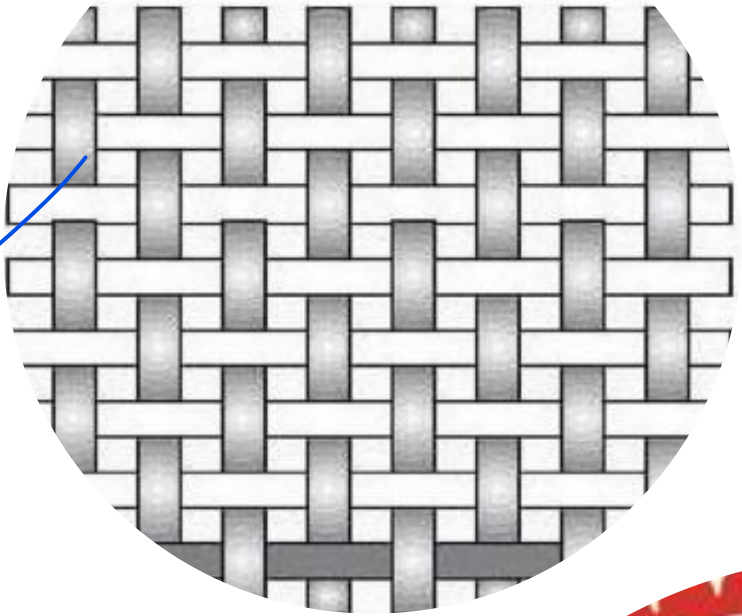

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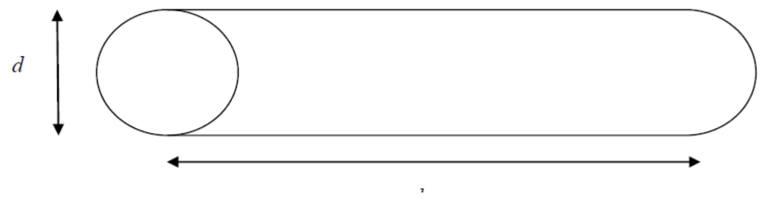
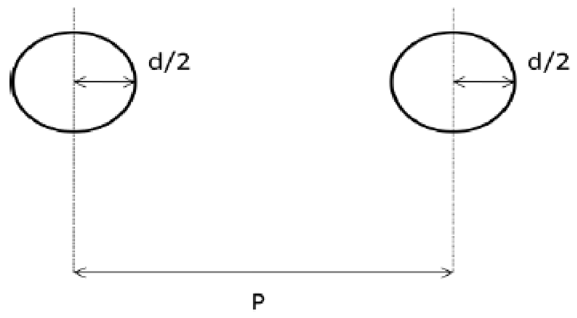
P1. The length of a fabric is 10 m. The length of a warp yarn, removed from the fabric, in straight condition is 10.8 m. Determine the crimp% in warp direction. What should be contraction %?

P2. Prove that for cotton yarn with packing factor of 0.6, (Note that- Yard: 840 x 36 inch, Density of cotton fibre is 1.51 g/cm^3)

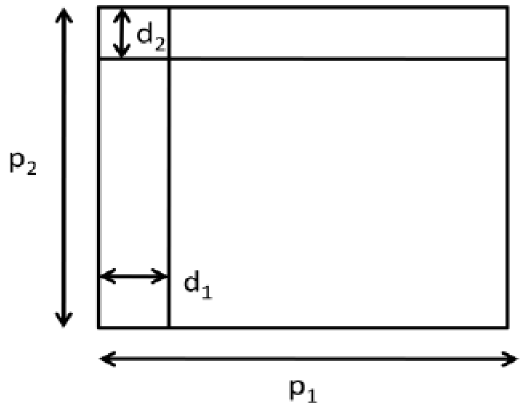
$$\text{diameter (inch)} = \frac{1}{28\sqrt{Ne}}$$



P3. A cotton fabric is made from 20 Ne warp and ends per inch is 50. Determine the warp cover factor



P4. Show that the expression for fabric cover factor is $K_1+K_2-(K_1.K_2/28)$, where K_1 is warp cover factor and K_2 is weft cover factor.



Fabric Manufacturing I (TXL231)

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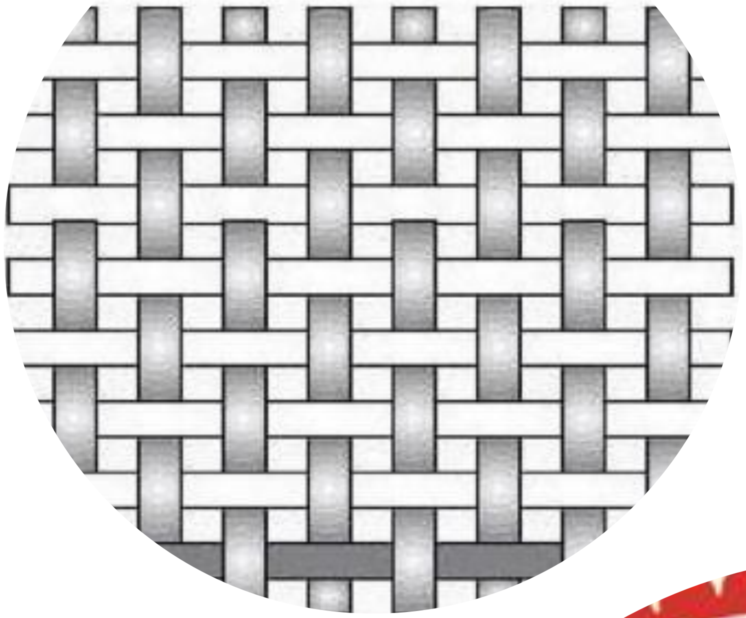


Winding- The Objectives

- ❑ To wrap the forming yarn on a package in a systematic manner or to transfer yarn from one supply package to another in such a way that the latter is adequately compact and usable for the subsequent operations.
- ❑ To remove the objectionable faults, present in original yarns.

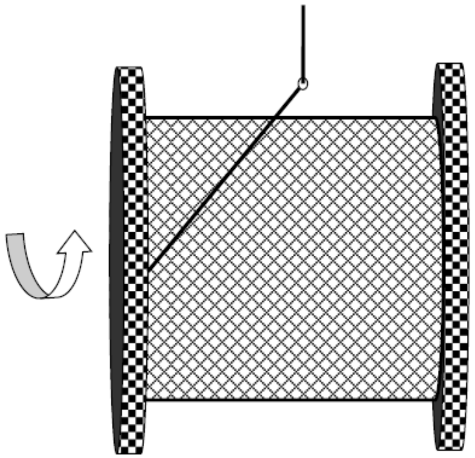
One ringframe bobbin (cop) typically contains around 100 grams of yarn. If the yarn count is 20 tex, then the length of yarn in the package will be around 5 km. As the warping speed in modern machines is around 1000 m/min, direct use of ringframe bobbins in warping will necessitate package change after every 5 minutes.

This is not a feasible solution..

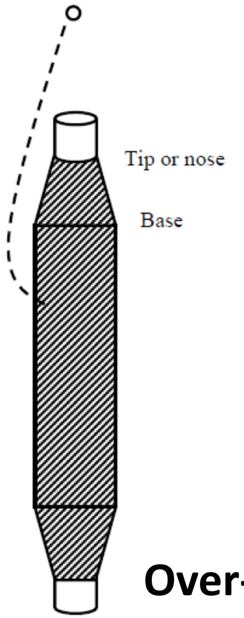
Winding- Basic Motions

- First, the rotational motion of the package, on which the yarn is being wound, is required. This rotational motion pulls out the yarn from the supply package.
- Second, the traverse motion is requited so that the entire width of the package is used for winding the yarn

The process of withdrawing yarn from supply package during winding



Side withdrawal

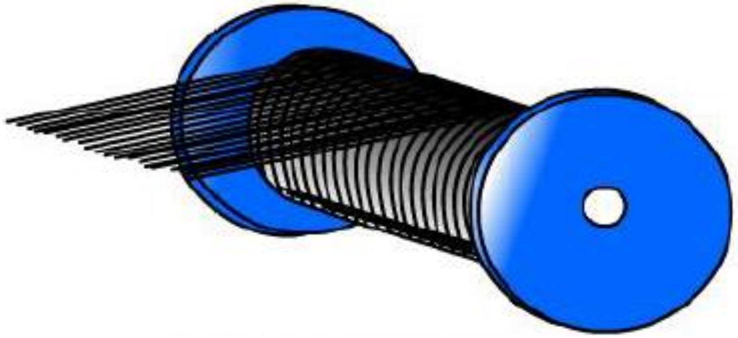


Over- end withdrawal

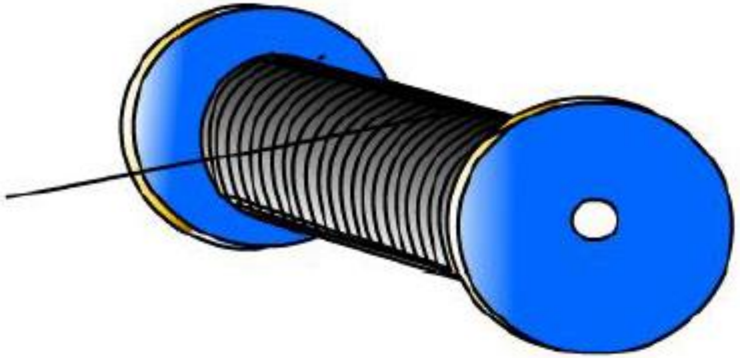
For flanged packages- Side withdrawal
For ringframe bobbin- over-end withdrawal

Types of Wound Packages

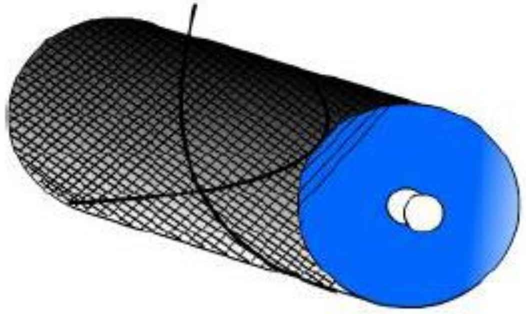
- In parallel wound package, yarns are laid parallel to each o
- In nearly parallel wound package, successive coils of yarn a laid with a very nominal angle. The rate of traverse is very in this case.
- In cross wound package, yarns are laid on the package at considerable angle.



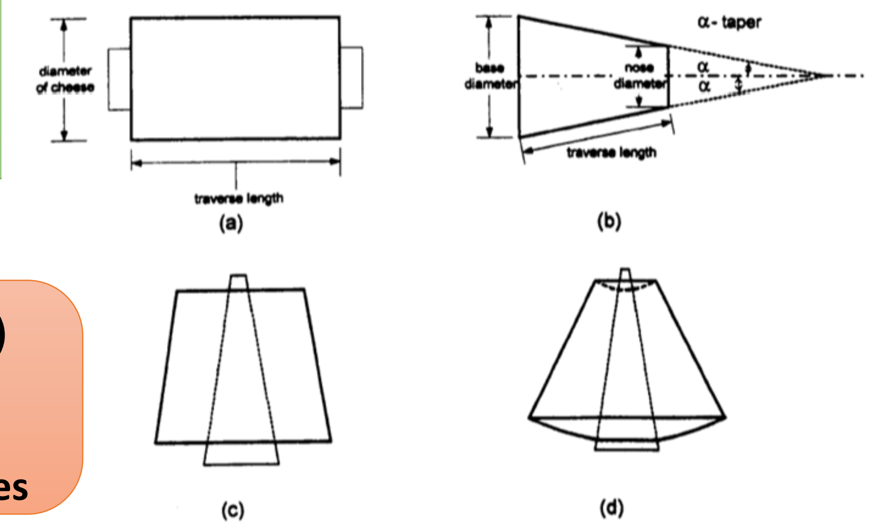
Parallel Wound Packages



Nearly Parallel Wound Packages



Cross Wound Packages

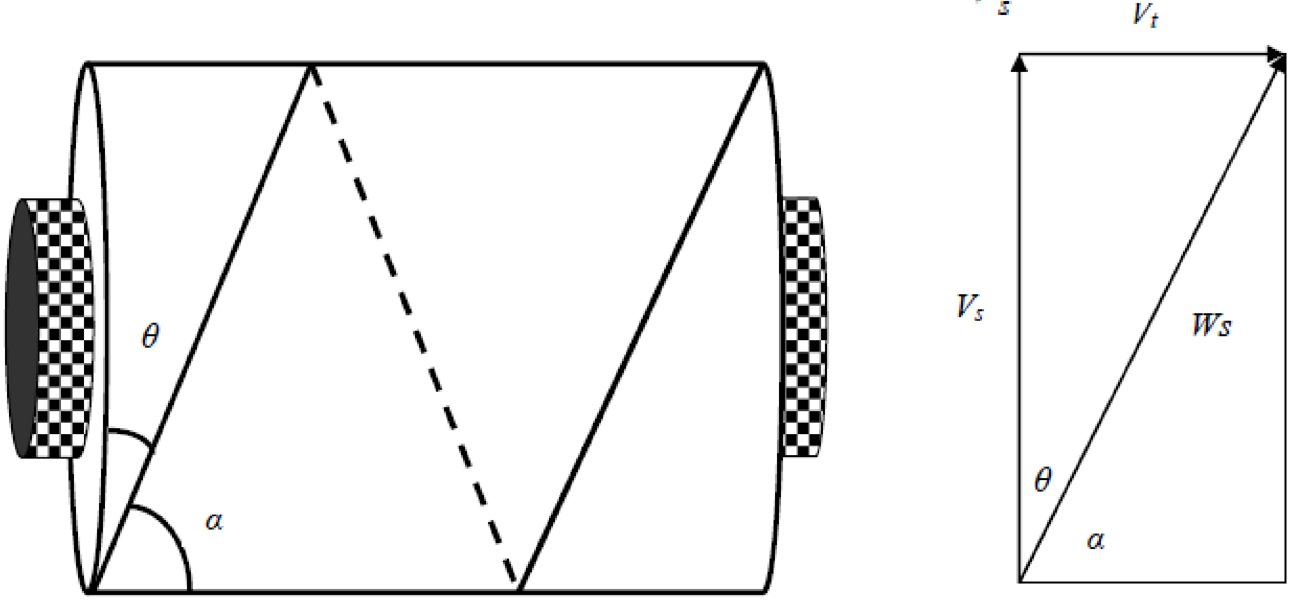


Types of cross wound- (a) Cheese (b) Cone (c) Tapered cone and (d) Accelerated-tapered cones

Some Definitions in Winding

- **Wind:** It is the number of revolutions made by the package (i.e. number of coils wound on the package) during the time taken by the yarn guide to make a traverse in one direction (say from left to right) across the package
- **Angle of wind (θ):** It is the angle made by the yarn with the sides of the package
- **Coil angle (α):** It is the angle made by the yarn with the axis of the package. The coil angle and angle of wind are complementary angles as they add up to 90^0

$$\tan\theta = \frac{V_t}{V_s}$$



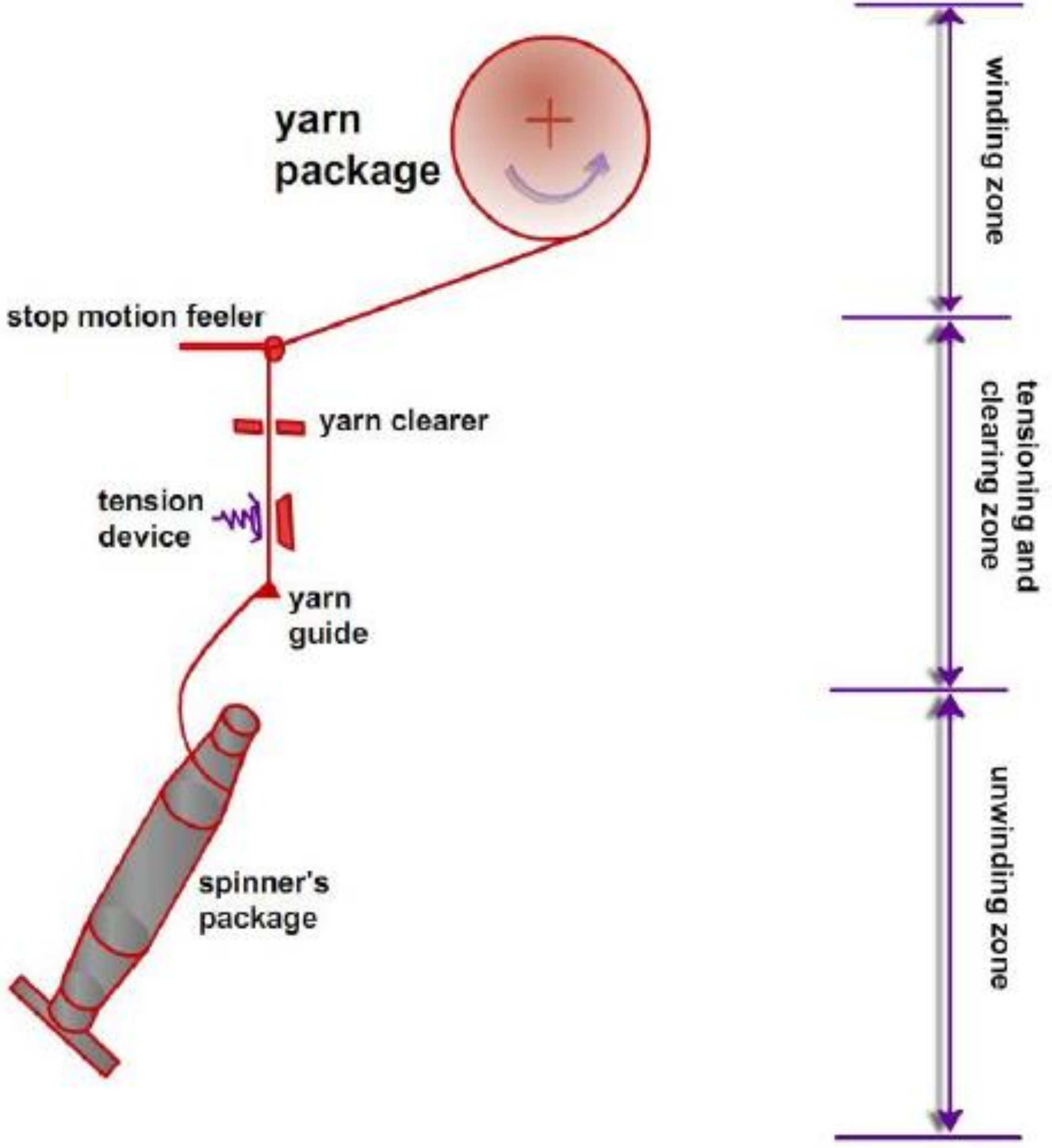
$$\text{Winding speed} = W = \sqrt{\text{Surface speed}^2 + \text{Traverse speed}^2}$$
$$= \sqrt{V_s^2 + V_t^2}$$

Winding Machine

Yarns are wound on the package by means of rotational motion of the package and traverse motion of the yarn guide

Tensions are applied on the yarns by using tensioners so that yarns are wound on the package with proper compactness

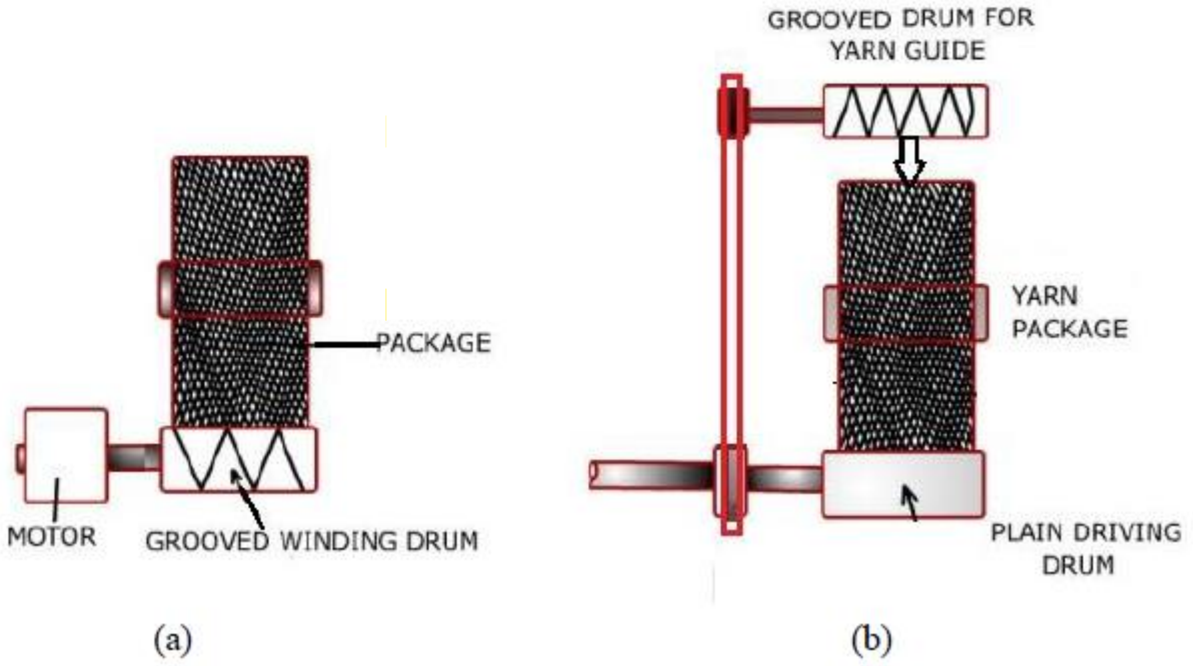
Yarns are unwound from the supply package which is ringframe bobbin in most of the cases. Yarn balloon is formed due to the high-speed unwinding of yarn from the supply package.

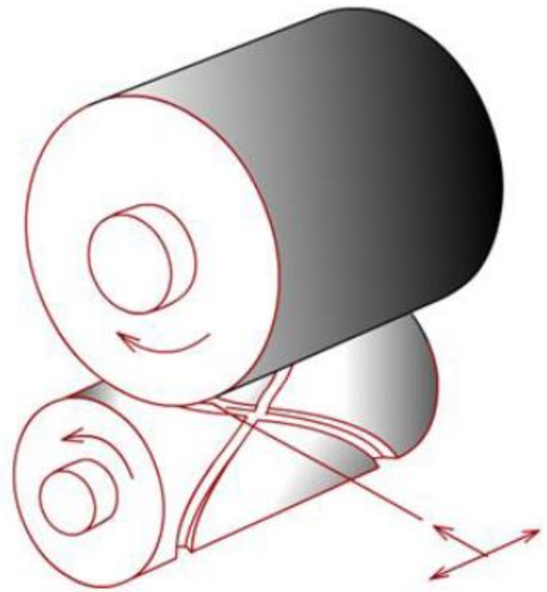


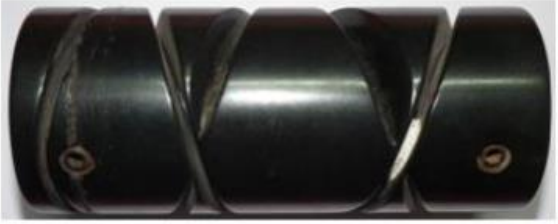
Winding Principles- Drum-driven

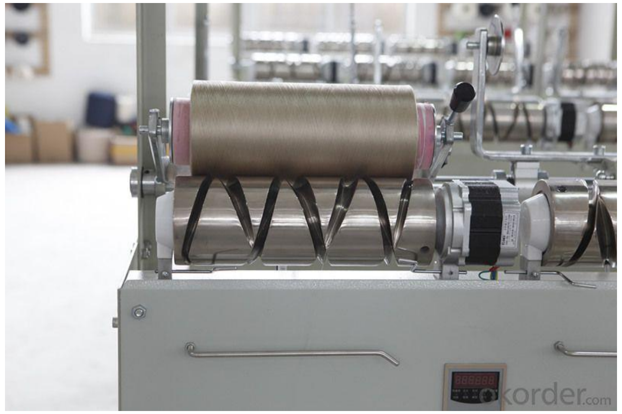
In drum-driven winder, the package is driven by a cylinder by surface or frictional contact

Traverse of yarn is given either by the grooves cut on the or by a reciprocating guide









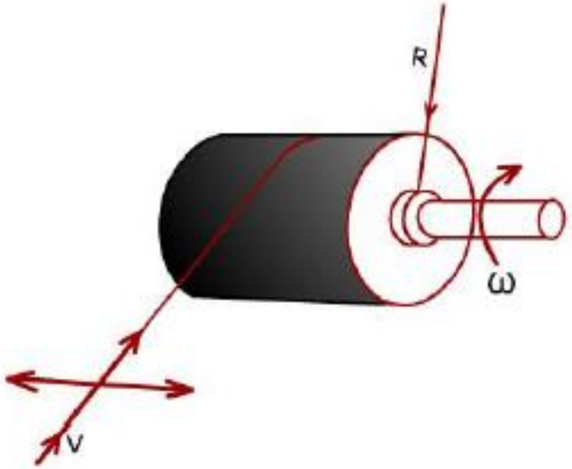
Winding Principles- Spindle-driven

In spindle-driven winder, the package is mounted on a spindle which is driven positively by a gear system

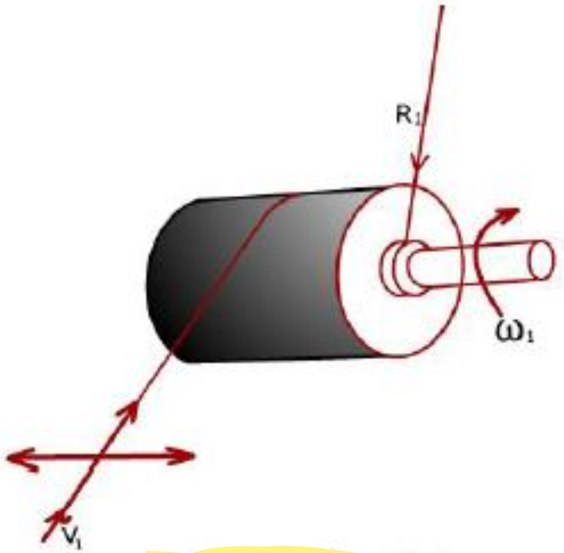
Constant r.p.m. spindle winders

Variable r.p.m. spindle winders

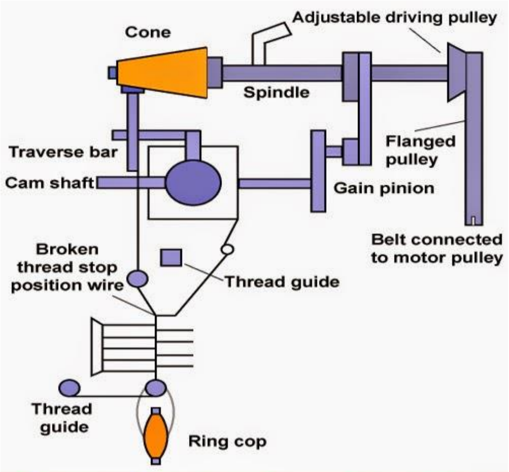
Spindle-driven winders are also known as precision winders as a precise ratio is maintained between the r.p.m. of spindle and r.p.m. of traversing mechanism



ω is constant
v increase as R increases



ω_1 is varied as R_1 increase so as to keep V_1 constant



Passage of yarn through a precision winder

Precision winders are preferred for winding delicate yarns as the package is not rotated by the surface contact and therefore the possibility of yarn damage due to abrasion is lower as compacted to that of surface driven winders.

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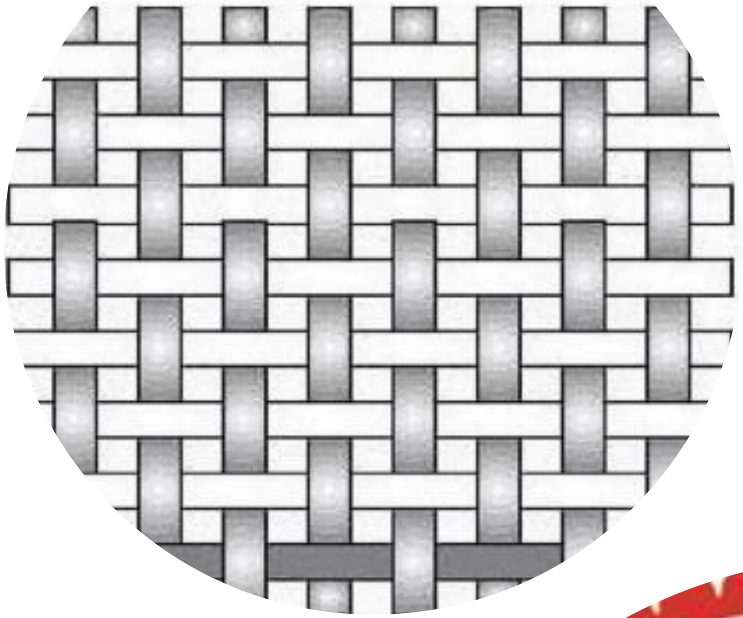

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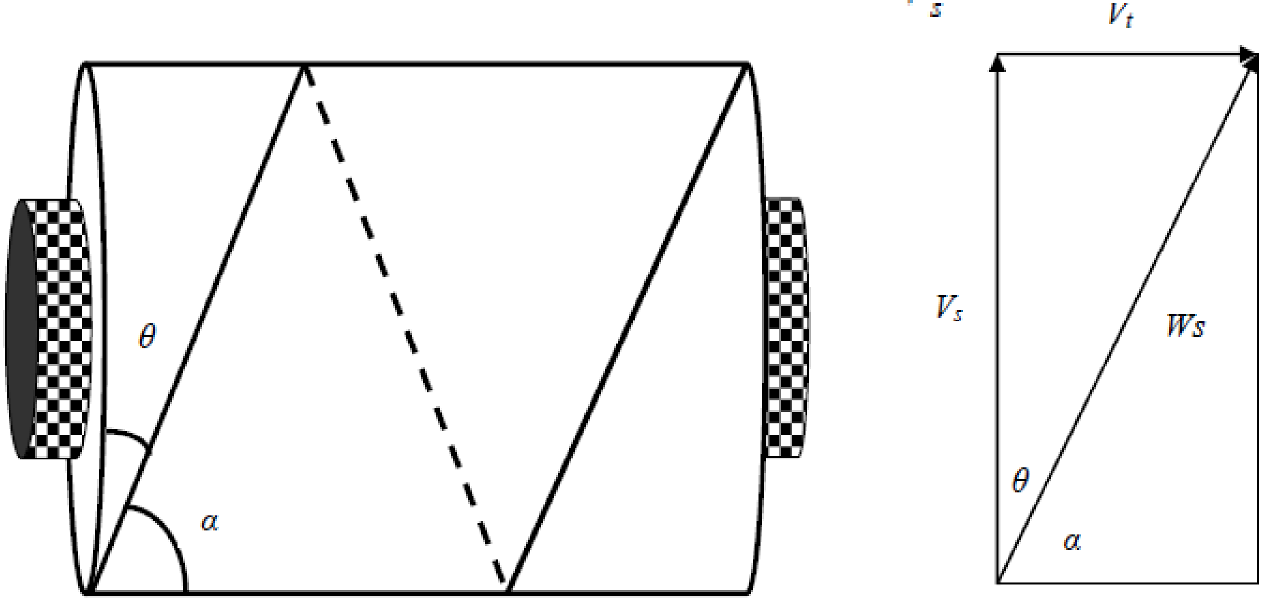


$$\text{Winding speed} = W = \sqrt{\text{Surface speed}^2 + \text{Traverse speed}^2}$$
$$= \sqrt{V_s^2 + V_t^2}$$

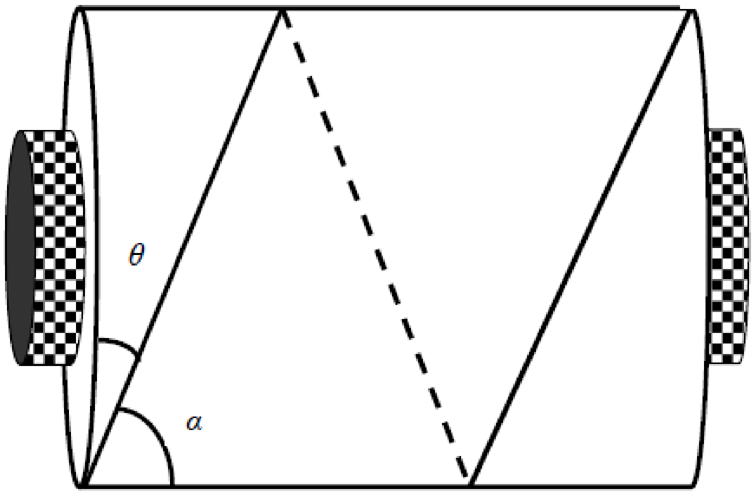
Some Definitions in Winding

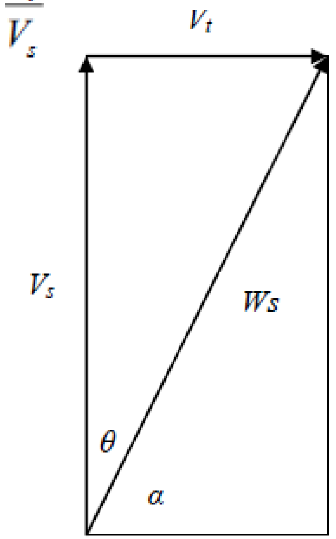
- **Traverse length:** is defined as the distance between extreme positions of a reciprocating thread-guide in one cycle of its movement

- **Gain:** Gain is the angular displacement of the yarn at the beginning of a double traverse, with respect to the corresponding position for the previous double traverse. The new yarn coil should fall slightly to one side or the other of the first coil. The gain to be used is a minimum gain if the coils are to be laid side by side so as to increase winding density.

- **Ribboning:** If yarn is repeatedly laid on top of or along the same path as the previously wound yarn, this duplication of yam path on the package creates a defect known as ribboning or patterning

$$\tan\theta = \frac{V_t}{V_s}$$





$$\text{Winding speed} = W = \sqrt{\text{Surface speed}^2 + \text{Traverse speed}^2}$$

$$= \sqrt{V_s^2 + V_t^2}$$

$V_S = \pi * D_P * N_P$

D_P- Package diameter

N_P- Package rotational speed (rpm)

$V_T = 2.L.N_d/k$

L – Traverse length

N_d-Rotational speed of the driving roller or cam drum (rpm)

k-driving roller revolutions per double traverse

Winding Machine

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Tensions are applied on the yarns by using tensioners so that yarns are wound on the package with proper compactness

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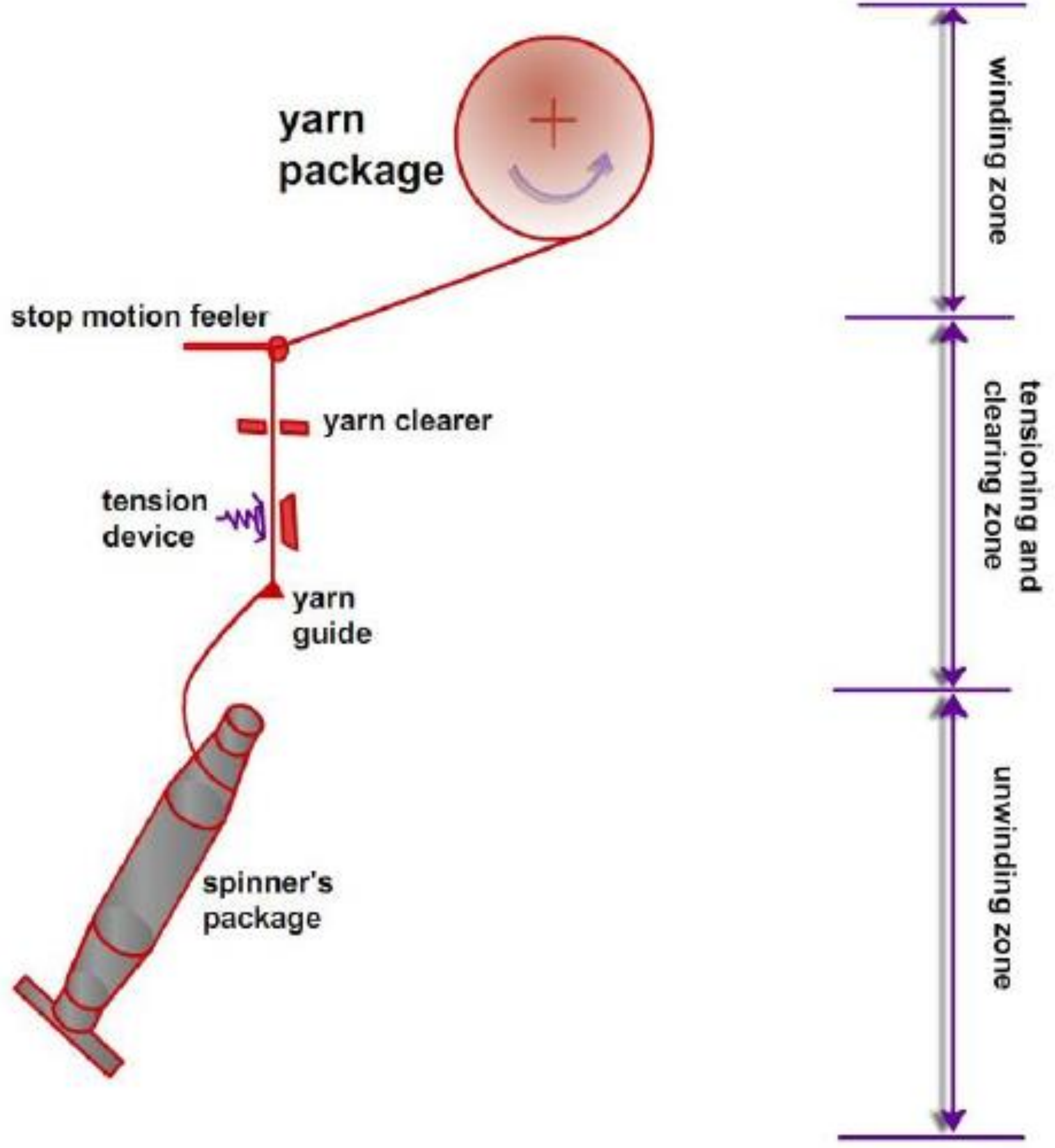
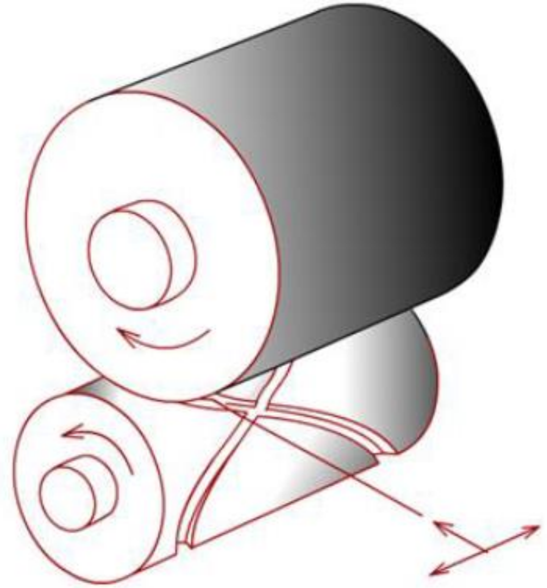
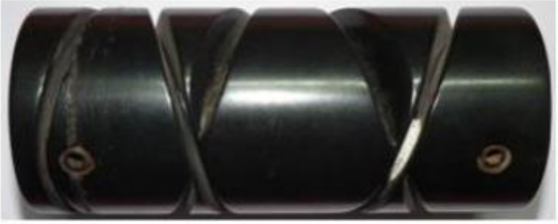


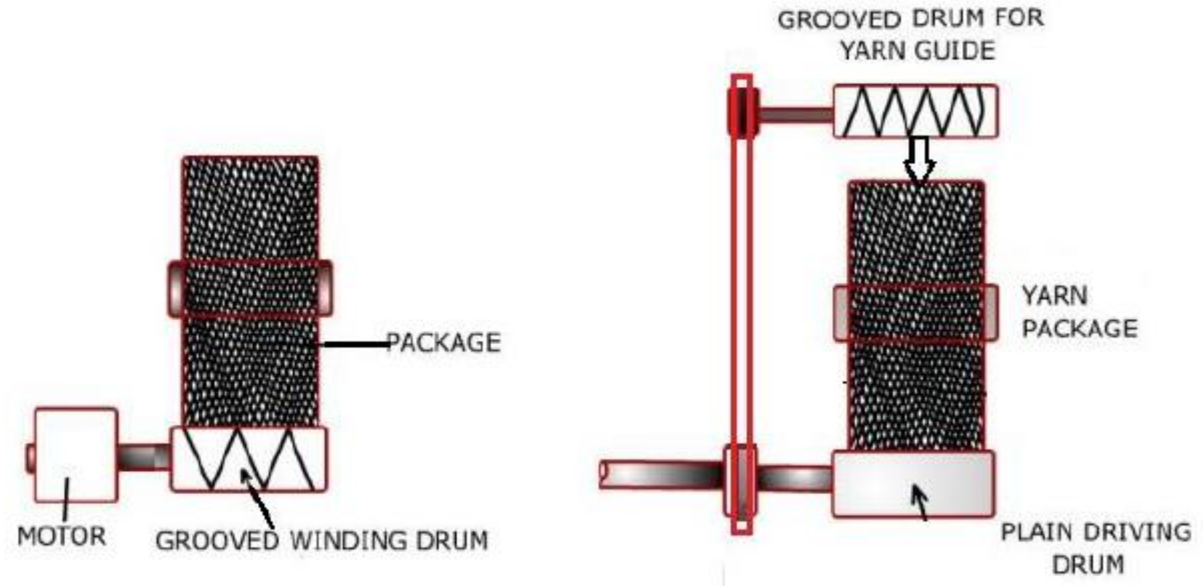
Winding Principles- Drum-driven



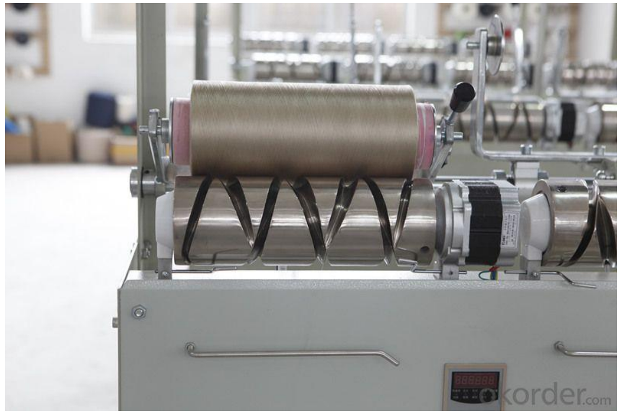
In drum-driven winder, the package is driven by a cylinder by surface or frictional contact

Traverse of yarn is given either by the grooves cut on the or by a reciprocating guide



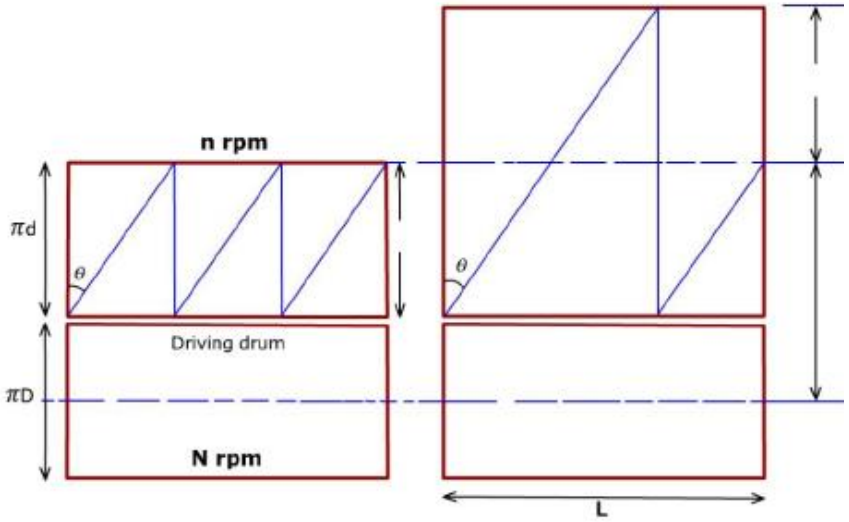


(a) (b)



Winding Principles- Drum-driven

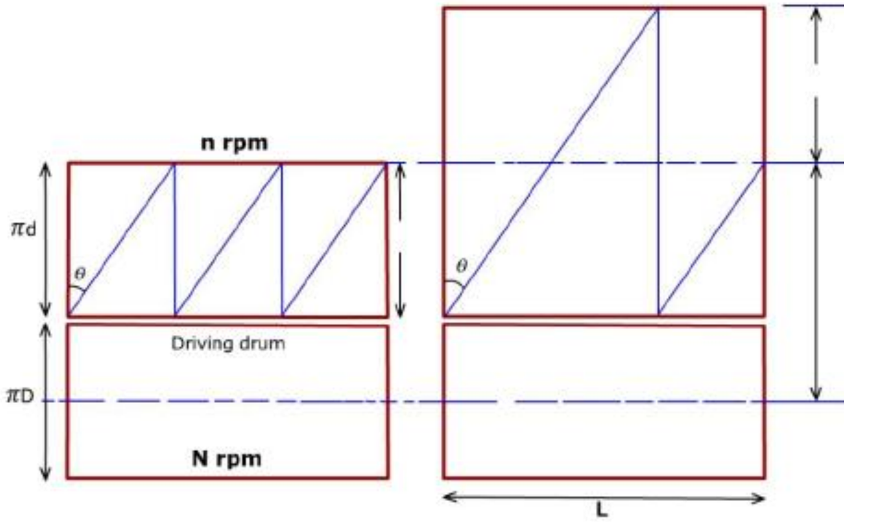
Let us consider that the diameters of the driving drum and package are D and d, respectively The r.p.m. of drum and package are N and n, respectively. D is constant whereas d increases with time due to the building of the package (formation of layers of coils).



For no slippage- N×D = n×d, but N is constant, so n should reduce with increasing d.

Reminder- For drum-driven winder, traverse speed and surface speed are also constant. Therefore, it gives constant angle of wind and winding speed

Winding Principles- Drum-driven



Let, L is the length of the drum and package.

Distance covered in one double traverse $= 2L$

Number of revolution required for the drum for double traverse $= S$

N revolution of drum takes 1 minute

S revolution of drum will take $\dfrac{S}{N}$ minute

S revolution of drum is equivalent to one double traverse

So, time for one double traverse $= \dfrac{S}{N}$ min

$$\text{Traverse speed} = \frac{\text{Distance covered in one double traverse}}{\text{Time for one double traverse}} = \frac{2L}{\frac{S}{N}} = \frac{2LN}{S}$$

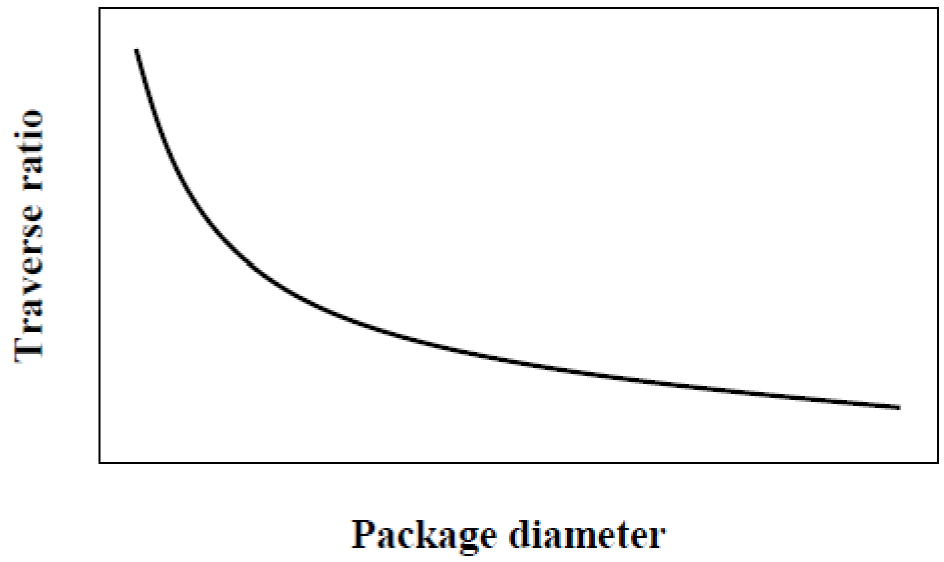
$$\tan\theta = \frac{V_t}{V_s} = \frac{\frac{2LN}{S}}{\pi DN} = \frac{2L}{\pi DS} = \text{constant (as } L, D \text{ and } S \text{ are constant for a gievn drum)}$$

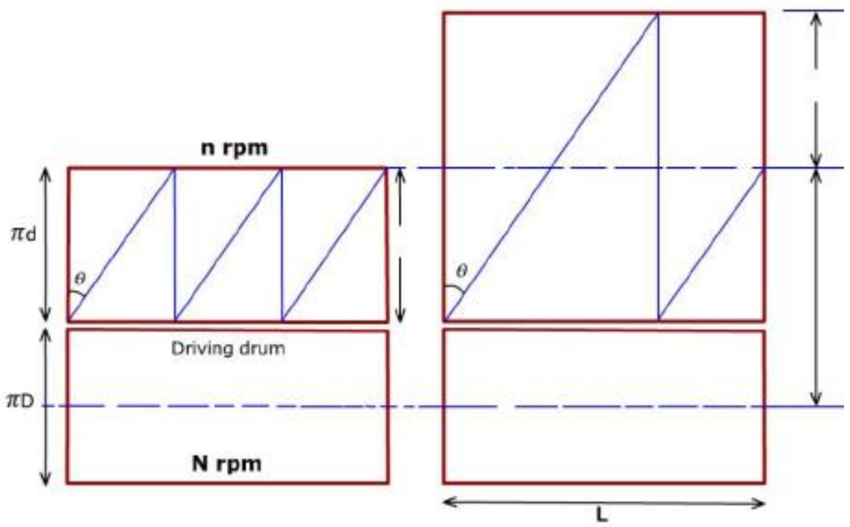
So, in drum-driven winder, angle of wind remains constant with the increase in package diameter

So, Traverse Ratio= wind/double traverse= (wind/min)/(double traverse /min)= n/(N/S)=S(D/d)

This leads to a 'patterning' problem in case of drum-driven winder.

Winding Principles- Drum-driven





$$\text{Winding speed} = \sqrt{\text{Surface speed}^2 + \text{Traverse speed}^2}$$

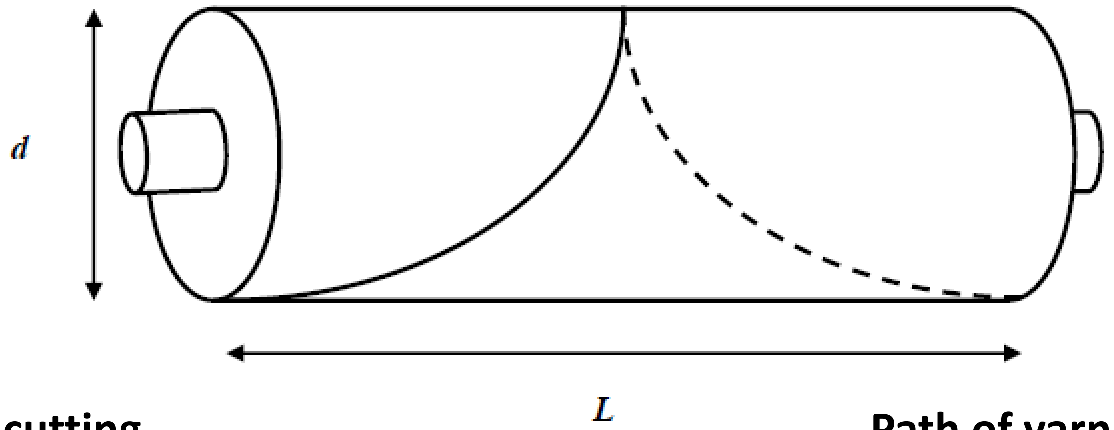
$$= \sqrt{(\pi DN)^2 + \left(\frac{2LN}{S}\right)^2}$$

$$= \sqrt{(\pi dn)^2 + \left(\frac{2LN}{S}\right)^2} \quad \text{(no slippage between drum and package)}$$

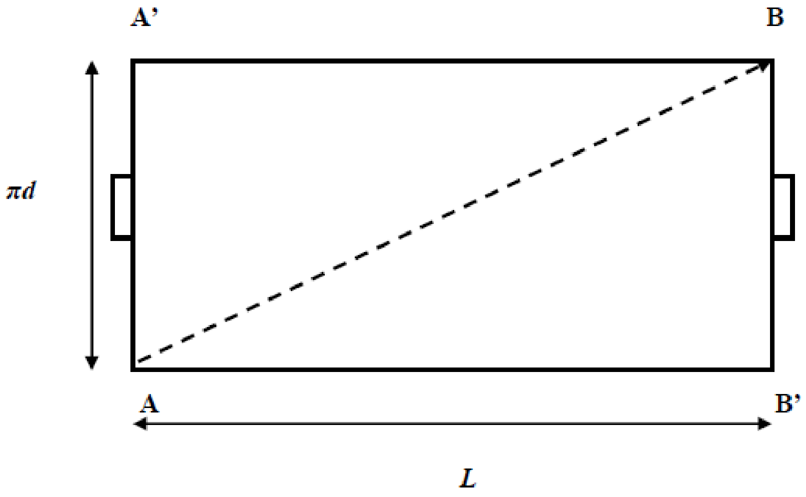
Patterning in Drum-driven Winder

If the traverse ratio (wind per double traverse) value is an integer, then the yarn comes back to the same position on the package surface after one double traverse. Therefore, in the next double traverse, the yarn is laid just over the yarn which was laid in the previous double traverse. As a result, a ribbon develops in the package.

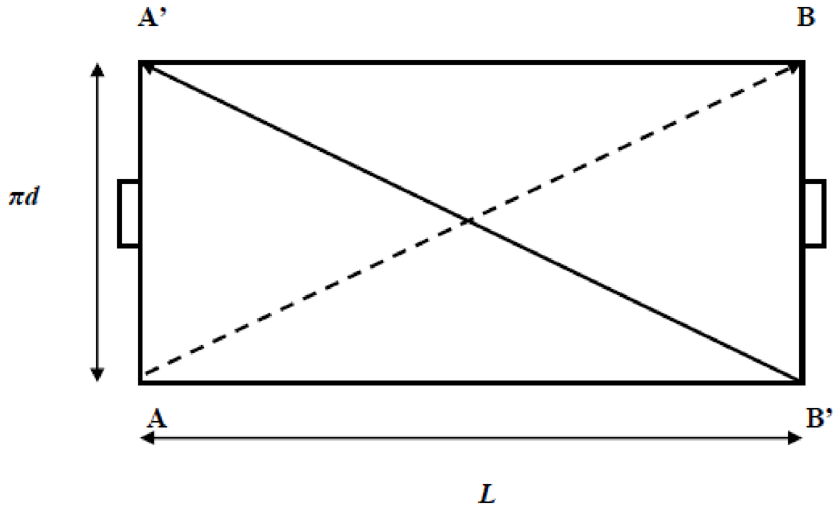
Path of yarn on cheese package



Path of yarn on cheese after cutting



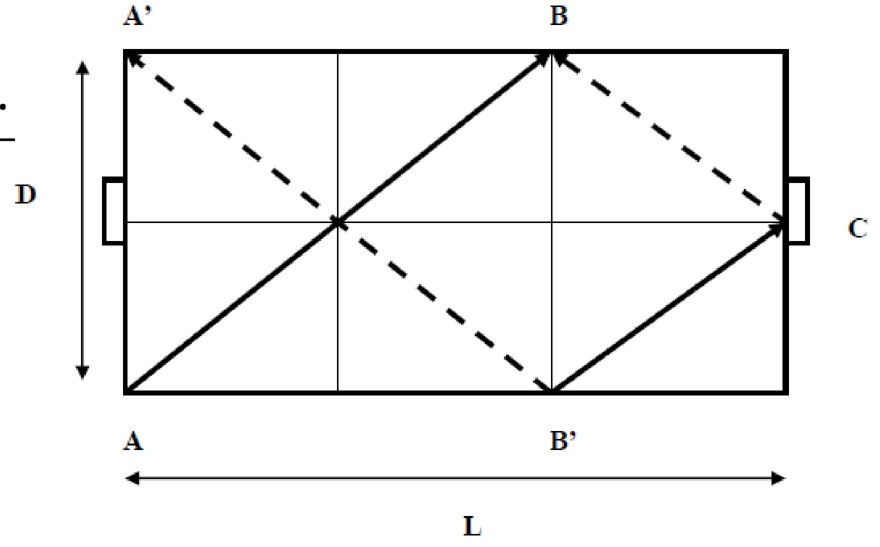
Path of yarn for traverse ratio value 2



Patterning in Drum-driven Winder

For any value of traverse ratio (wind per double traverse) the path of yarn on the cheese can be drawn and analyzed

- ❑ Traverse ratio (wind per double traverse) = x (integer)
- ❑ Wind per traverse = x/2
- ❑ Traverse per wind = 2/x
- ❑ Divide the opened package in two equal parts (as the numerator is 2) in the vertical direction and x number of equal parts in the horizontal directions. This will create some smaller rectangles within the opened package.
- ❑ Draw the diagonals for the small rectangles.
- ❑ When one coil is complete, shift the winding point from upper parallel line to lower parallel line and vice-versa.
- ❑ Reverse the direction of traverse when the one traverse is complete.

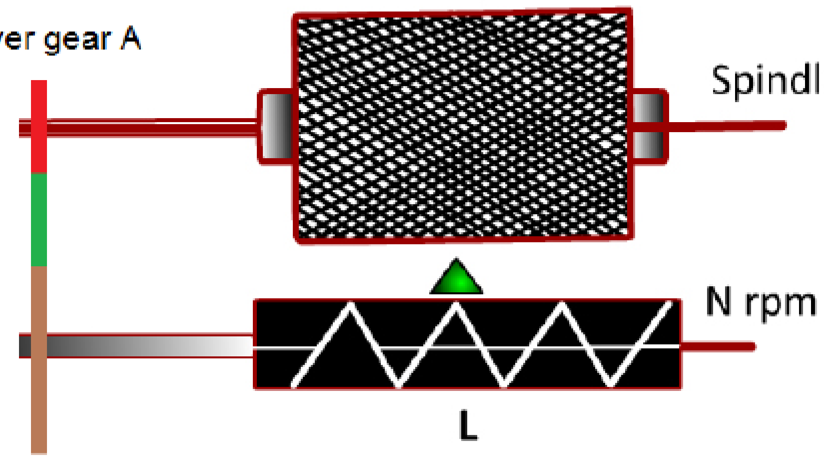


Advantages in Drum-driven Winder

- The simplicity of this arrangement is that a cam type traverse arrangement is not required
- The yarn being wound, due to the winding tension, falls readily into the groove, without the need for any threading action to be carried out
- As the package is driven by frictional contact with drum, the surface speeds of drum and package are equal
- The wind angle of the yarn on the package remains the same at all points, as this is decided by the resultant velocity of yarn on the surface of the package, which is constant. This also contributes to a uniform package density.

Winding Principles- Spindle-driven

If these gears (A and B, both are tooth numbers) are not changed then the ratio of spindle speed (r.p.m.) and traverse speed (number of traverse/ min) remains same and therefore the value of traverse ratio remains constant



Let R is the number of double traverse made by the traversing device per minute

$$\tan\theta = \frac{\text{Traverse speed}}{\text{Surface speed}}$$

$$= \frac{V_t}{V_s} = \frac{2LR}{\pi d n}$$

RPM of traversing drum, N= n(A/B) and if the grooved drum fives S revolutions for one double traverse, then, R= N/S

$$\tan\theta = \frac{2LR}{\pi d n} = \frac{2L}{\pi d} \times \frac{n \times \frac{A}{B} \times \frac{1}{S}}{n}$$

$$= \frac{2L}{\pi d} \times \frac{A}{B} \times \frac{1}{S} \propto \frac{1}{d}$$

Reminder- As, d increases with the package building, the angle of wind decreases and d x tanθ remains constant for spindle-driven winders.

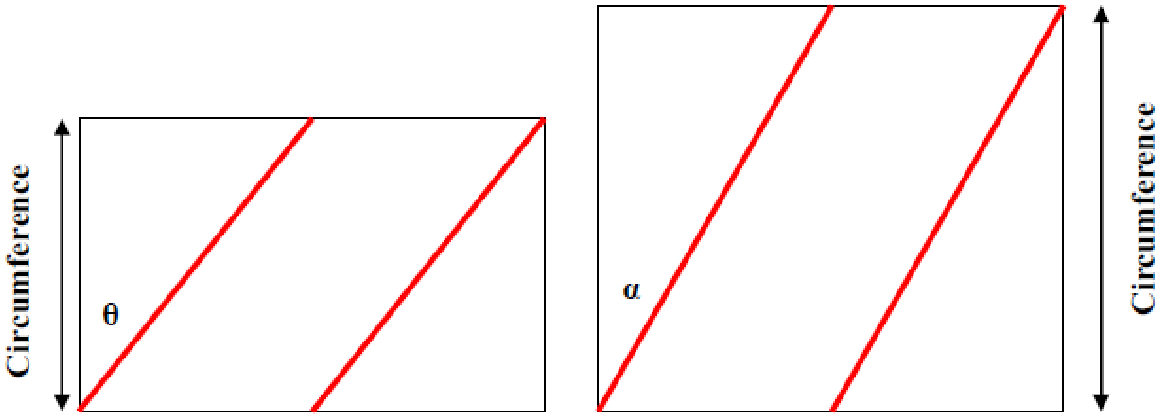
Question- What happens with traverse ratio and winding speed?

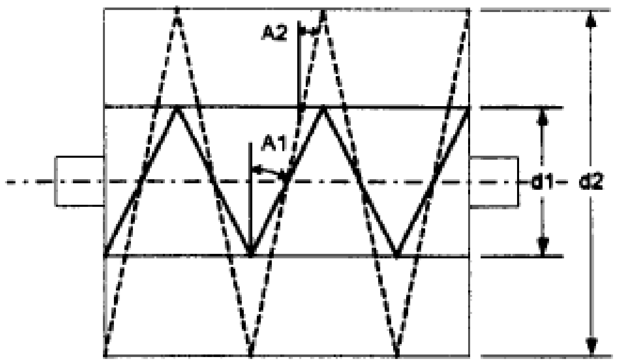
Winding Principles- Spindle-driven

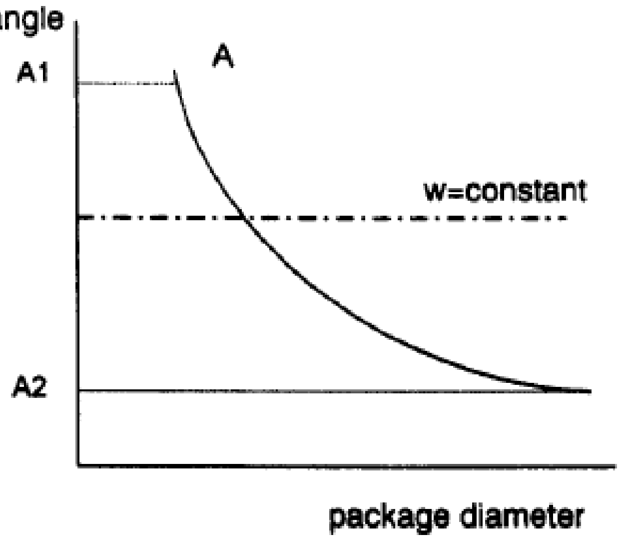
Traverse ratio= wind/double traverse

$$= \frac{\text{wind/min}}{\text{double traverse/min}} = \frac{n}{R} = \frac{n}{n.\frac{A}{B}.\frac{1}{S}} = \frac{B \times S}{A} = \text{Constant}$$

$$\text{Winding speed} = \sqrt{(\pi dn)^2 + (2LR)^2} \text{ (generally increases with '}d\text{')}$$



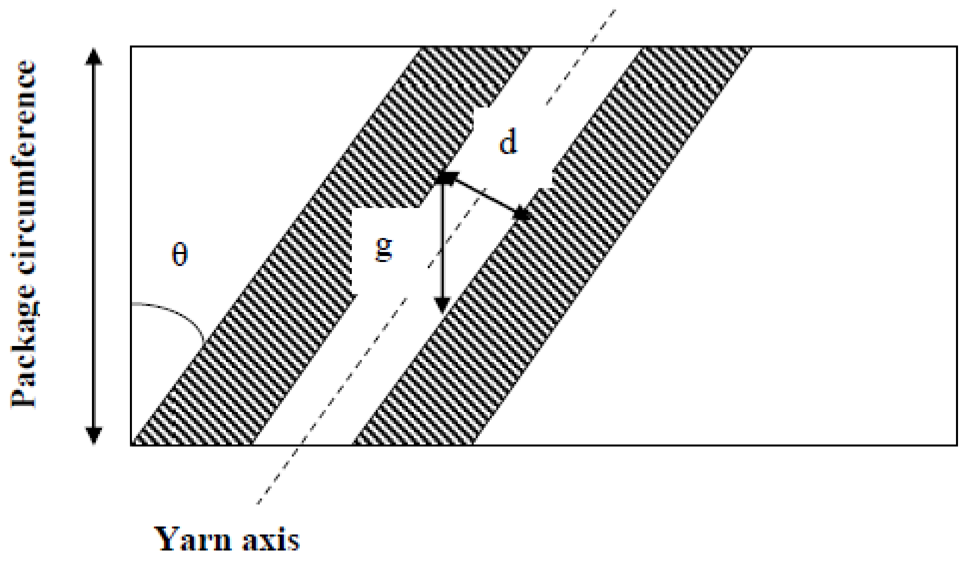




Advantages in Spindle-driven Winder

- The main advantage of precision winding is that the gain in this type of winding is a constant which when adjusted to a suitable value, enables the production of a cross-wound package with no ribboning

What is GAIN?



$$\text{Linear gain} = g = \frac{\text{Yarn diameter}}{\sin\theta}$$

- Gain is the distance by which the winding point must be shifted for avoiding patterning. Linear gain is measured in the direction of perpendicular to the direction of package axis
- linear gain cannot be added or subtracted with the traverse ratio as traverse ratio basically quantifies the number of package revolution within a certain time
- Linear gain can be divided with the package circumference to obtain revolution gain which can be added or subtracted with traverse ratio

Comparison

Parameter	Drum-driven	Spindle driven
Angle of wind	Remains constant	Decreases with increase in package diameter
Traverse ratio	Decreases with increase in package diameter	Remains constant
Winding speed	Remains constant	Generally increases with package building
Package density	Low (very high at ribbons)	High
Pattern zone	Anti-patterning required	Free of patterns
Unwinding	Problem of patterning (poorer than precision winding)	Good unwinding

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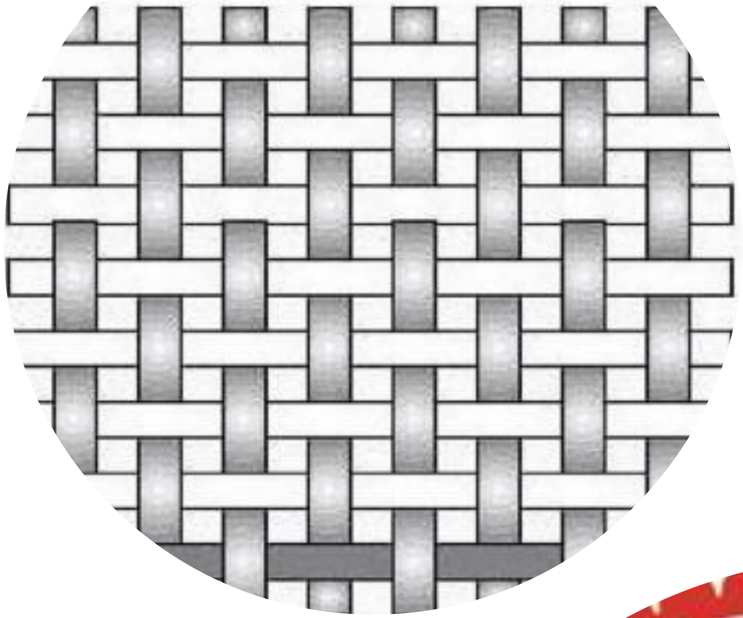

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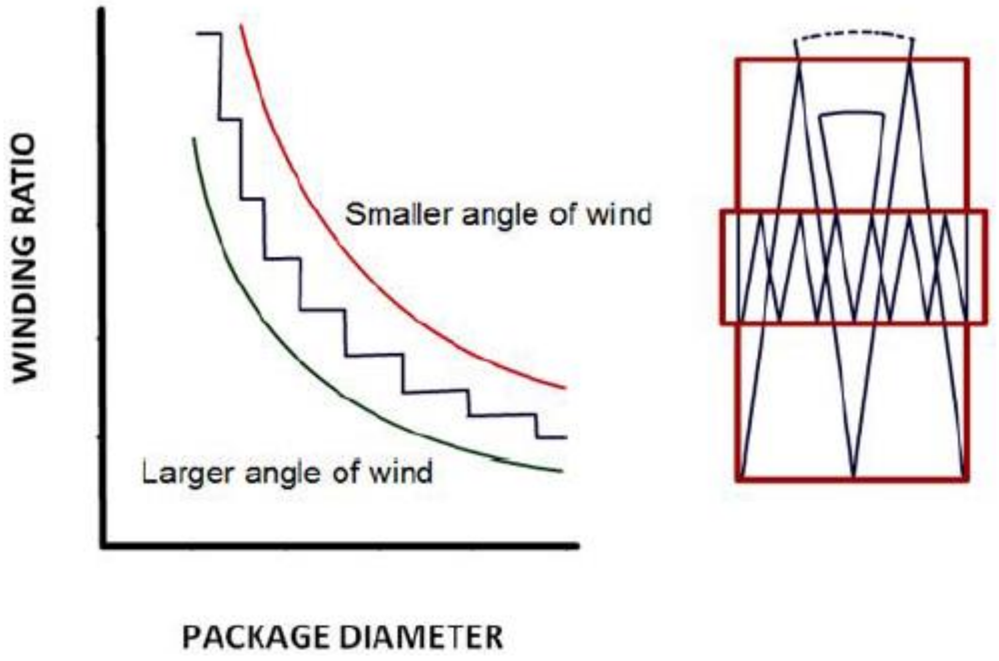
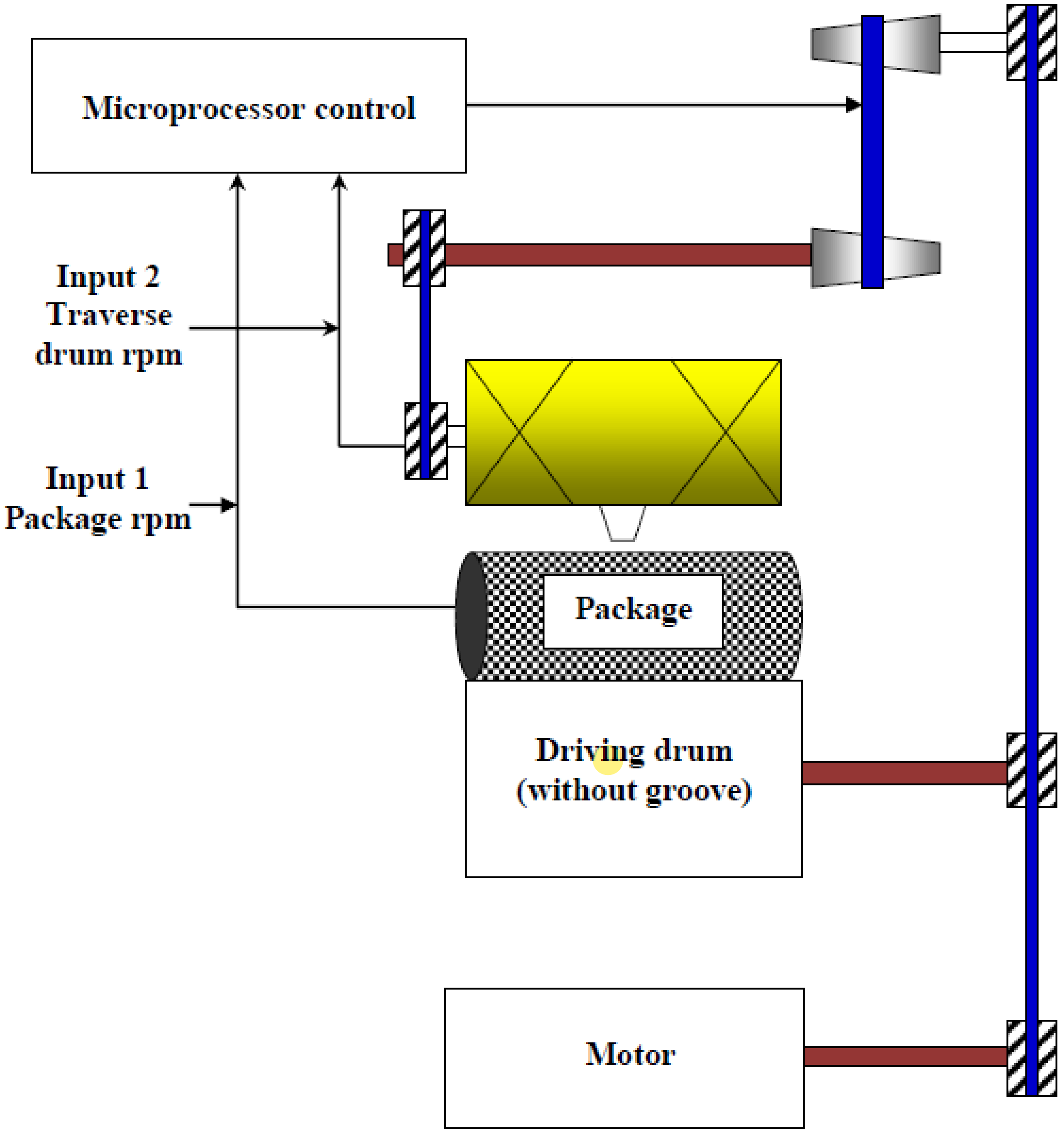
Step Precision Winder or Digicone Winder

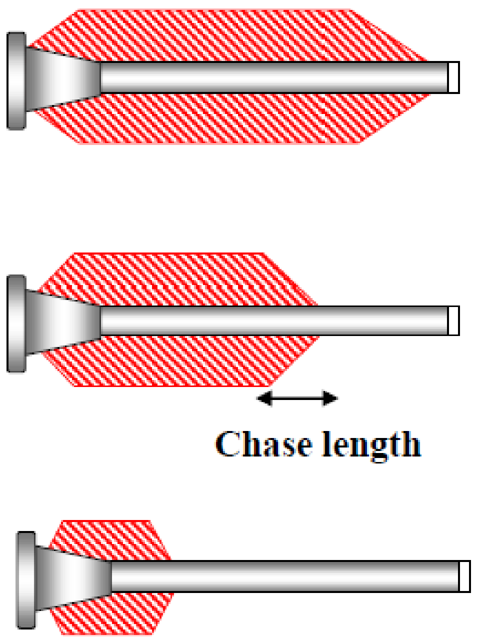
In step precision winder the problem of patterning is prevented by changing the traverse speed proportionately with the package speed (r.p.m.) so that the traverse ratio value remains constant over a period of time.



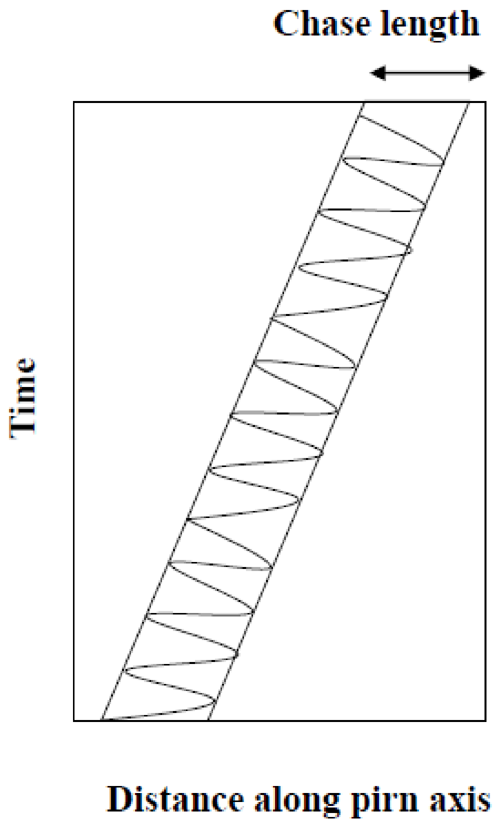


Pirn Winding

Pirns are the yarn packages used within the shuttle to supply the yarns for pick insertion during weaving. In contrast to cone winding, where the supply packages (ringframe bobbins) are small and the delivery packages are big, the supply packages are bigger than the delivery package (pirn) in pirn winding.

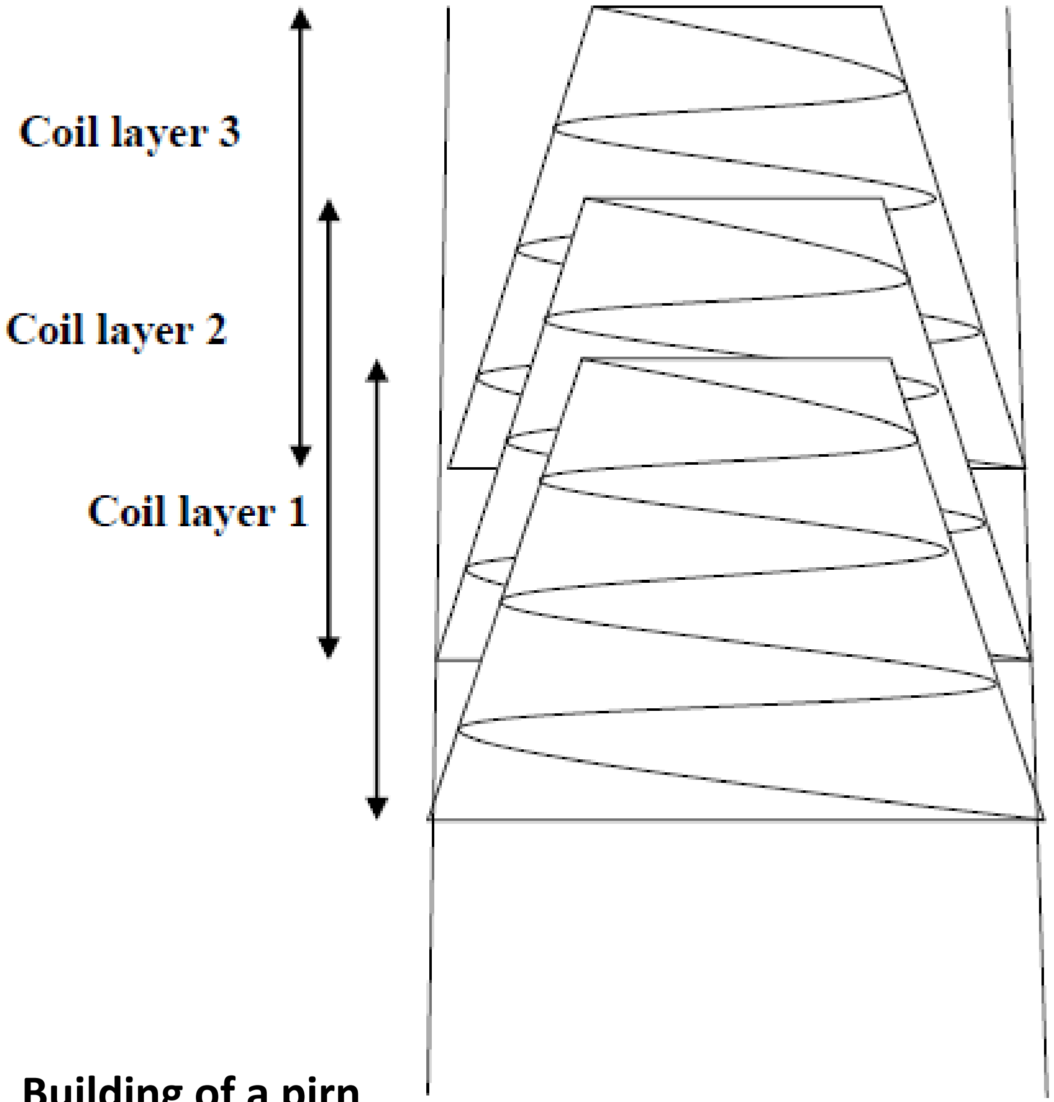


Stages of pirn winding



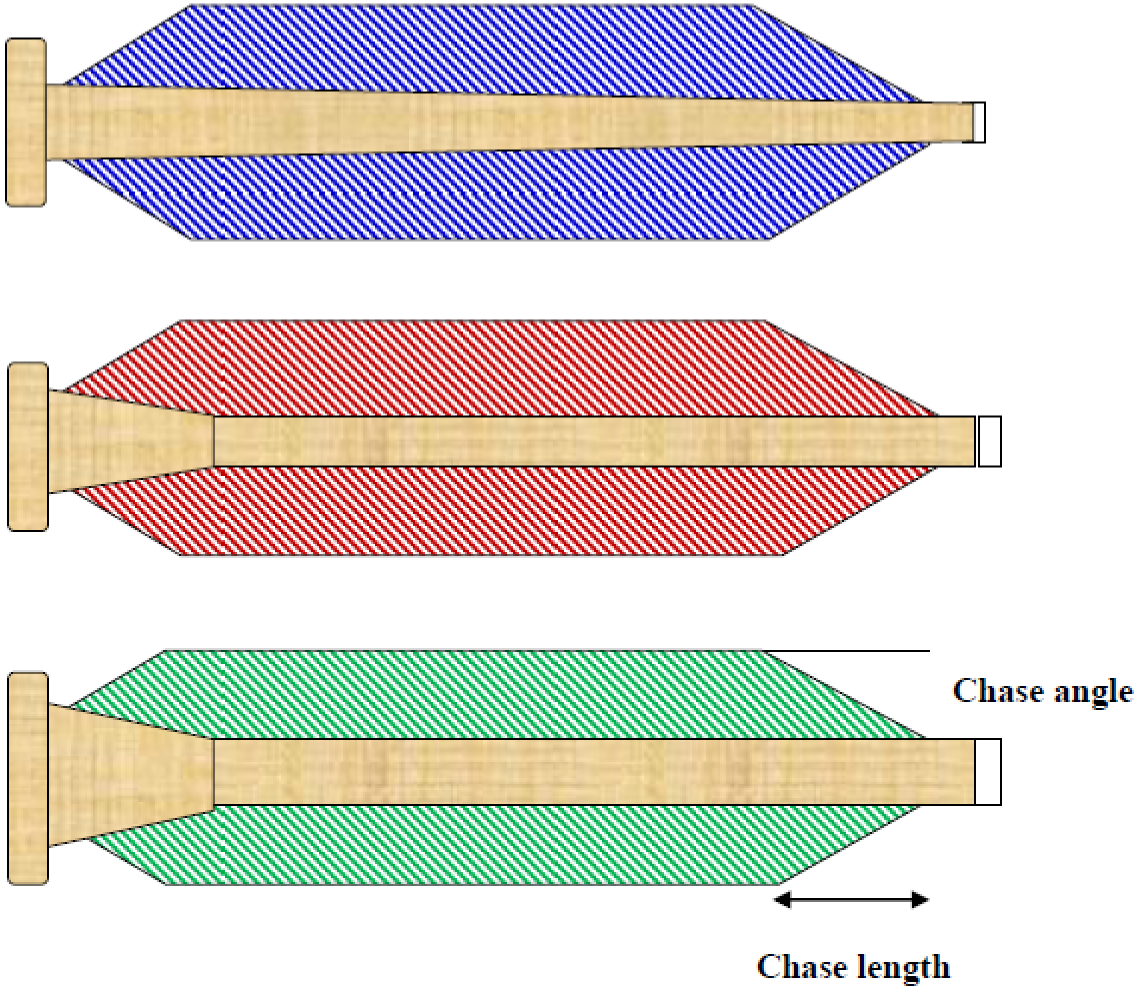
- The pirn winding starts from the conical base and progressively proceeds towards the tip of the pirn. The distance travelled in one stroke of traverse is known as **chase length**
- One layer of coils are laid on the conical base during the forward and as well as during the return movement of the traverse mechanism. Thus, the conicity of the package is maintained and thus the tip of the cone formed by the coils of yarn slowly proceeds towards the tip of the pirn.

Pirn Winding



Building of a pirn

Plain, half base and full base pirns

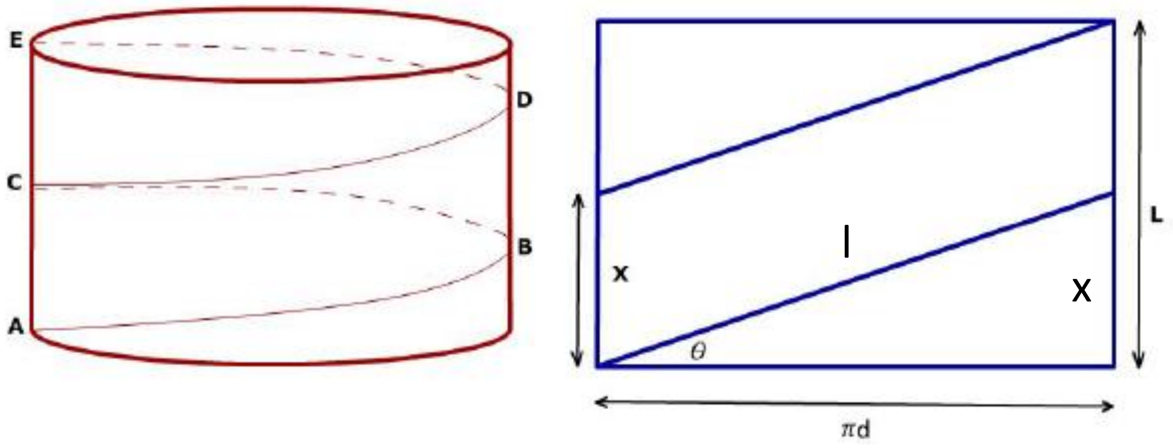


If the full and empty pirn diameter is D and d respectively, L is the chase length and α is the chase angle

$$\tan \alpha = \frac{D - d}{2L}$$

Conditions for Uniform Package (Cheese) Building

Assumption: Length of yarn wound per unit surface area of the package should be constant for uniform building of package



Diameter of package is d and height of the package is L

Legth of one coil= AC= $\dfrac{\pi d}{\cos\theta}$ (θ is angle of wind)

Number of such coils in one traverse $= \dfrac{L}{X} = \dfrac{L}{\pi d.\tan\theta}$

*x= traverse for 1 coil= πd tanθ
*l= 1 coil= πd/cosθ
* Length of yarn= length of one coil x no. of coil

Length of yarn/ surface area

$$= \frac{\text{Total length of yarn wound at diameter } d}{\text{Total surface area of package at diameter } d}$$

$$= \frac{\dfrac{\pi d}{\cos\theta} \times \dfrac{L}{\pi d.\tan\theta}}{\pi d L} = \frac{1}{\pi d \sin\theta}$$

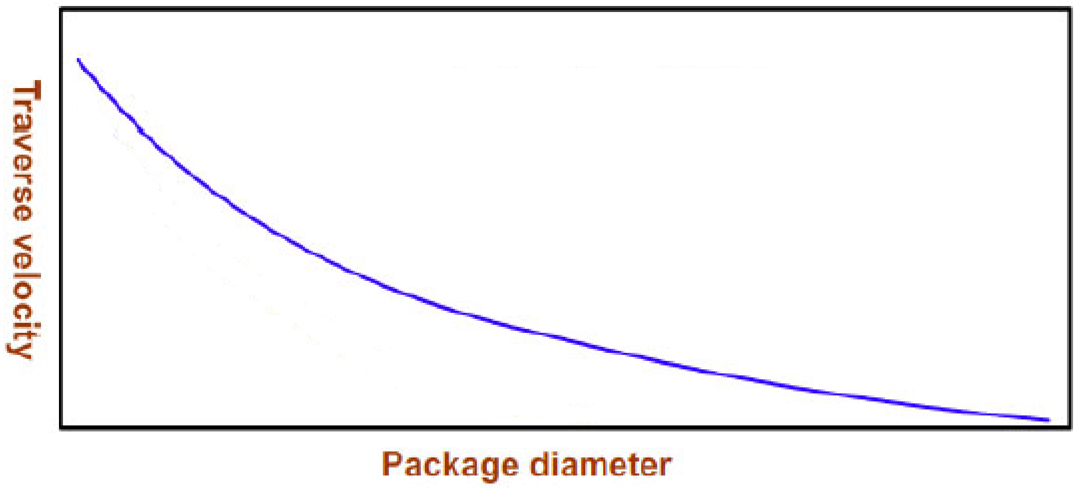
So, $\pi d \sin\theta$ must be kept const for uniform building of the cheese.

Conditions for Uniform Package (Cheese) Building: Drum-driven

$\tan\theta = V_t/\pi nd$ = Traverse speed/ package speed   where d and n are package diameter and r.p.m

$V_t \cos\theta = \pi nd \sin\theta$, But $d\sin\theta$ should be constant and for drum driven n x d is also constant. So n is inversely proportional to d

$$\mathbf{V_t \cos\theta \propto n \propto 1/d}$$



Conditions for Uniform Package (Cheese) Building: Spindle-driven

For spindle driven machine package r.p.m n is constant

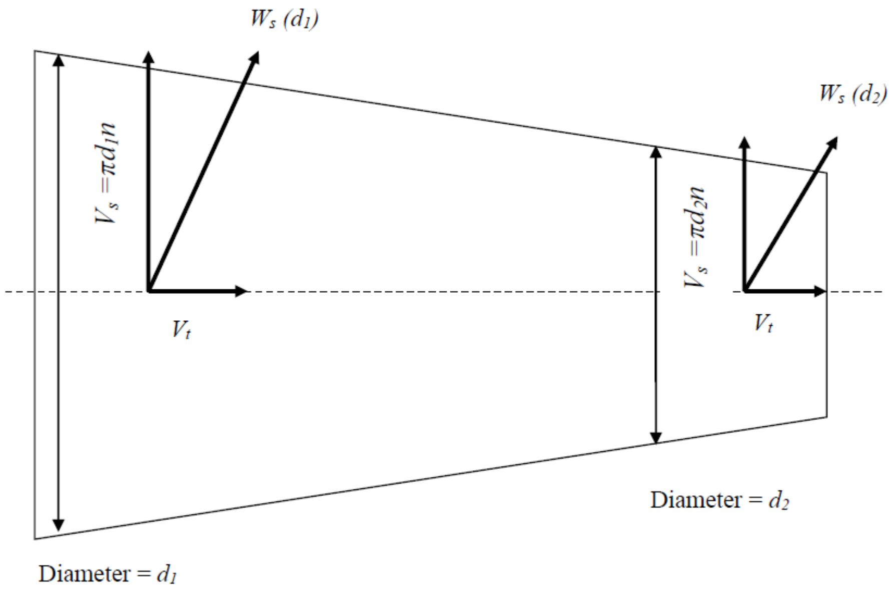
$$\mathbf{V_t \cos\theta \propto constant}$$

Note:

1. For drum-driven winder, θ is constant provided the ratio of Vt and Vs are constant. But if V_t is reduced (keeping V_s constant theoretically, which is possible if traversing mechanism is separate from groove drum), θ will also reduce and Cosθ will increase.
2. In spindle-driven machine, θ reduces (even when V_t is constant) as package diameter (d) increases

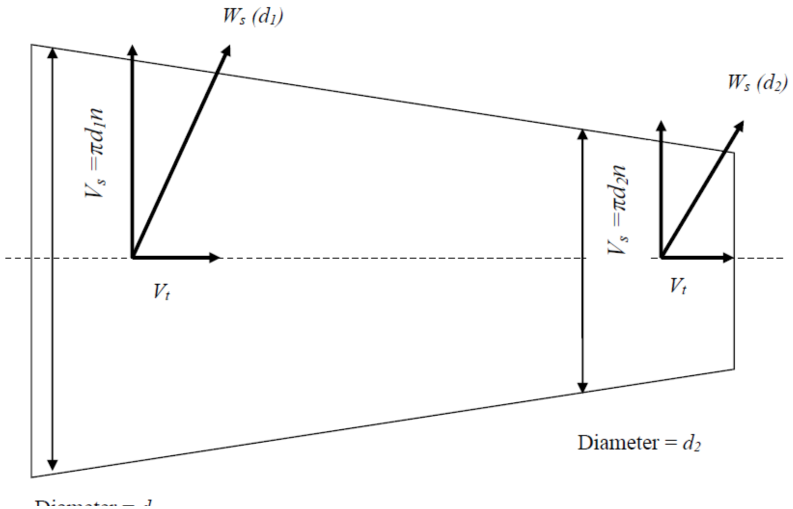
Conditions for Uniform Package (Cone) Building: Spindle-driven

In case of cone, the diameter of package reduces as the yarn traverses from the base to the tip. Therefore, situation becomes more complicated than the cheese winding. It is important to maintain the conditions so that the diameter in the base and diameter at the tip increases at the same rate. Surface speed of the cone is also less in the tip part as compared to that of base part.



Let w_1, v_1 and s_1 are the winding, traverse and surface speeds respectively at cone section diameter d_1. Similarly, w_2, v_2 and s_2 are the winding, traverse and surface speeds respectively at cone section diameter d_2. For the analysis, a small-time interval δt is considered

Conditions for Uniform Package (Cone) Building: Spindle-driven



Length wound per unit surface area at cone diameter $d_1 = \dfrac{w_1 t}{\pi d_1 v_1 \delta t}$

Length woundper unit surface area at cone diameter $d_2 = \dfrac{w_2 t}{\pi d_2 v_2 \delta t}$

For uniform increase in cone diameter, the boundary condition is

$$\frac{w_1 t}{\pi d_1 v_1 \delta t} = \frac{w_2 t}{\pi d_2 v_2 \delta t} \quad or \quad \frac{w_1}{w_2} = \frac{d_1 v_1}{d_2 v_2}$$

It is known that $\tan\theta = \dfrac{\text{Traverse speed}}{\text{Surface speed}} = \dfrac{v}{s}$

Therefore, $\tan\theta_1 = \dfrac{v_1}{s_1}$ and $\tan\theta_2 = \dfrac{v_2}{s_2}$

and $w_1^2 = s_1^2 + v_1^2$ and $w_2^2 = s_2^2 + v_2^2$

$$\text{So, } \frac{w_1^2}{w_2^2} = \frac{s_1^2 + v_1^2}{s_2^2 + v_2^2} = \frac{v_1^2\left(1 + \dfrac{s_1^2}{v_1^2}\right)}{v_2^2\left(1 + \dfrac{s_2^2}{v_2^2}\right)} = \frac{v_1^2(1 + Cot^2\theta_1)}{v_2^2(1 + Cot^2\theta_2)}$$

$$= \frac{v_1^2 Sin^2\theta_2}{v_2^2 Sin^2\theta_1}$$

From boundary condition we know that $\dfrac{w_1}{w_2} = \dfrac{d_1 v_1}{d_2 v_2}$

$$\text{So, } \left(\frac{w_1}{w_2}\right)^2 = \left(\frac{d_1 v_1}{d_2 v_2}\right)^2 = \frac{v_1^2 sin^2\theta_2}{v_2^2 sin^2\theta_1}$$

or $d_1^2 sin^2\theta_1 = d_2^2 sin^2\theta_2$ or $d \sin\theta = \text{constant}$

$$\tan\theta = \frac{\text{Traverse speed}}{\text{Surface speed}} = \frac{V_t}{\pi d n}$$

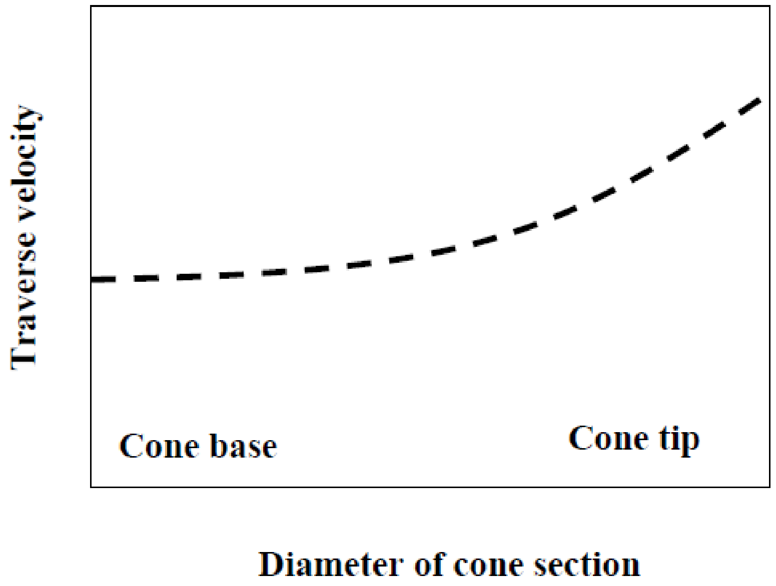
where d and n are package diameter and r.p.m. respectively

$$V_t \cos\theta = \pi d n Sin\theta$$

Conditions for Uniform Package (Cone) Building: Spindle-driven

Remarks:

1. For uniform increase of diameter, $d\sin\theta$ should be constant. Therefore, $V_t\cos\theta$ should be constant during one traverse from base to the tip of the cone.
2. As we move towards the tip, the d reduces, so θ increases. As θ increases, $\cos\theta$ reduces. So we need to increase V_t such that the $V_t\cos\theta$ remains constant



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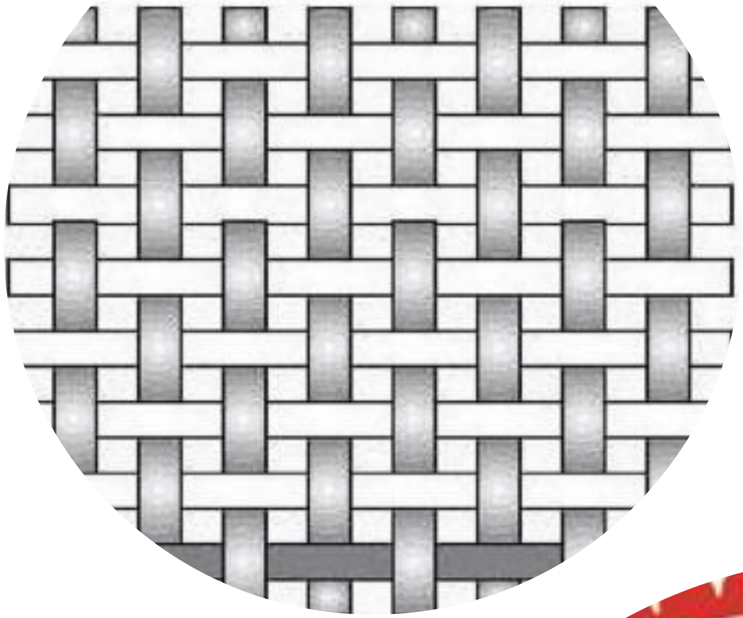

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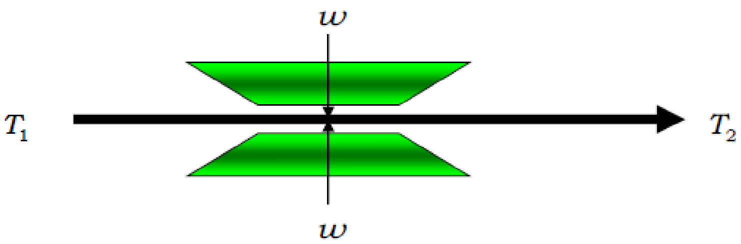
Yarn Tensioning: Why?

The primary objective of yarn tensioning is to build a package with adequate compactness

***As a rule of thumb, yarn tension in winding is around 1 cN/tex**

Types of Tensioning Device

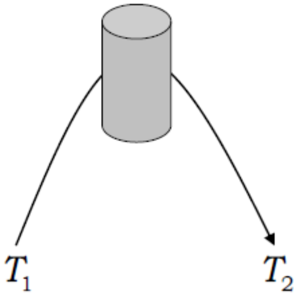
Additive type or disc type tensioner



The yarn is passed through two smooth discs one of which is weighted with the aid of small circular metallic pieces

$$T_2 = T_1 + 2\mu w$$

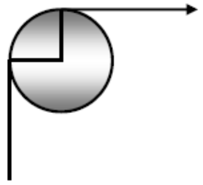
Multiplicative type tensioner



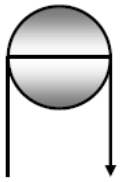
The yarn is passed round a curved or cylindrical element

$$T_2 = T_1 e^{\mu\theta}$$

θ is the angle of wrap (in radian)



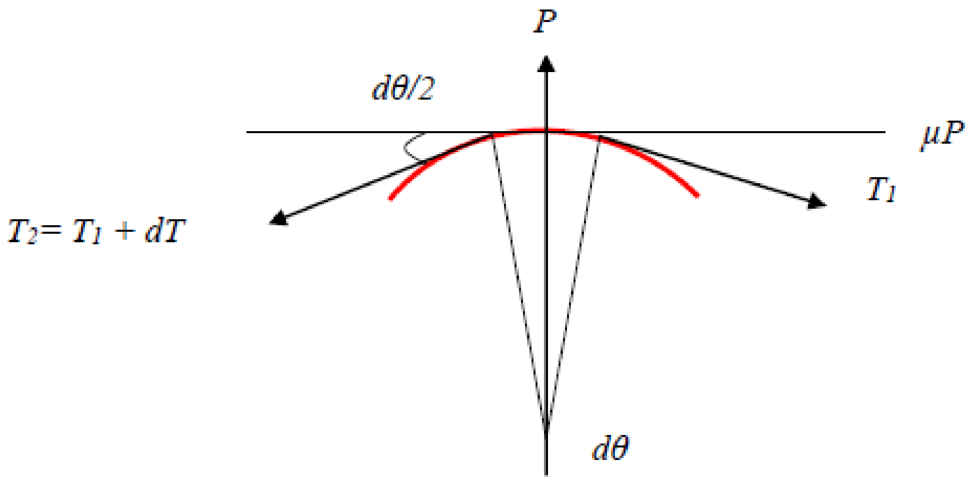
Angle of warp = $\pi/2$



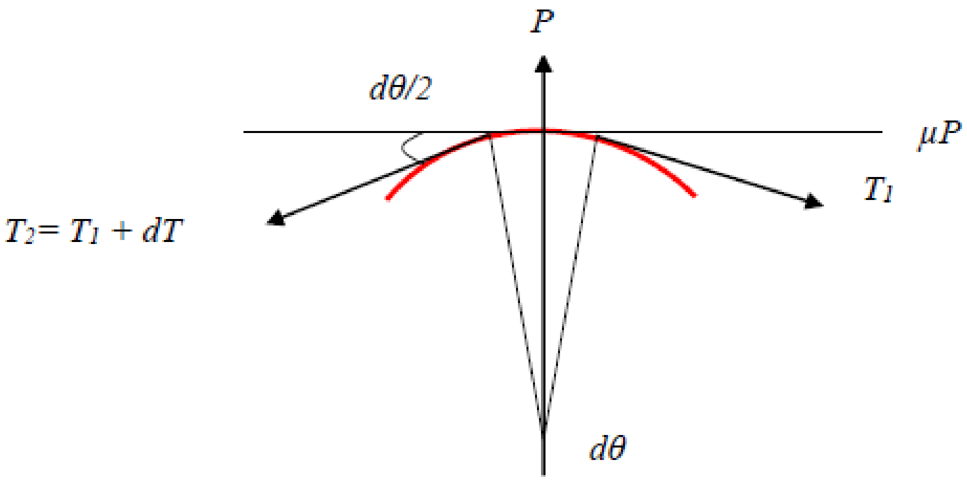
Angle of warp = π

Relation between Input and Output Tensions in Multiplicative Tensioner

The contact region between the curvature and yarn has created a small angle dθ at the centre of the assumed circle. The yarn tension in the input side is T_1 and tension in the output side is T_2. The difference in tension is dT. The difference between the horizontal component of T_2 and T_1 will balance the frictional resistance which will depend on coefficient of friction between the yarn and tensioner (μ) and the resultant vertical component of T2 and T1



Relation between Input and Output Tensions in Multiplicative Tensioner



For the vertical components

$$P = (T_1 + dT_1)\sin\frac{d\theta}{2} + T_1 \sin\frac{d\theta}{2}$$

$$\cong 2T_1 \sin\frac{d\theta}{2} \text{ (as } \frac{d\theta}{2} \text{ is small, } \sin\frac{d\theta}{2} = \frac{d\theta}{2} \text{ and product of } \frac{d\theta}{2} \text{ and } dT_1 \text{ can be ignored)}$$

$$\cong 2T_1 \times \frac{d\theta}{2} = T_1 d\theta \quad \textbf{(a)}$$

For the horizontal components

$$\mu P = (T_{1,} + dT_1)\cos\frac{d\theta}{2} - T_1 \cos\frac{d\theta}{2}$$

$$= dT_1 \cos\frac{d\theta}{2} \cong dT_1 \text{ (as } \frac{d\theta}{2} \text{ is very small, } \cos\frac{d\theta}{2} \approx 1) \quad \textbf{(b)}$$

Equate (a) and (b) to get $T_2 = T_1 e^{\mu\theta}$

Reversal Point at Cylindrical Package and Wind Angle

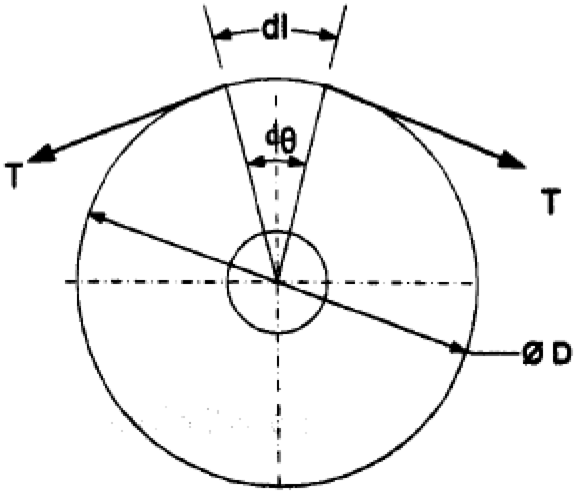
The problem of hard edges on cross wound packages is caused by the inability of the traversing mechanism to sharply reverse the direction of traverse at the edges of the package

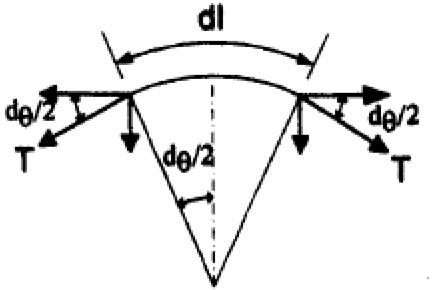
Two distributed loads act on the yarn at a reversal point on the package surface

- ❑ Normal load due to the friction between the yarn and the package surface
- ❑ Tangential load as a component of the yarn tension at the turn

The yarn reversal is in equilibrium until the radius of curvature ρ reaches its minimum value at the point of reversal. In this condition the product of normal tension load P and coefficient of fibre friction μ must equal the tangential load Q

α	-	wind angle	degree
α_{max}	-	maximum wind angle	degree
T	-	yarn tension	g
P	-	distributed normal load	g/cm
Q	-	distributed tangential load	g/cm
l	-	length of the yarn	cm
θ	-	radial angle	degree
φ	-	peripheral angle	degree
ρ	-	radius of curvature	cm
μ	-	coefficient of friction	-
ϵ	-	stroke ratio	-
D	-	diameter of the package	cm



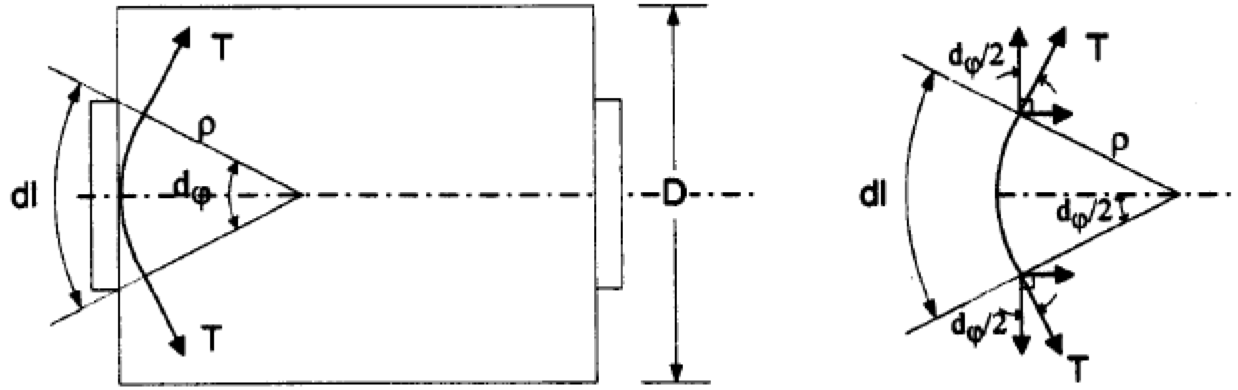


$\mu . P = Q$

Reversal Point at Cylindrical Package and Wind Angle

From the previous calculation set--------, For normal load $2T \sin(d\theta/2) = P.dl$ and $dl = D/2.\, d\theta$ and $\sin(d\theta/2) = d\theta/2$

So $P = 2T/D$



From the previous calculation set--------, For tangential load $2T \sin(d\phi/2) = Q.dl$ and $dl = \rho.\, d\phi$ and $\sin(d\phi/2) = d\phi/2$

So $Q = T/\rho$

But for ρ to be minimum $\mu 2T/D = T/\rho_{min}$

the minimum reversal radius depends on the radius of package and the fibre friction

$P_{min} = D/2\mu$

Reversal Point at Cylindrical Package and Wind Angle

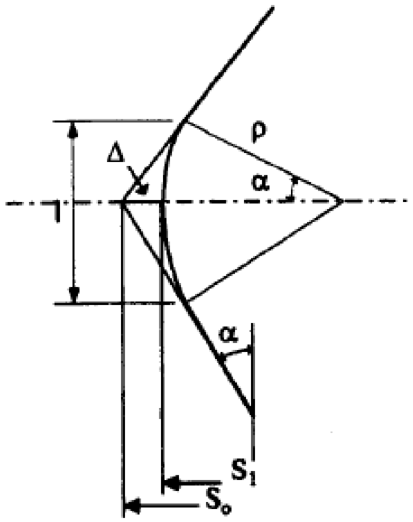
Yarn reversal is assumed to be a circular arc

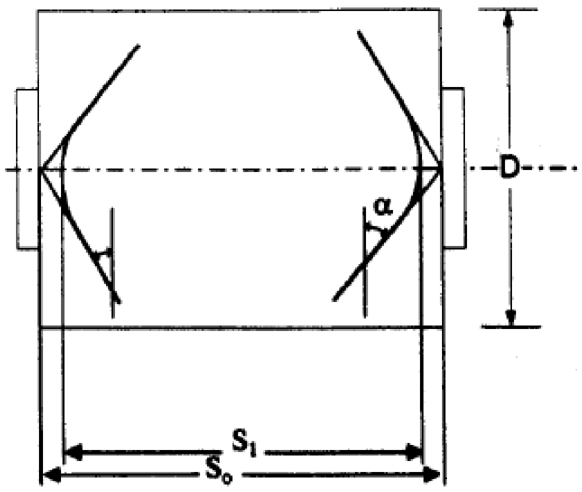
So, $\cos\alpha=\rho/(\rho+\Delta)$

The stroke ratio is a measure of the reduction of the traverse stroke. It can be defined as

$\varepsilon=S_1/S_o$

S_o - theoretical length of package
S_1 - actual length of package





$$\Delta=(S_o-S_1)/2= S_1/2.(1-\varepsilon)/\varepsilon$$

$$\text{So, } \rho=S_1/2[\cos\alpha/(1-\cos\alpha)][(1-\varepsilon)/\varepsilon]$$

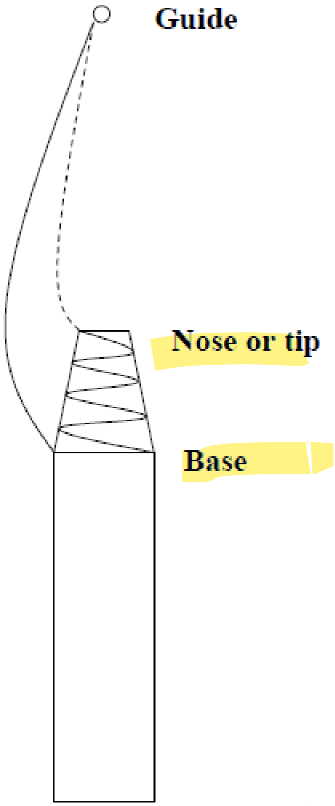
But for ρ to be minimum and a to be maximum

$$\mu=D/S_1[(1-\cos\alpha_{max})/\cos\alpha_{max}][\varepsilon/(1-\varepsilon)]$$

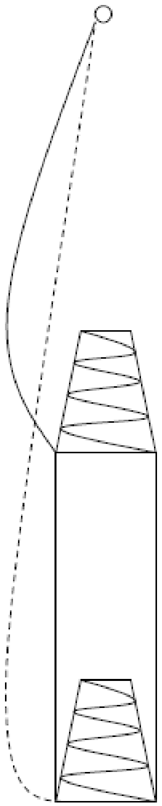
It shows that the maximum wind angle is a function of yarn friction, actual length of package, diameter of the package and stroke ratio

Tension Variation During Unwinding

During the unwinding of yarns from cop build packages (ringframe bobbin, pirn etc.) short term and long-term tension variation is noticed. Short term tension variation arises due to the movement of the yarn from the tip to the base and vice versa. On the other hand, long term tension variation occurs due to the change in height of the balloon formed between the unwinding point and the yarn guide



Short term



Long term

Padfield's empirical relation-

Unwinding tension= $mv^2[C1+C_2(H/r)^2]$

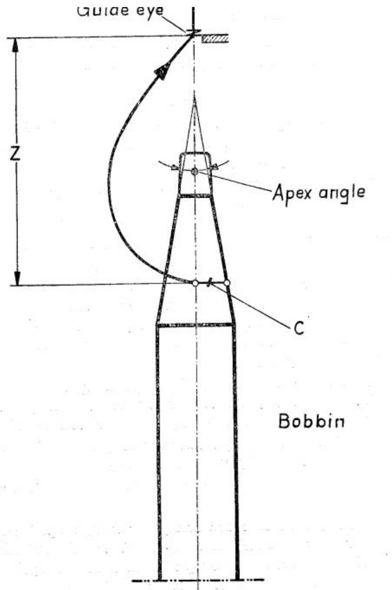
H is balloon height

r is package radius (varies between tip and base)

m is mass per unit length of yarn

V is unwinding speed

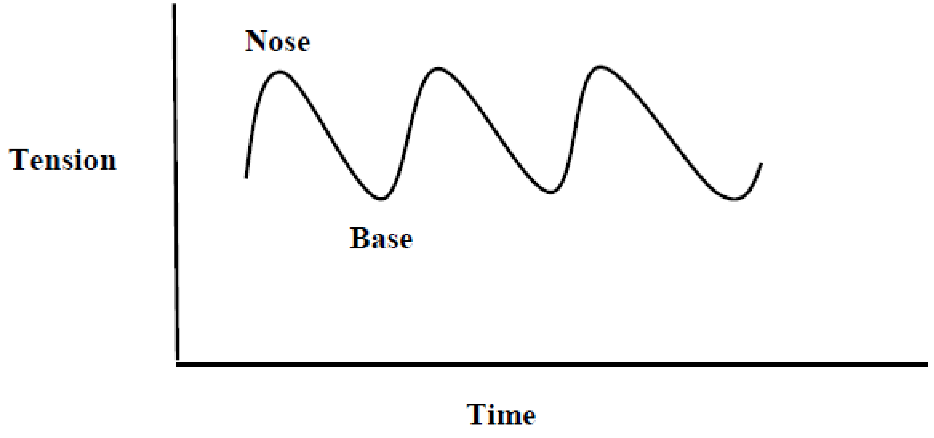
C_1 and C_2 are constants dependent upon yarn count climactic condition, apex angle etc.



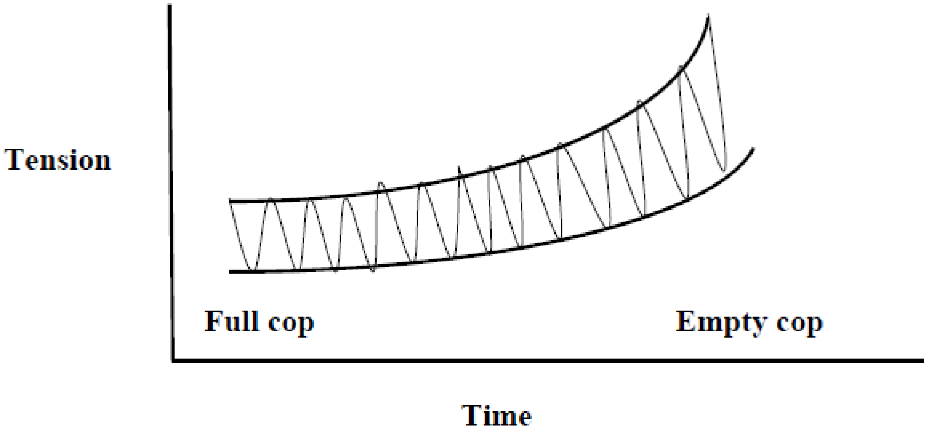
Tension Variation During Unwinding

Unwinding tension= $mv^2[C1+C_2(H/r)^2]$

Stronger function of r than H



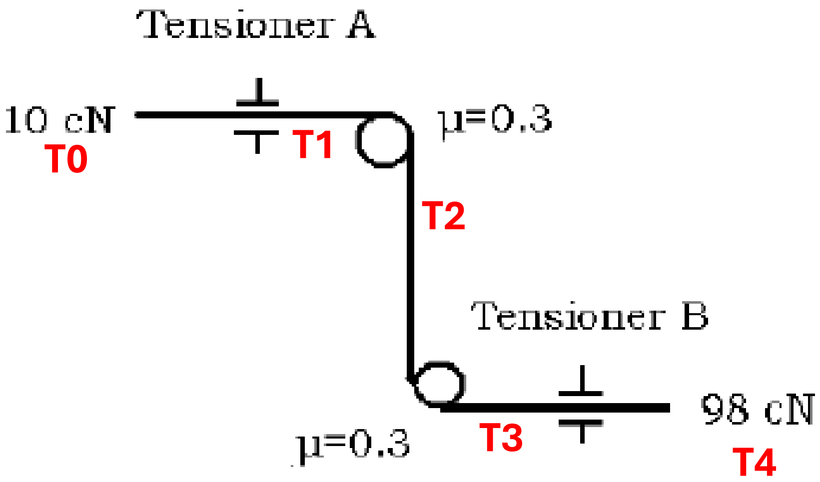
over a long period of time, successive conical layers of yarns are removed from Pirns and thus the conical section of yarns move towards the base of the pirn. Therefore, the balloon height increases resulting in progressive increase in mean unwinding tension



Tension Variation During Unwinding

Numerical Example

1. The tensioning system shown in Figure is being used in a winding system. The input and output tensions are 10 cN and 98 cN respectively. If disc (additive) type tensioners A and B are identical then calculate the weights used in tensioners A and B.



To solve, follow the red fonts in the image

T0 and T4 are given
T1/T0- additive
T2/T1- Multiplicative
T3/T2- Multiplicative
T4/T3-Additve

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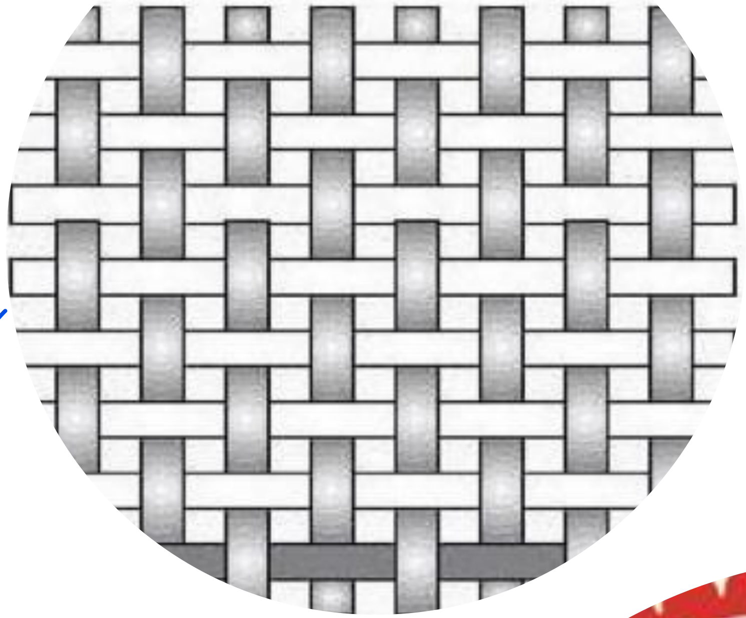

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Yarn Clearing: Objectives

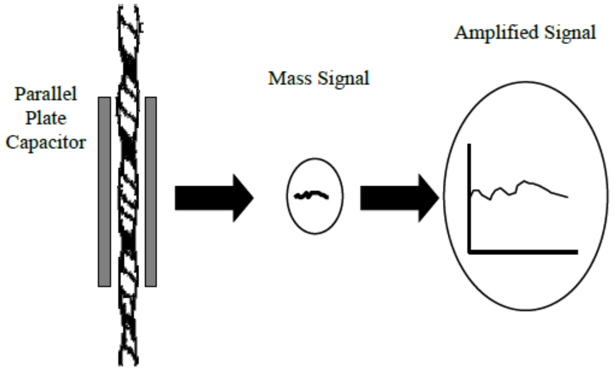
The objective of yarn clearing is to remove objectionable faults from the supply package

Can we clean all the faults?

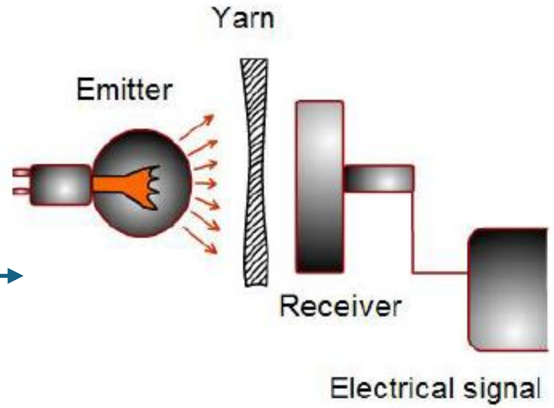
- Removal of yarn faults during winding is associated with the machine stoppages which reduces the machine efficiency
- When a yarn fault is removed, the yarns are joined again by the knotting or splicing operation which actually introduces a new blemish (we are not going to have the same strength as the original yarn)

How can we do it?

- Using capacitance



- Using optical measurement



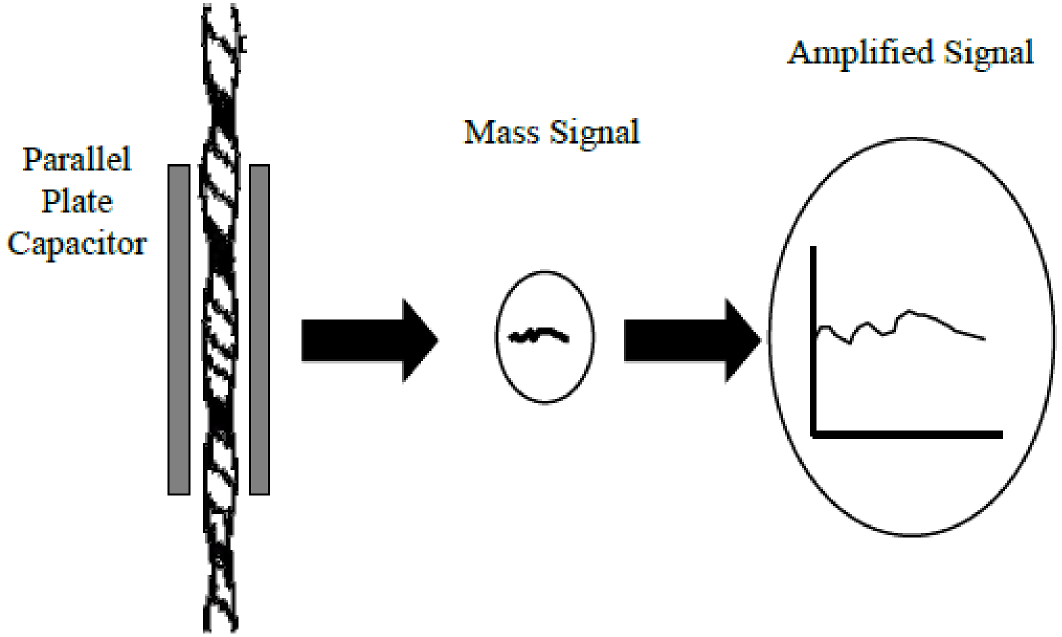
Yarn Clearing: Capacitive Measurement

The yarn is passed at a constant velocity through two parallel plate capacitors

Capacitance= $C= \varepsilon A/d=\kappa\varepsilon_0 A/d$

where A is the area of the places, d is the distance between the plates, ε is the permittivity of the medium present between the places, ε_0 is the permittivity of vacuum and κ is the dielectric constant of the medium

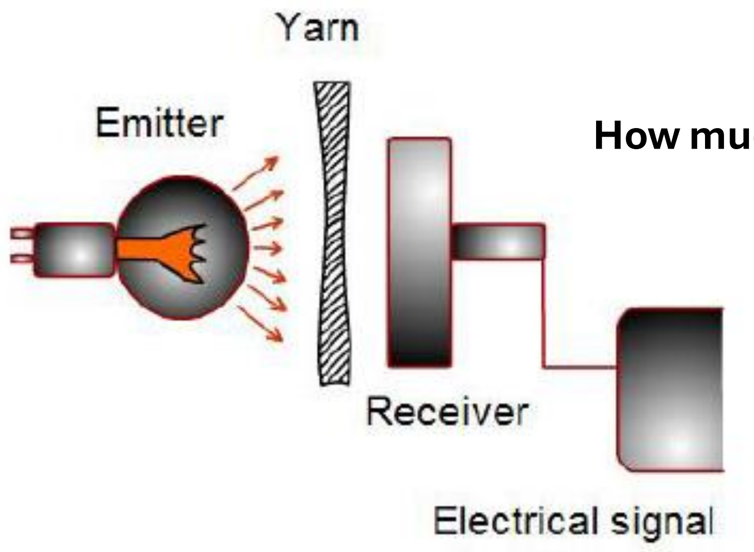
$$C = \frac{A}{\left(\frac{d_1}{\varepsilon_1}+\frac{d_2}{\varepsilon_2}\right)} = \frac{A\varepsilon_0}{\left(\frac{d_1}{k_1}+\frac{d_2}{k_2}\right)}$$



The dielectric constant of water is 80 whereas for textile fibres it is around 2-5 and for air it is nearly 1. Thus, the measurement is highly sensitive to the presence of moisture and therefore conditioning of samples in standard atmospheric conditions is of paramount importance

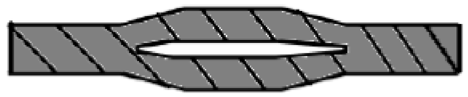
Yarn Clearing: Optical Measurement

The emitter emits light, and the receiver detects it and converts to proportional electrical signal. The light received by the receiver will obviously depend on the diameter of the yarn passing between emitter and receiver



How much deviation in measurement can we tolerate?- Mass is proportional to diameter^2

Although capacitance-based measurement is more accurate, if the fault is a low twisted region or a hole within the yarn structure and still exhibits same mass per unit length, capacitance type testers will not detect the yarn irregularity although there is a deviation in diameter that can produce fabric defects.



Yarn Imperfections

These blemishes occur very frequently in the spun yarns. However, they do not pose serious threat to the subsequent processes or fabric appearance. Frequently occurring faults are measured by yarn unevenness testers and expressed by the frequency of occurrences per km.

1) Thick places (mass exceeds by at least + 50% of the nominal mass)

2) Thin places (mass is lower than by at least - 50% of the nominal mass)

3) Neps (mass exceeds by + 200% of the nominal mass with reference length of 1 mm)

Yarn Faults

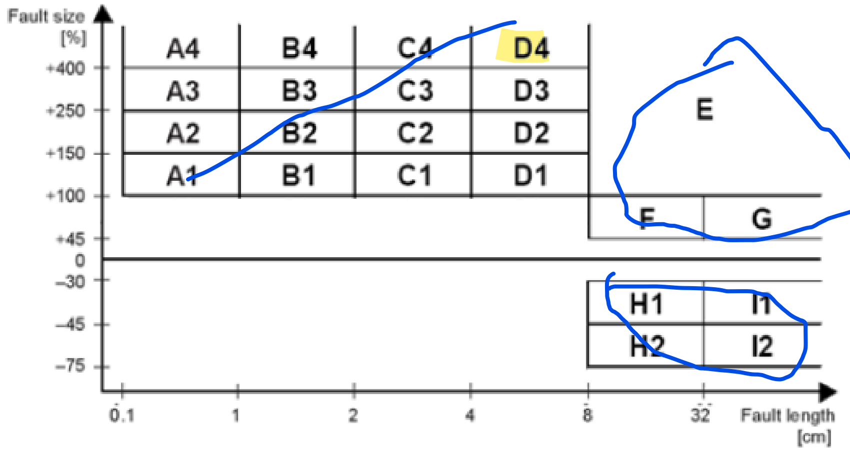
Yarn faults are seldom occurring mass variation in the yarn. They can adversely affect the running performance of the loom due to frequent breakage. Besides they can severely damage the appearance of the fabric. Yarn faults generally expressed by the number of occurrences per 100 kilometers.

The Classimat III faults are classified under three major categories:

a) Short thick faults: A1 to D4

b) Long thick faults: E, F and G

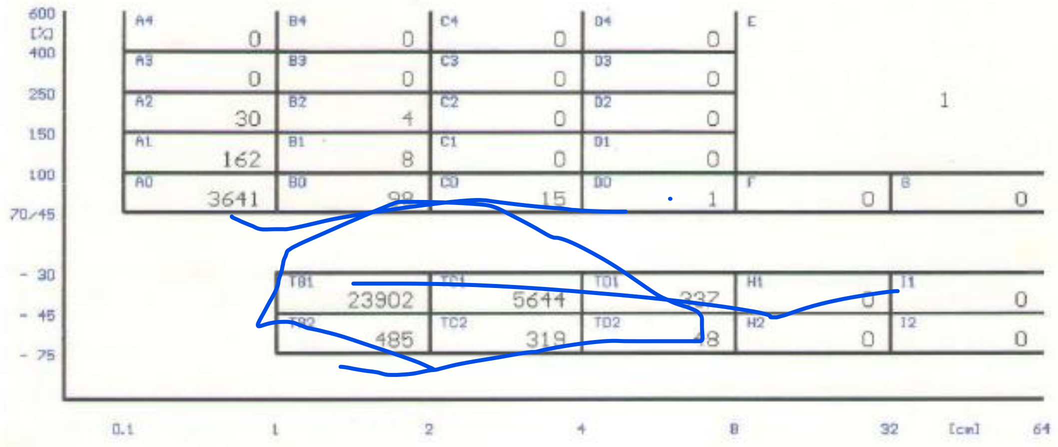
c) Long thin faults: H1, I1, H2, I2



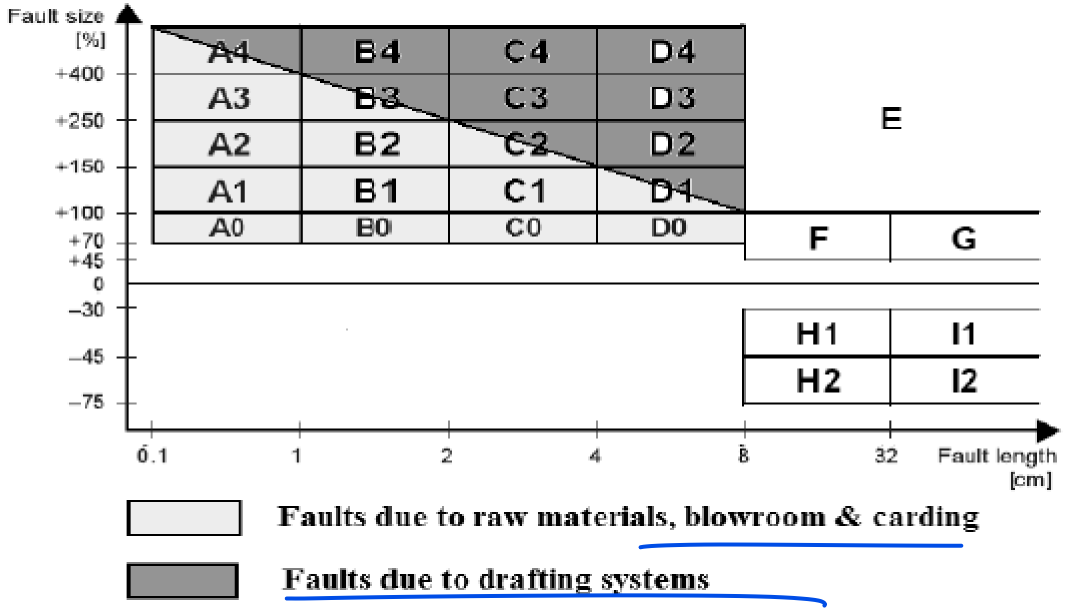
In addition to the 23 faults of Classimat III, there are 10 additional faults making up Classimat IV faults. These are as follows:

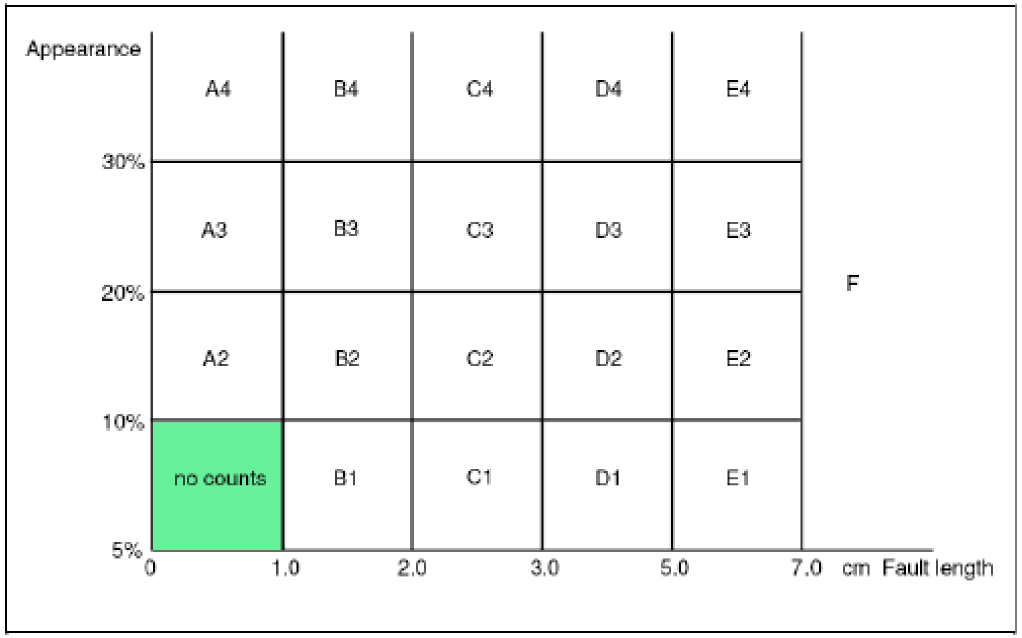
a) Very short thick fault (A0, B0, C0 and D0)

b) Short thin faults (TB1, TC1, TD1, TB2, TC2, TD2)



Yarn Faults

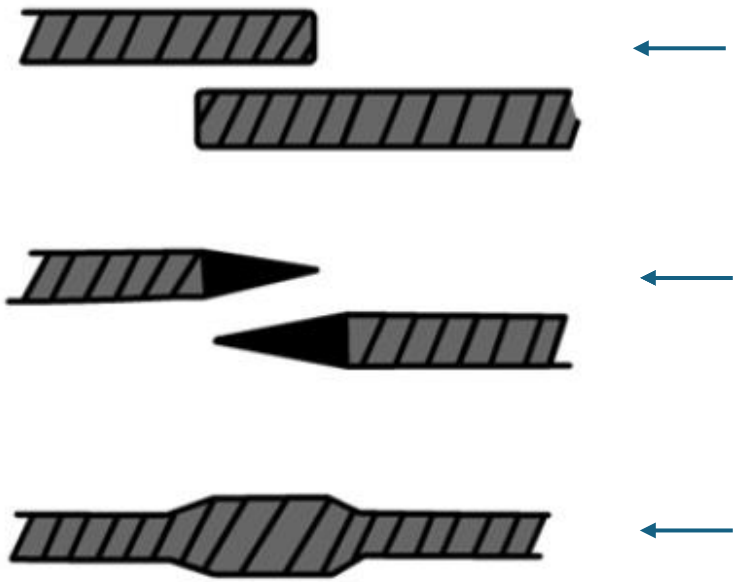




Identifying foreign fibres using Uster Quantum 2 (image analysis)

Splicing

Splicing is the process by which the two ends of yarns are joined



Robotic arms aided with air suction bring two ends of the yarns inside the splicing chamber

↓

compressed air is jetted to create turbulence inside the chamber so that the yarn is untwisted

↓

Some fibres are removed from the yarn ends to create wedge shape.

↓

Jetting of compressed air is done again to twist the two superimposed ends of yarns

$$\text{Retained splice strength (\%)} = \boxed{\frac{\text{Strength in spliced yarn}}{\text{Strength in original yarn}} \cdot 100}$$

$$\text{Splice breaking ratio} = \frac{\text{No of breaks in splice zone } (\pm 1 \text{ cm})}{\text{Total number of tests}}$$

Higher retained splice strength (85-90%) and lower splice breaking ratio imply good splicing performance

Splicing

The performance of a splicer is also evaluated by the parameters like clearing efficiency and knot factor (also known as splice factor)

$$\text{Clearing efficiency} = \frac{\text{Nunber of objectionable faults removed}}{\text{Total number of objectionable faults in yarn}} \times 100$$

$$\text{Knot factor} = \frac{\text{Total number of yarn clearer related breaks}}{\text{Number of objectionable faults removed}}$$

Higher clearing efficiency and lower splice factor (close to 1) signifies desirable performance of a splicer

Yarn Winding for Package Dyeing

Yarn packages intended for dyeing should have certain characteristics to facilitate uniform dyeing within and between the packages-

- ❑ For cotton yarn, the density of package should be around 0.35-0.40 g/c.c (Low density will ensure better penetration and flow of dye liquor across the yarn layers)
- ❑ Density variation within and between the packages should be less than ± 2.5%
- ❑ Dye package outer diameter variation should be ± 1mm

Some basic issues:

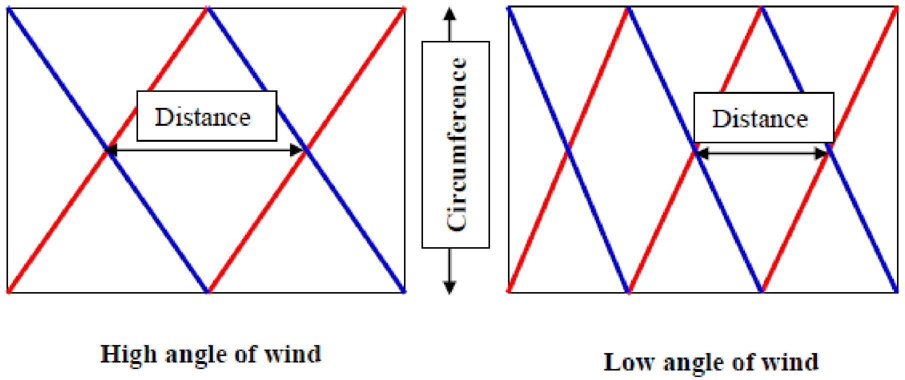
- ❖ Drum-driven random winders are not preferred for packages intended for dyeing due to patterning problem which may increase the package density drastically
- ❖ For precision winder, the angle of wind reduces as the package diameter increases. Thus, the package density increases towards the outer side of the package

Hence, digicone winders are the best for package dyeing

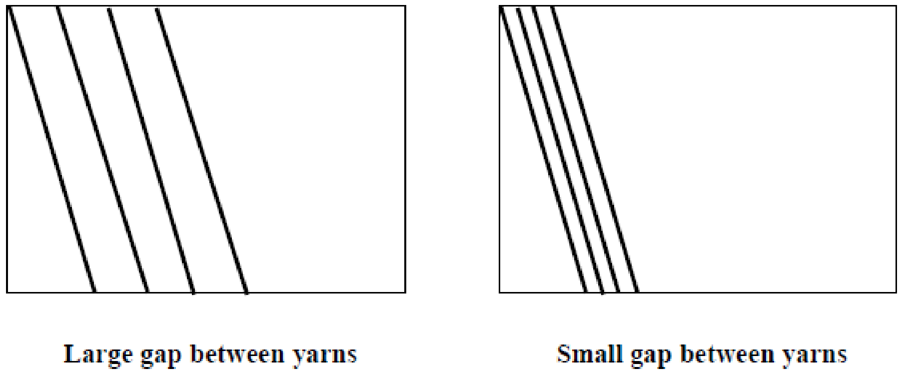
Yarn Winding for Package Dyeing

The density of the package can be varied by following ways:

- Changing the angle of wind
- Changing the distance between neighboring yarns within a layer
- Changing the pressure between the package and drum
- Changing the winding tension



Angle of wind and package density



Gap between yarns and package density

Fabric Manufacturing I (TXL231)

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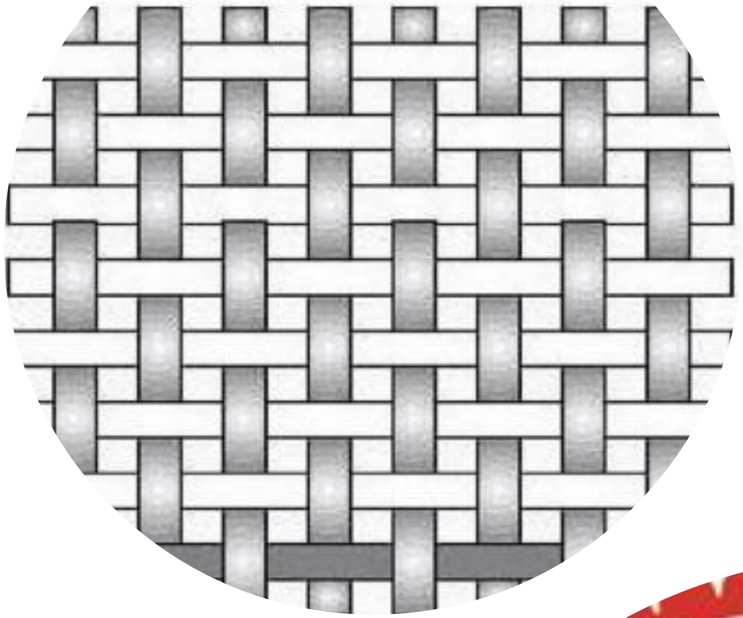
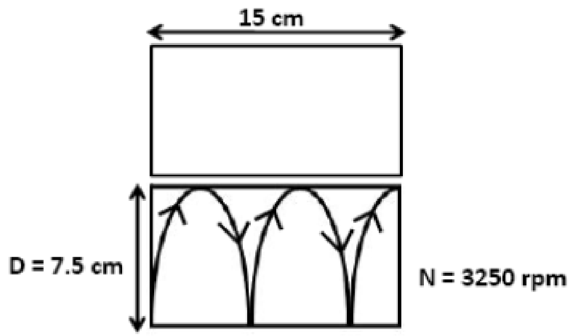


P1. The empty diameter of a spindle-driven cylindrical package is 5 cm. The spindle speed is 2000 r.p.m. and traverse velocity is 100 m/min. Determine:

a) Winding speed and angle of wind at the start

b) Winding speed and angle of wind when package diameter becomes double

P2. A cheese of 150 mm traverse length is wound on a rotary traverse machine equipped with 75 mm diameter drums of 2.5 crossings. Calculate the winding speed and coil angle if the drum rotates at 3250 r.p.m.

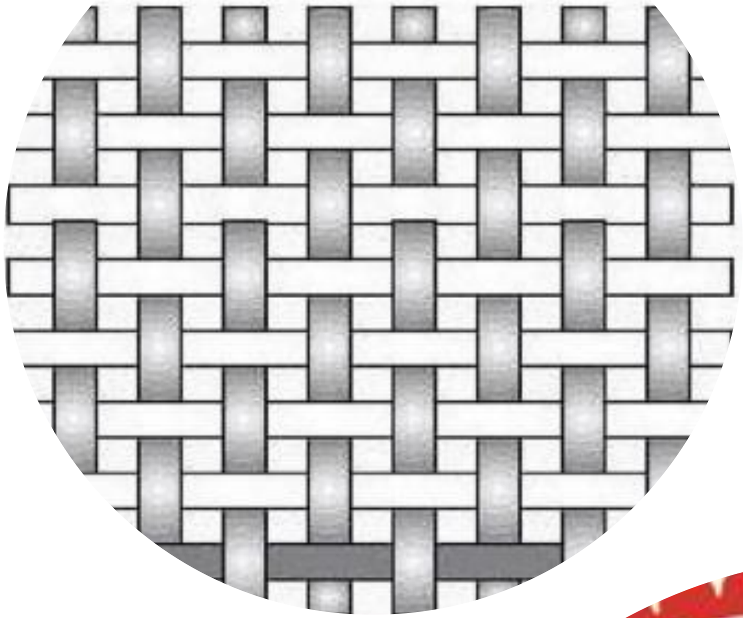


P3. What is the nearest value of traverse ratio to 3 to prevent patterning in a cheese when the diameter is 5 cm? The yarn is made up of cotton fibre and the count is 20 Ne.

P4. a) For a spindle-driven winder when the package diameter is 10 cm the wind angle is 200. Determine the angle of wind when package diameter is 15 cm.

b) In a drum-driven winder the angle of wind is 30°. The drum having 5 cm diameter makes 5 revolutions for one double traverse. Calculate the length of the winding drum.

Fabric Manufacturing I (TXL231)



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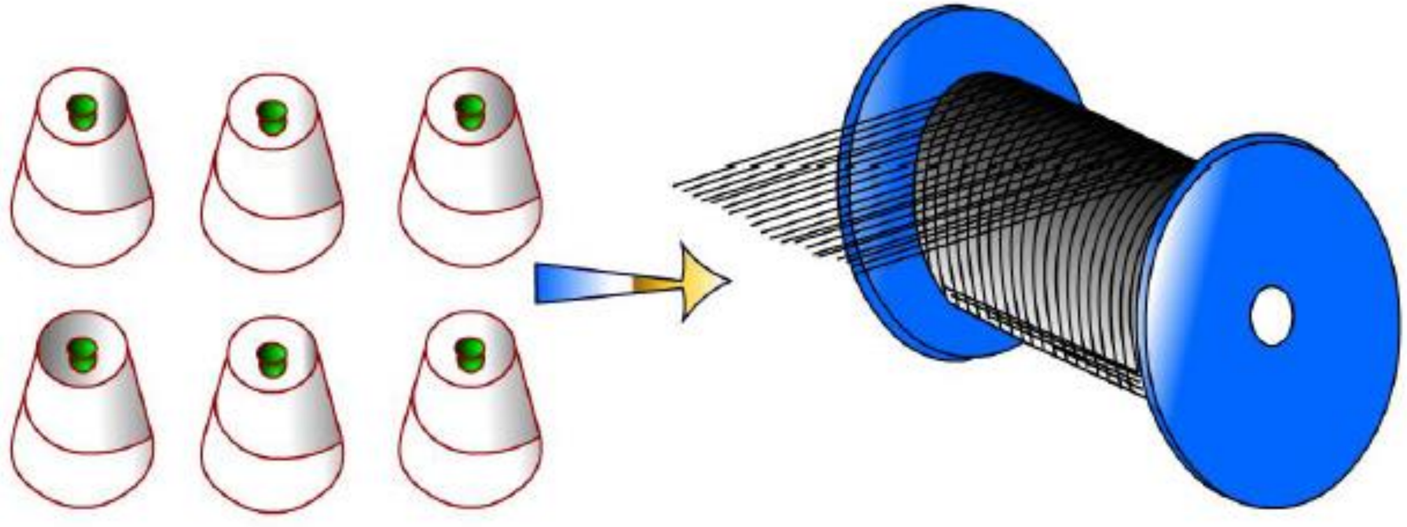
Warping: Objectives

The objective of warping process is to convert the yarn packages into a warper's beam having desired width and containing requisite number of ends



The yarns are would on the warper's beam in the form of a sheet composed of parallel bands of yarns each coming out from a package placed on the creel

Warping: Objectives

Let us take the following hypothetical example to understand the various options of warping process

- Assume that a piece of woven fabric of 5 m width and 1000 m length is to be produced from warp yarn of 10 Tex arranged 20 yarns per cm in the fabric. This would necessitate production of a beam in which 10,000 yarns are arranged parallel to each other in a sheet form.
- The length of this sheet must be somewhat higher than 1000 m to account for the crimped path of warp in the final fabric as well as wastages during weaving and contraction of fabric during subsequent relaxation processes.

Let contraction of grey fabric during relaxation process = 6%
Let warp crimp in fabric = 5.5%
Let wastage of warp during conversion of beam to fabric = 0.001%

Warping: Objectives

So, based on the previous calculations-

- Length of fabric- 1060 m
- Warp yarn- 10000, each of length 1118 m with wastage count of 1.12 m and that makes them of length 1119.2 m or 1120 m
- Yarn- 10 Tex (10 g/1000 m)
- Warp sheet weight- 112 Kg (10 x 1.12 x 10000/1000 kg= 112 kg)
- If a 2 kg cone contains 10 Tex yarn of length 200,000 m of yarn, then we need 56 cones

BUT!! 56 cones= 56 Ends! In order to generate 10,000 ends from 56 cones, one has to take out 1120 m from each cone in the form of a sheet and then break the yarns from the cones and take out another 1120 m in the form of a sheet and **repeat this process 178.57 (nearly 179) times**

Neither the 178.57 times is a whole number, nor the effort makes sense

Warping: Objectives

One feasible solution- **The number 10,000 has to be therefore broken up into combinations**

Number of cones (**A**) and the number of times (**B**) the yarn has to be broken from a cone with each cone containing **l** m yarn weighing **g** grams.

The possible combinations {A, B, ℓ, and g} are

Very difficult as a very large number of cones each containing a very small quantity of yarn would be required (Case I)

{10,000, 1, 1200, 12},

{5000, 2, 2400, 24},

{2000, 5, 6000, 60},

{1000, 10, 12,000, 120},

{500, 20, 24,000, 240},

The number of times the yarn has to be broken is reasonably small (Case II)

{250, 40, 48,000, 480},

{100, 100, 120,000, 1200}, and

{50, 200, 240,000, 2400}.

Reasonably small number of cones each of commercially standard dimensions(Case III)

Warping: Objectives

Reasonably small number of cones each of commercially standard dimensions(Case III)

{50, 200, 240,000, 2400}

The manufacturer knows that the order is not going to get repeated and would like to complete those cones (let's call them special fabric)

Sectional warping

The number of times the yarn has to be broken is reasonably small (Case II)

{500, 20, 24,000, 240}

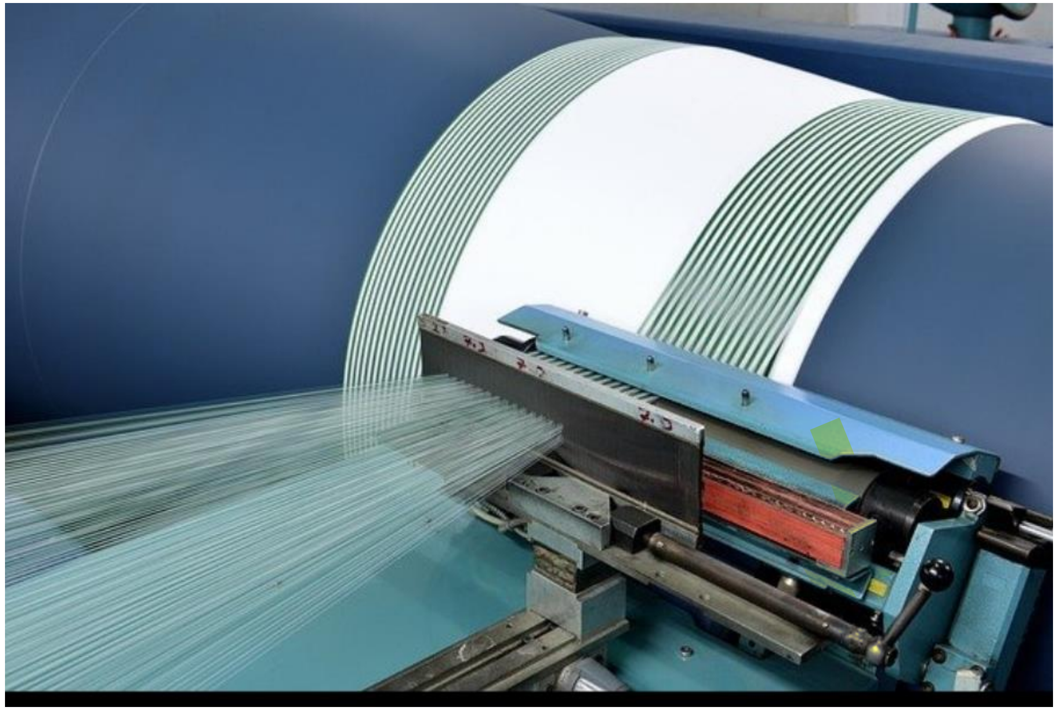
In case cones of 10 tex yarns, cones can be employed either for production of a sufficiently large number of such fabric rolls, say 10 or more, or for production of other beams for which the chosen combination applies (let's call them regular fabric)

No need to keep an inventory of partially consumed cones as cones containing only 240 g material are not normally produced in the manufacturing sector

Beam warping

Warping: Beam and Sectional

Beam warping



Sectional warping

Warping: Requirements

Quality of good warp

- Uniformly strong
- Uniform in cross-section
- Uniform warp tension
- Uniformly sized
- Less hairy and clean

Requirements of warping

- The tension of all wound ends must be uniform
- Warping process should not disturb the mechanical and physical properties of yarns
- The yarns in the sheet should be in a uniform spacing

Warping process involves

- Cone from winding
- Creel
- Control system
- Reed
- Measuring device
- Winding on beam

Warping: Creel and its types

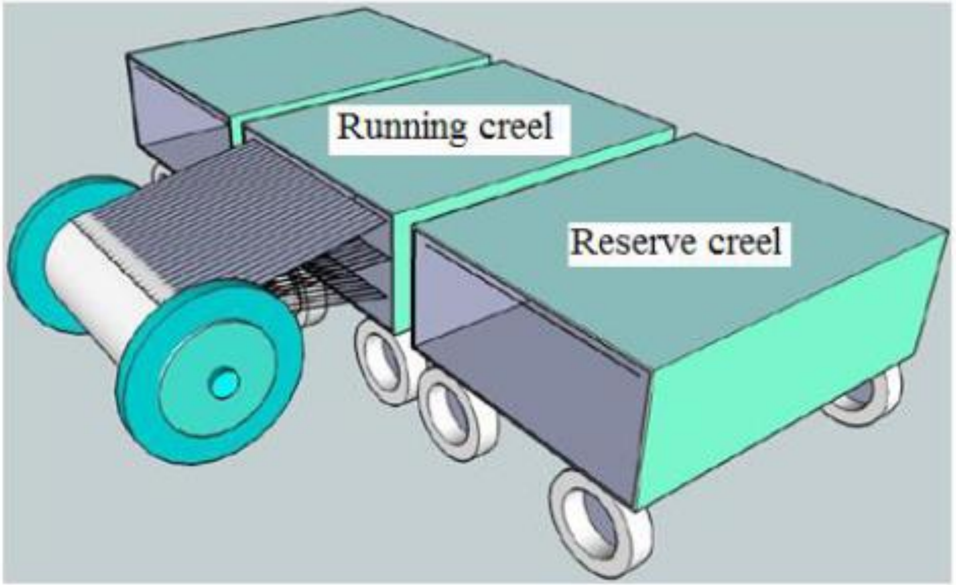
- Single end creel
- Magazine creel
- Traveling or multiple package creel

A creel is a three-dimensional assembly of pegs. Each peg is designed to grip the inside wall of the shell of a cone securely and be strong enough to support a cone in space. As yarn from a cone is withdrawn around its nose, a balloon is formed that is made to pass through a yarn guide, a tensioning system, and a thread detector (broken thread stop motion), all mounted on the frame of a creel.

Warping: Creel and its types

Single end creel: In single end creel, one position of the creel is used for one end on the warper's beam.

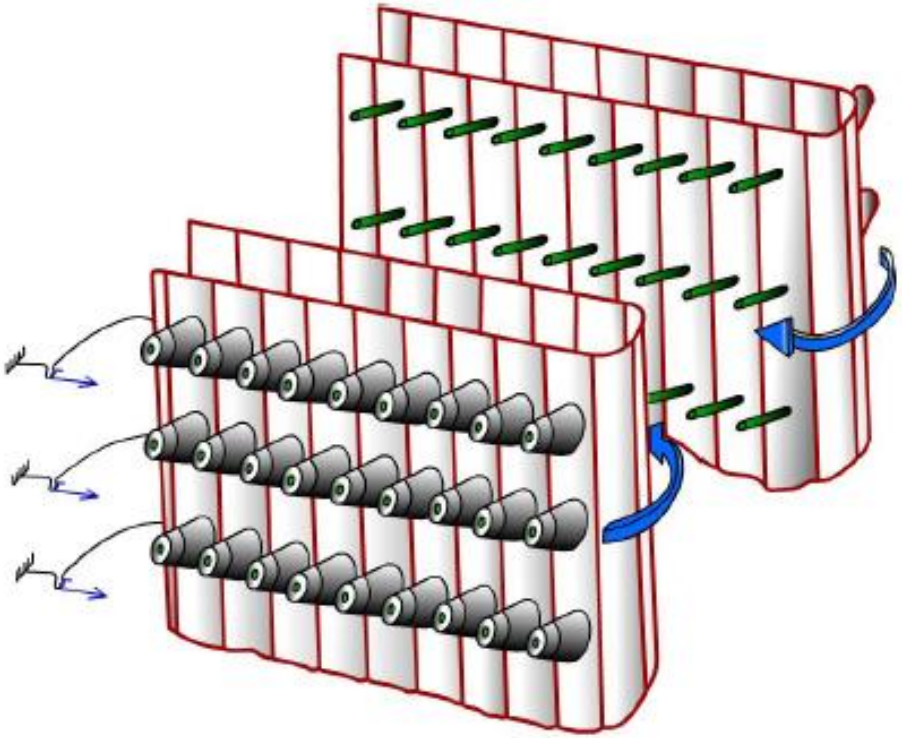
- ❑ Two types namely truck creels and duplicated creels
- ❑ Truck creel-when the packages from the running creel are exhausted, it is moved sideways, and the reserve creel moves into the vacant space



Warping: Creel and its types

Travelling or Swivelling creel: the pegs (package holders) with full packages can move from inside (reserve) position to the outside (working) position when the running packages are exhausted.

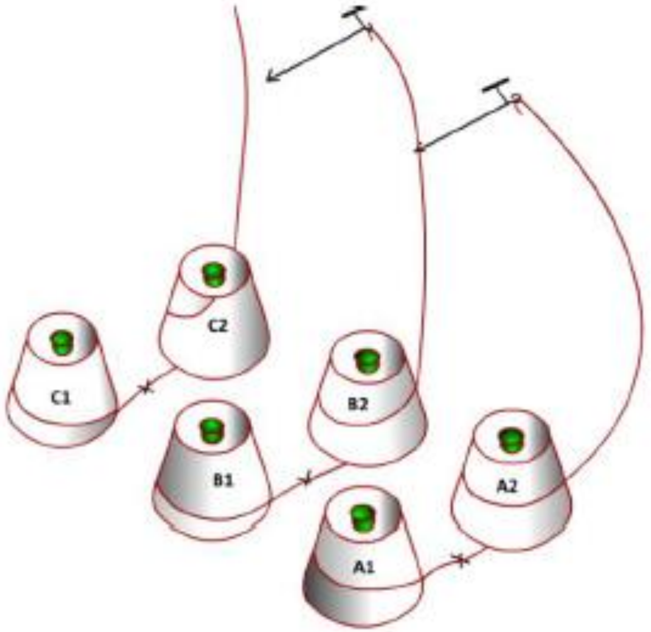
- Considerable time is saved
- The operator replaces the exhausted packages with full packages when the machine is running.



Warping: Creel and its types

Magazine creel: the tail end of yarn from one cone is tied with the tip of the yarn of another neighbouring cone.

- When the first cone is exhausted, the transfer of yarn withdrawal to the second cone takes place automatically and machine does not stop
- The creeling time is eliminated which helps to improve the running efficiency of warping process
- Sudden change in unwinding position and tension variation associated with this, some of the yarns break during the transfer (known as transfer failure)
- The magazine creel has reduced capacity. If the creel has 1000 package holders, then the warp sheet can actually have 500 ends



Calculation for Warping Efficiency with Different Creels

Warping operation is being carried out with the following particulars:

- The yarn mass on full beam is 300 kg,
- number of ends is 500,
- yarn count is 30 tex,
- Warping speed is 1000 m/min,
- cone weight is 2 kg,
- end break rate 0.1/100 end/ 1000 m,
- time to repair a break is 0.5 min,
- Beam doffing time is 5 min,
- Creeling time is 45 min/ creel,
- Headstock change time is 3 min/ beam,
- transfer failure is 2%

The mass contributed by a single yarn = 300/500= 0.6 kg

The length of the warp sheet =0.6 x1000/30= 20 km = 20,000 m

Running time = 20,000/1000= 20 minutes

Creeling time = 45 minutes/ creel= 15 minutes/beam

In case of single end creel, this 45 minutes will be divided between three warper's beam as from one cone of 2 kg mass at least three beams will be made.

For duplicated creel, the headstock is moved in front of the new creel which is ready with full packages. So, no creeling time is considered. However, it needs the headstock moving time i.e. 3 minutes.

Number of breaks in warping= (500x 20000x 0.1)/(100 x 1000)=10

Repair time = Number of breaks × repair time per break =10 × 0.5 = 5 min=Time for repairing the transfer failure (2% of 500 ends)

This 5 minutes should be equally allocated among multiple warper's beam as from one cone of 2 kg mass at least three beams will be made. So, when the yarns of two cones are tied, six warper's beam can be made without any further creeling=0.83 min

Calculation for Warping Efficiency with Different Creels

Item	Calculation/ beam	Single-end (min)	Duplicated (min)	Magazine (min)
Running time	20000 yard sheet	20	20	20
Repair time	0.5 min/ break	5	5	5
Beam doffing	5 min/ beam	5	5	5
Creeling time	45 min/ creel	15	0	0
Headstock change	3 min/ headstock	0	3	0
Transfer failure	2 %			0.83
Total time		**45**	**33**	**30.83**
Efficiency %		**44.44**	**60.60**	**64.87**

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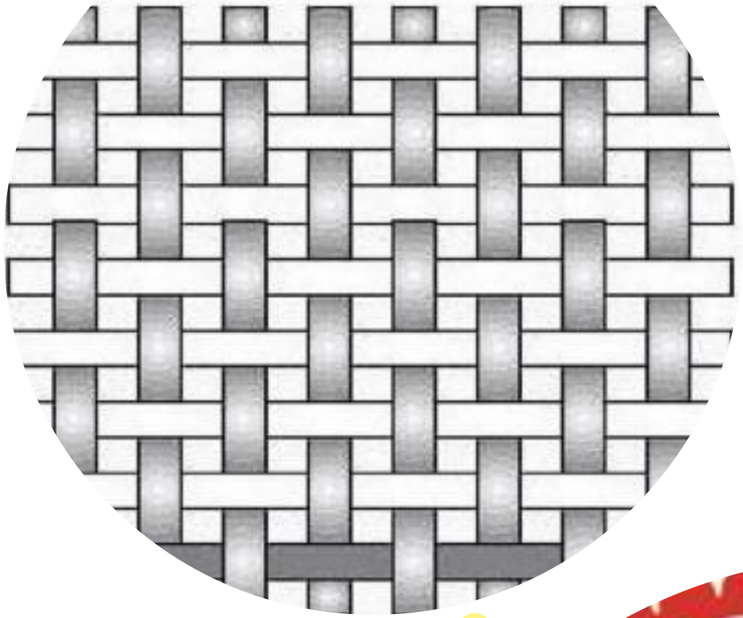
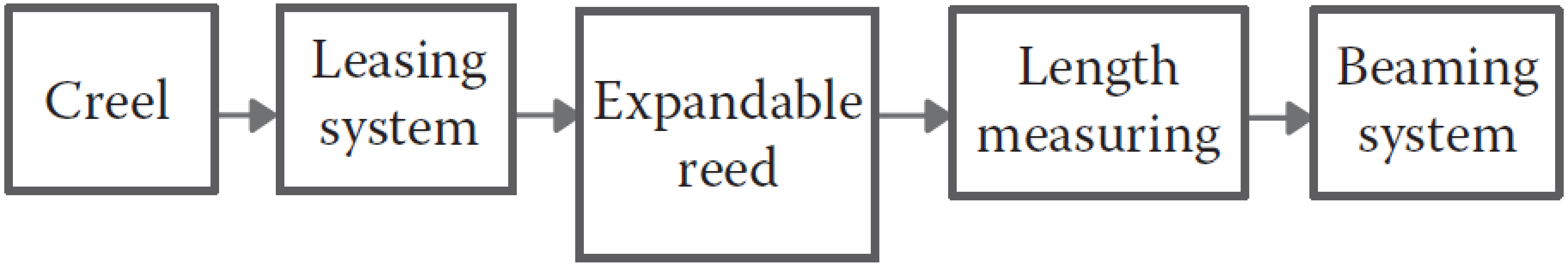
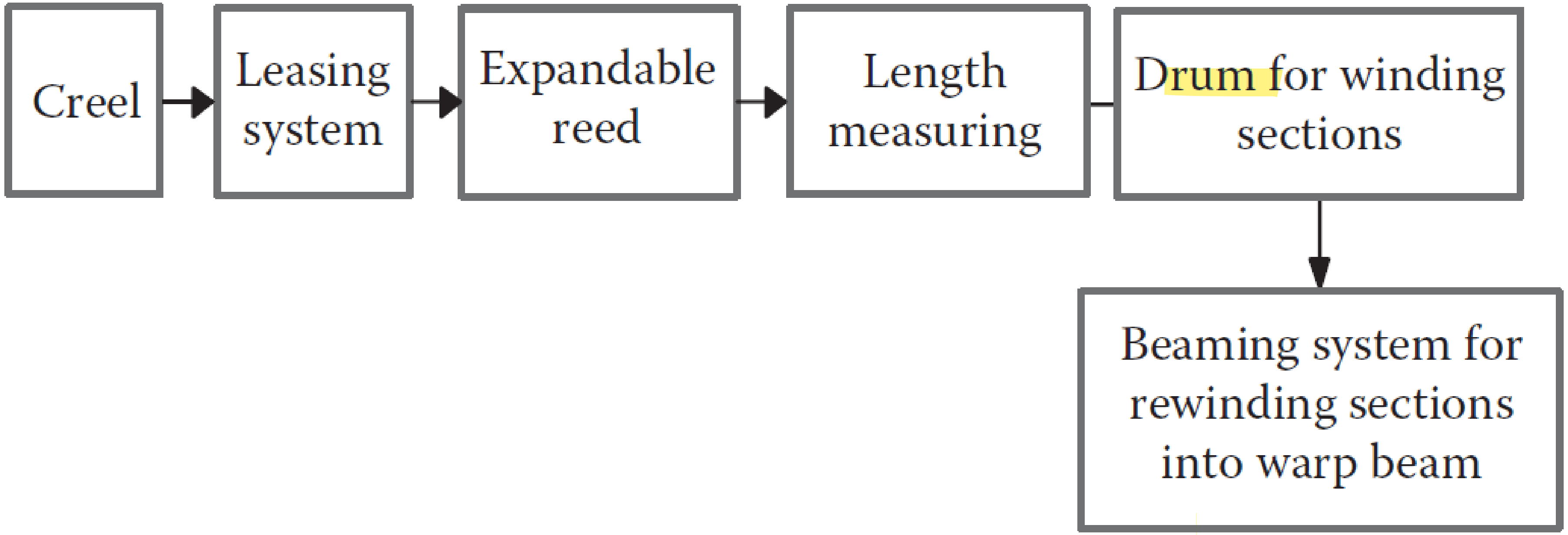


Warping: Steps

Beam Warping



Sectional Warping

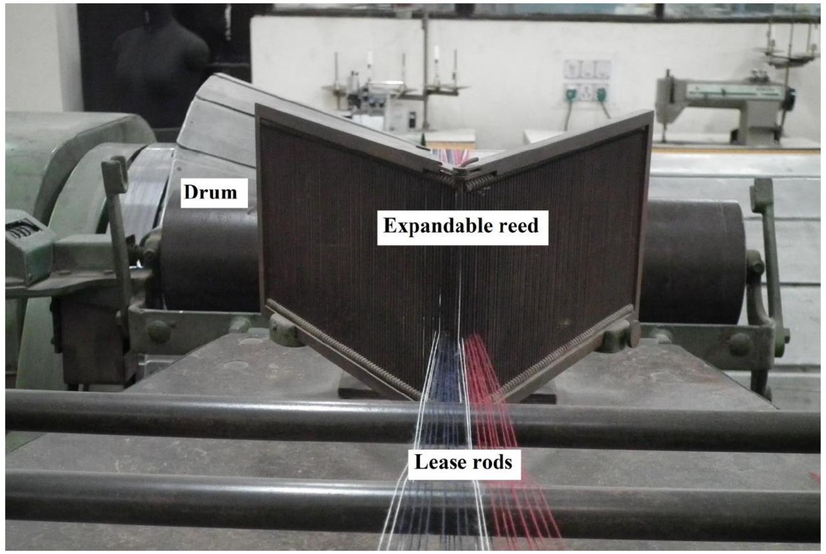


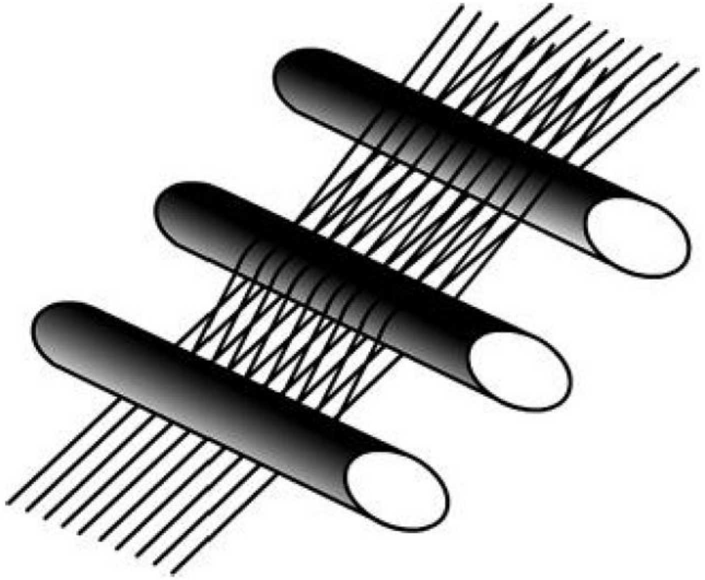
Warping: Creels

- Single end creel
- Magazine creel
- Traveling or multiple package creel

Warping: Leasing system

Leasing is a method of segregating yarns from neighboring ones and maintaining their location in a warp sheet

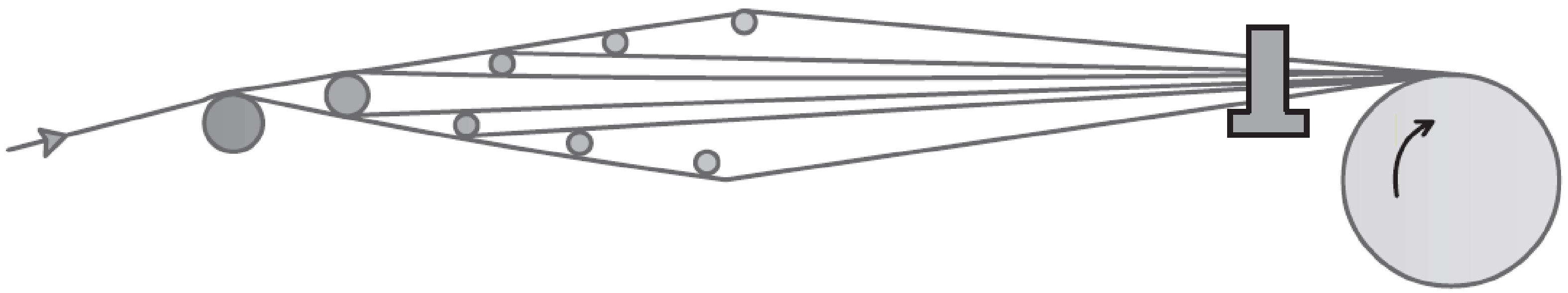




- Simple end-and-end leasing involves splitting a warp sheet into two layers of odd- and even-numbered ends
- A rod inserted between these two layers would show either the odd-numbered or the even-numbered yarns passing above the band or rod
- To create a neat crossover line, another rod or band is subsequently introduced between the two layers with the order reversed

Warping: Leasing system

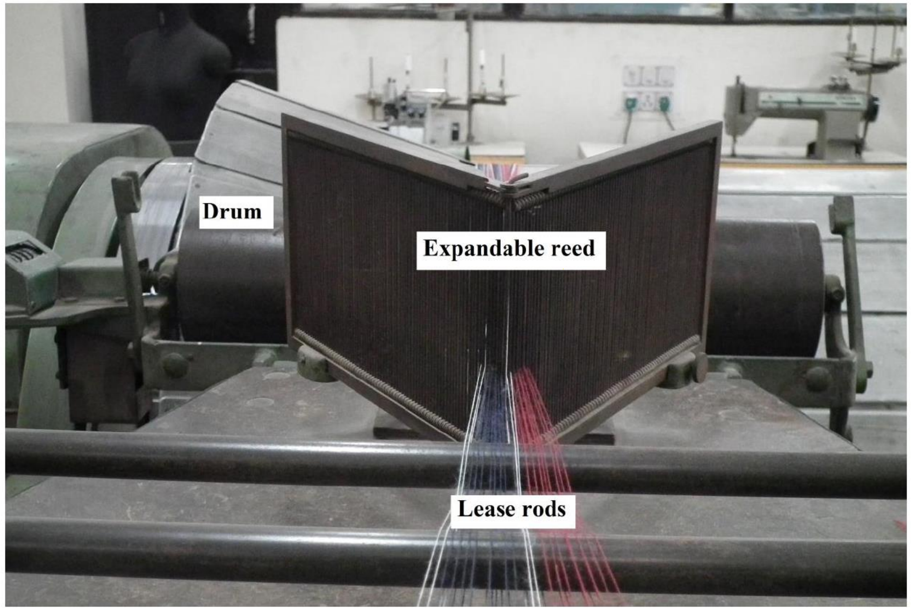
- A sized warp sheet is completely encased in size film and cannot be used in the subsequent process unless yarns are individualized
- To avoid any stress concentration of sized yarns, multiple leasing is resorted to in which the warp, depending on the closeness of yarns in the sheet, is split into multiple layers, say six or eight or 10



In case the warp needs no sizing, then a multiple leasing is not required, and end-and-end leasing would suffice

Warping: Expandable Reed and Length Measurement

A warp sheet from a creel converges into the expandable reed through the dents of which warp yarns pass. As the reed wires can be moved either closer to or away from each other, the distance between dents can be adjusted to the desired value of yarn spacing in the warp sheet



The two limbs of V shaped expandable reed can be expanded or collapsed as per the required spacing of ends

- The length of warp sheet in a beam is crucial from the point of minimizing wastage
- In its simplest form, the moving warp sheet is taken around a freely mounted roller whose angular displacement can be translated both into yarn speed and yarn length by a suitable electronic counting system

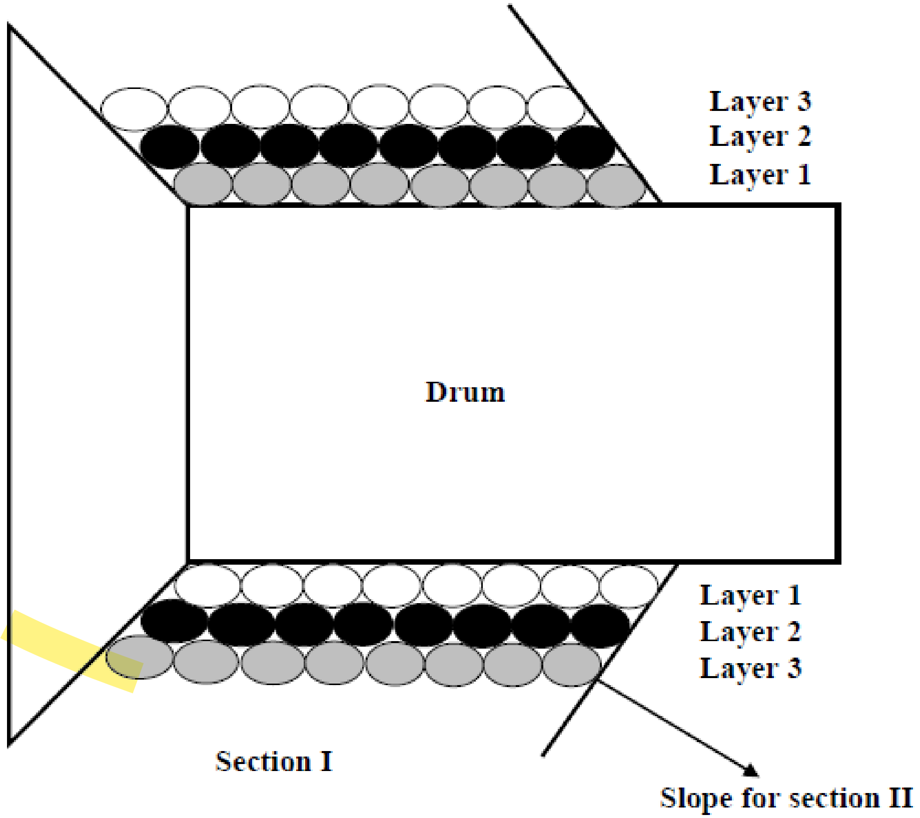
Warping: Sectional warping

- The drum on a sectional warping machine is a hollow cylinder with a conical flange on one end. The leading edge of a section of warp sheet is hooked on the drum surface at an appropriate location, and then, as the drum rotates, the section starts getting wrapped on the drum surface.

- Sectional warping is preferred over beam warping for multi-coloured warp. Here the entire width of the warping drum is not developed simultaneously. It is developed section by section.

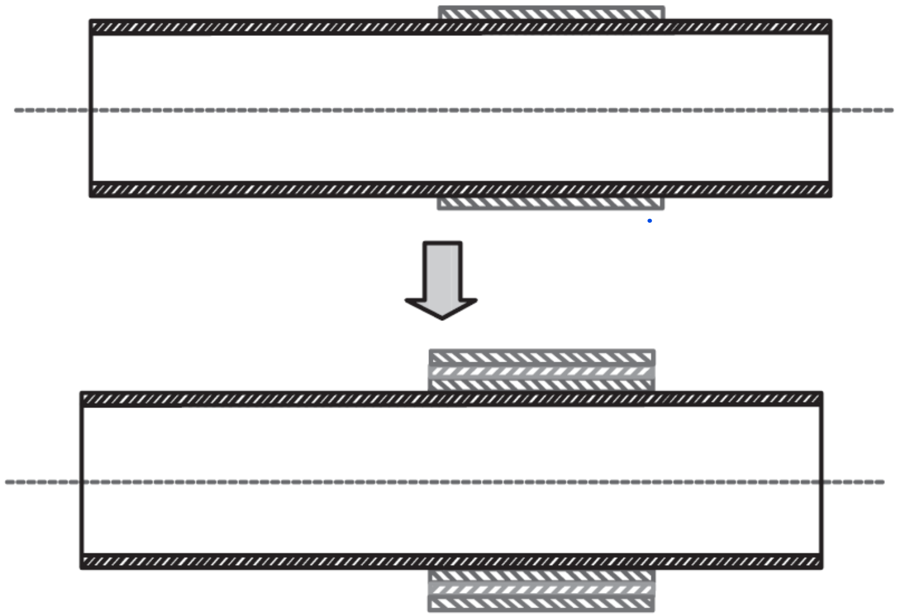
- only one section is built at a time, a support is needed at one side of the drum. This is provided by making one side of the drum inclined.

Fixed angle
Variable angle (7°, 9°, 11° etc.)

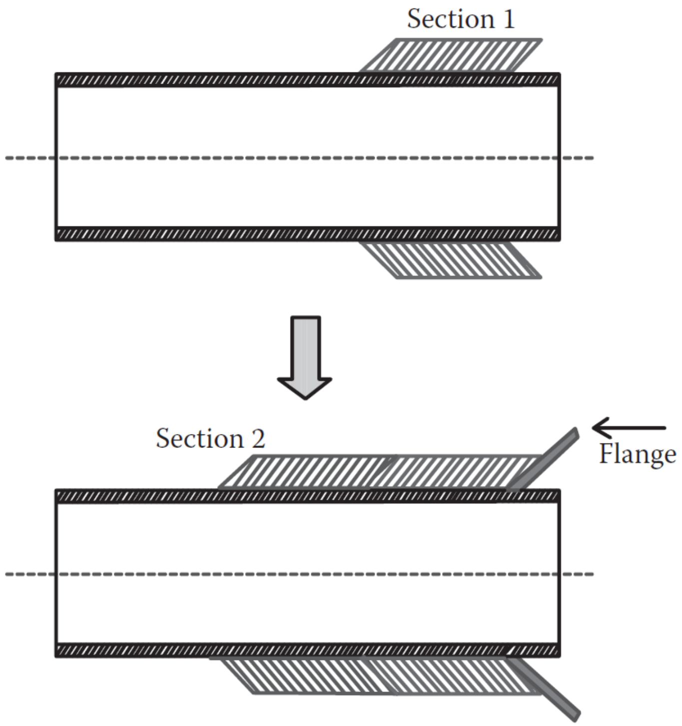


Warping: Sectional warping

- If the layers of a section were allowed to be wrapped on the same location ofnthe drum, then, after a while, the sectional view of warp sheet would appear like a rectangle, and the two edges of the warp sheet would tend to collapse in the absence of any lateral support



- Every section is given a lateral shift or a traverse during the winding process such that the cross-section of warp sheet wound on the drum appears like a parallelogram instead of a rectangle



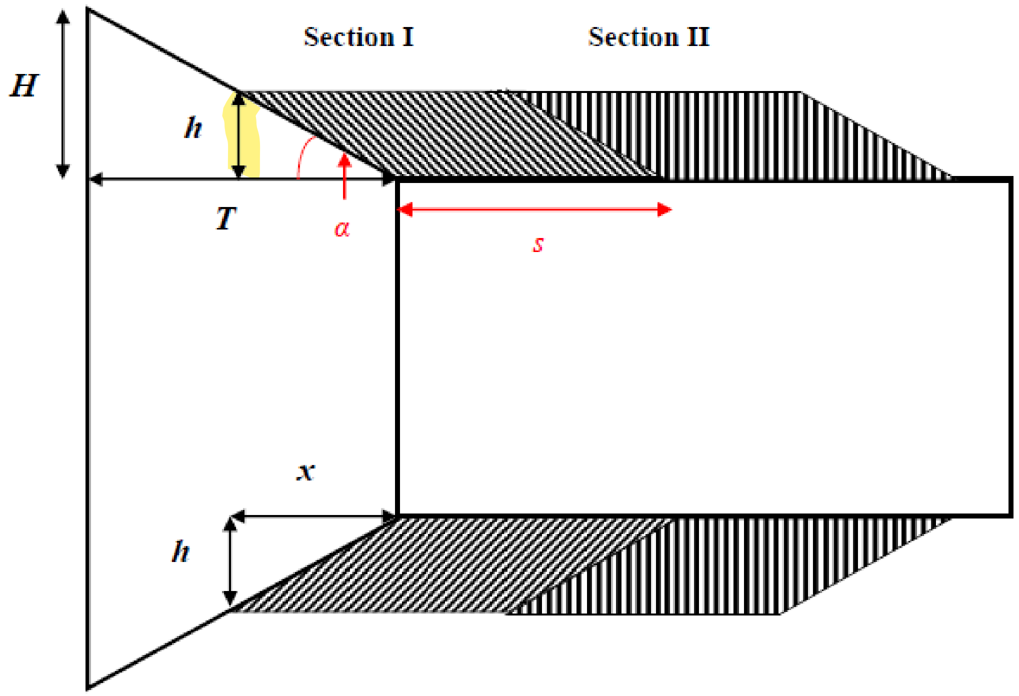
Warping: Sectional warping

- As the process continues, the thickness (or height) of the section gradually increases. When requisite length has been wound in a section, next section is started by shifting the expandable reed assembly by suitable distance

If α is the angle of inclination, x is the traverse given to the section and h is the height of the section then

$$\frac{h}{x} = \frac{H}{T} = \tan\alpha$$

$$\text{So, } x = \frac{h}{\tan\alpha}$$



For drum with fixed angle, if the yarn is coarser then one layer of the warp ribbon will result in higher increase in thickness (Δh) and thus to match the inclination, the traverse speed (Δx) should be higher

Warping: Sectional warping

- The resultant yarn sheet is then is governed by thickness of yarn and yarn spacing as well as tension applied to a section during winding. Higher yarn thickness, lower yarn spacing, and lower yarn tension result in a higher value of yarn sheet thickness for the same length wound

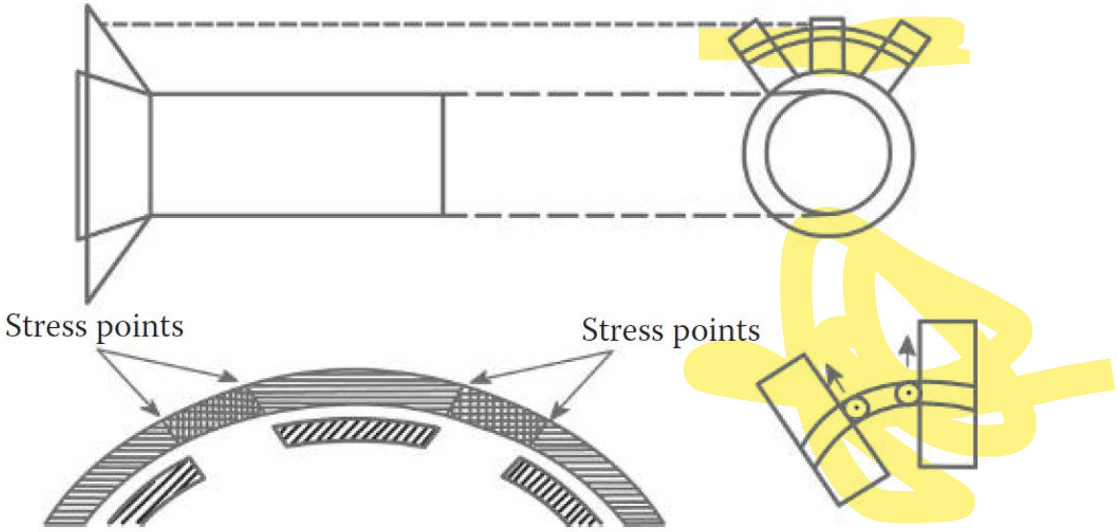
- For fixed angle drums, only one variable i.e. traverse speed is to be adjusted while with variable angle drums both traverse and the angle of inclination can be varied

- For drums with variable angle, the angle is changed by changing the inclination of metal plates which are supported at the end of the drum. When the angle is increased, larger gaps are created between the neighboring metal plates. Therefore, the yarn will remain unsupported at the gaps between two metal plates (**But what does it lead to??**)

Warping: Sectional warping

- In the variable conicity drums, plates hinged at one end on the drum body are arranged along the circumference of the drum. By raising the free ends of the plates simultaneously away from the drum by an equal amount, the conical surface is created.

- As one moves away from the hinge of the plates toward their tips, the gaps between the edges of neighboring plates keep on increasing.



These two factors result in stress concentration on yarn segments due to difference in length between yarns wound on the flange and those on the main body of the drum at the corresponding diameters

Warping: Some prevalent question

- Can we define the interdependence of among the distance between the creel, the speed of winding, and the braking torque that can be applied on the drum?

When yarn breaks during the winding process, the drum has to be brought to a stop within less than one revolution as otherwise the broken end would get embedded in the subsequent layer. Reversing the drum for finding out the broken end in the absence of any accumulating system would create entanglements among yarns and, hence, is not feasible. Thus, the larger the winding drum and the higher its speed, the more efficient the braking system has to be. Although a higher distance between the creel and the winding drum would ease the situation, it would also mean a higher space requirement

- Where should we use a fixed conicity drum?

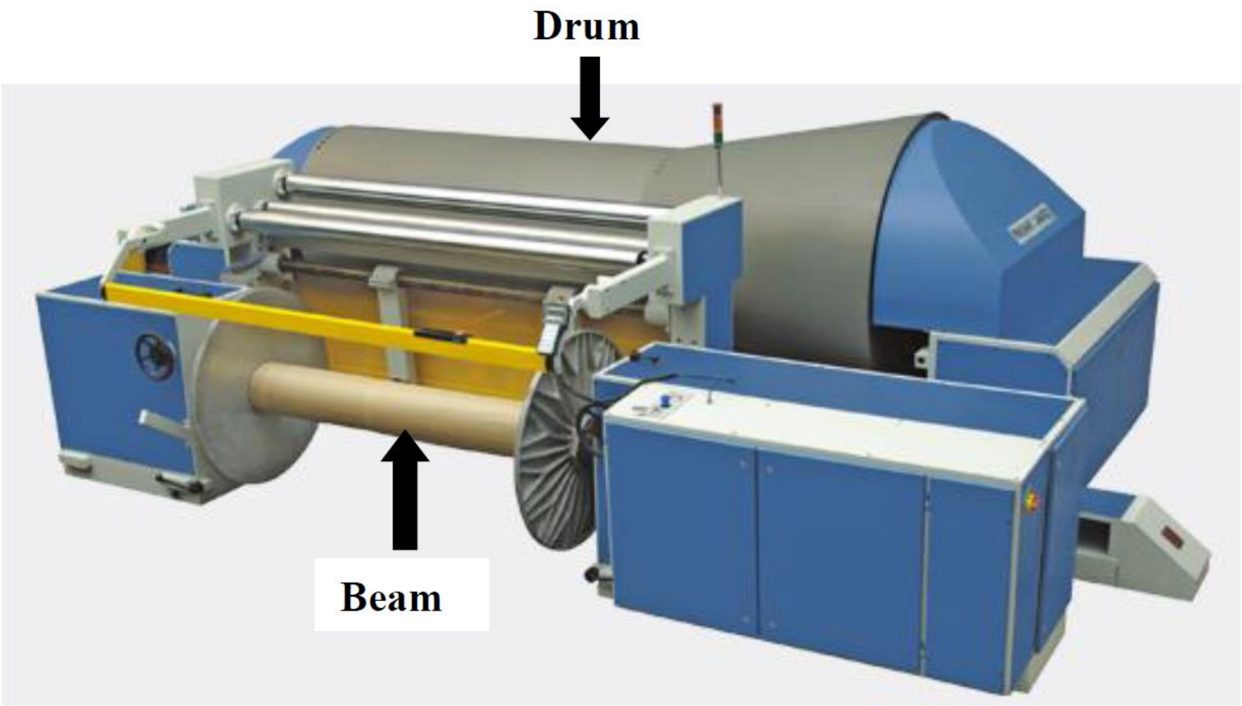
Drums with fixed conicity are preferred for winding delicate yarns, that is, yarns with low modulus and high extensibility

Warping: Beaming Systems

- In the indirect system of beaming, the ends of sections wound on a drum are collected in a sheet form and then wrapped onto a flanged barrel
- The barrel is given a spindle drive, and the resultant tension created in the warp sheet rotates the winding drum, unwinding all the sections wound on the drum simultaneously.
- The beaming operation is carried out at a fairly low speed of around 300 m/min
- Proper density of the resultant warp beam is regulated with the help of press rolls, and the angular velocity of the beam is gradually reduced with a build up of diameter

- In a direct-beaming system, a reasonably small number of yarns, varying, for example, between 250 and 500, is pulled out of the creel and wound on a flanged barrel

- The beaming speed can be in excess of 1000 m/min



Warping: Differences

Beam warping	Sectional warping
Used for high volume production	Used for small volume and customised production (stripes and specialised yarns)
One step process	Two step process
High creel capacity is required	Low creel capacity is sufficient
Comparatively less expensive	Comparatively more expensive
Beaming speed is high	Beaming speed is low
More common	Less common

Sizing: Objectives

The objective of warp sizing is to improve the weaveability of yarns by applying a uniform coating on the yarn surface so that protruding hairs are laid on the yarn surface

Benefits of Sizing

- It prevents the warp yarn breakage due to abrasion with neighboring yarns or with back rest, heald eye and reed.
- It improves the yarn strength by 10 to 20%, although it is not the primary objective of sizing process.

Characteristics of Sized Yarn

- ✓ Higher strength
- ✓ Lower elongation
- ✓ Higher bending rigidity
- ✓ Higher abrasion resistance
- ✓ Lower hairiness
- ✓ Lower frictional resistance

Sizing materials

- ❑ Starch
- ❑ PVA

Basic definitions

$$\text{Size concentration (\%)} = \frac{\text{Oven dry mass of size materials}}{\text{Mass of size paste}} \times 100 = \frac{S}{P} \times 100$$

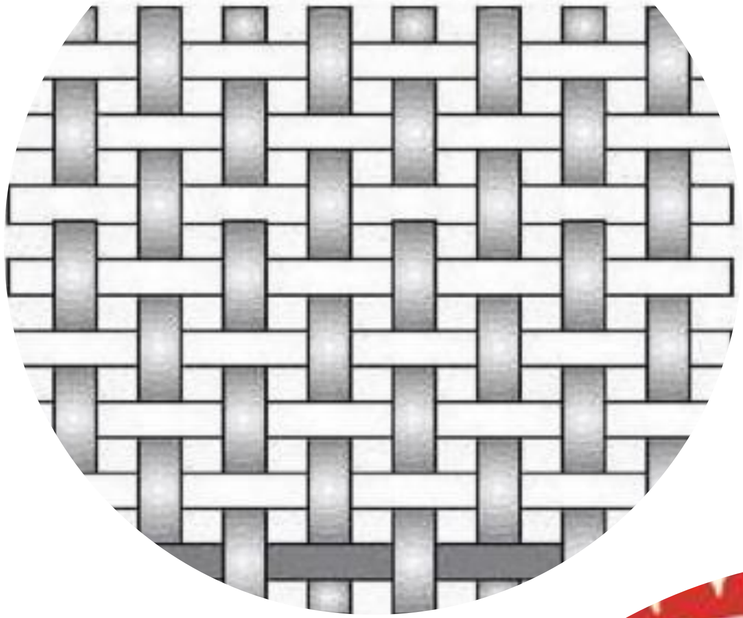
$$\text{Size add on(\%)} = \frac{\text{Oven dry mass of size materials}}{\text{Oven dry mass of unsized yarns}} \times 100 = \frac{S}{Y} \times 100$$

$$\text{Wet Pick up} = \frac{\text{Mass of size paste}}{\text{Oven dry mass of unzized yarns}} = \frac{P}{Y}$$

$$= \left(\frac{S}{Y} \times 100\right) \times \left(\frac{P}{S} \times \frac{1}{100}\right)$$

$$= \frac{\text{Add on (\%)}}{\text{Concentration (\%)}}$$

Fabric Manufacturing I (TXL231)



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- It prevents the warp yarn breakage due to abrasion with neighboring yarns or with back rest, heald eye and reed.
- It improves the yarn strength by 10 to 20%, although it is not the primary objective of sizing process.

Characteristics of Sized Yarn

- ✓ Higher strength
- ✓ Lower elongation
- ✓ Higher bending rigidity
- ✓ Higher abrasion resistance
- ✓ Lower hairiness
- ✓ Lower frictional resistance

Sizing materials

- ❑ Starch
- ❑ PVA

Basic definitions

$$\text{Size concentration (\%)} = \frac{\text{Oven dry mass of size materials}}{\text{Mass of size paste}} \times 100 = \frac{S}{P} \times 100$$

$$\text{Size add on(\%)} = \frac{\text{Oven dry mass of size materials}}{\text{Oven dry mass of unsized yarns}} \times 100 = \frac{S}{Y} \times 100$$

$$\text{Wet Pick up} = \frac{\text{Mass of size paste}}{\text{Oven dry mass of unzized yarns}} = \frac{P}{Y}$$

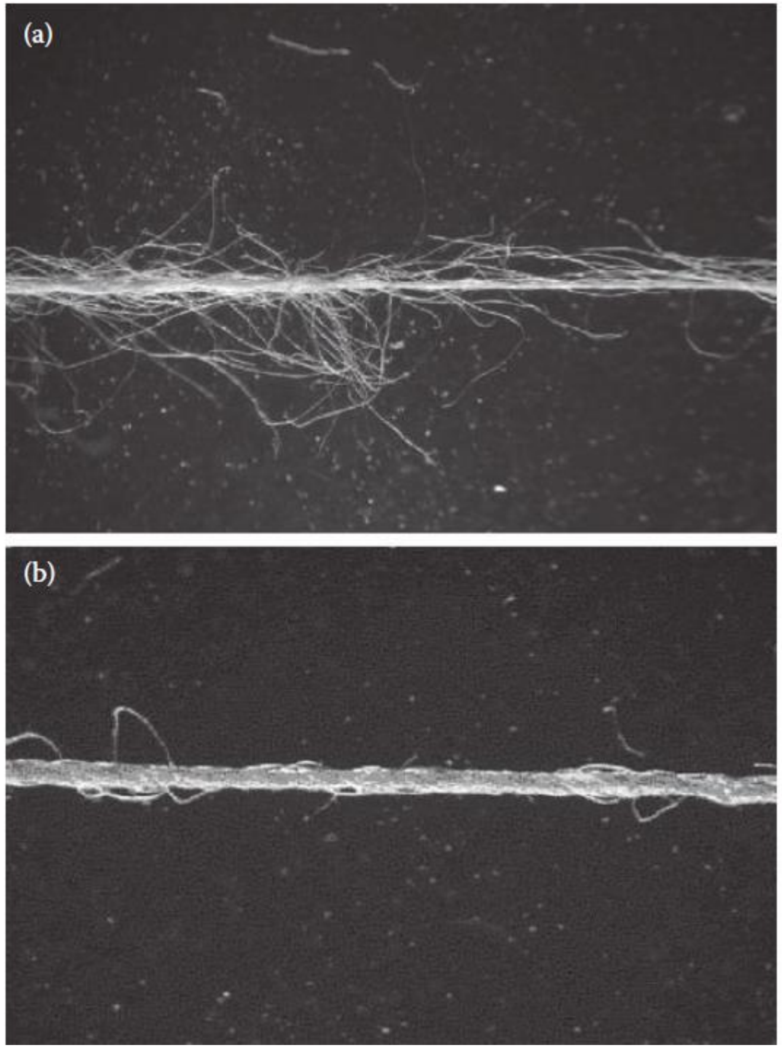
$$= \left(\frac{S}{Y} \times 100\right) \times \left(\frac{P}{S} \times \frac{1}{100}\right)$$

$$= \frac{\text{Add on (\%)}}{\text{Concentration (\%)}}$$

Sizing: Objectives

- The size material should penetrate the body of yarn to such an extent that the size film gets firmly anchored
- However, excess penetration of size not only means an excess material consumption but also reduced yarn flexibility

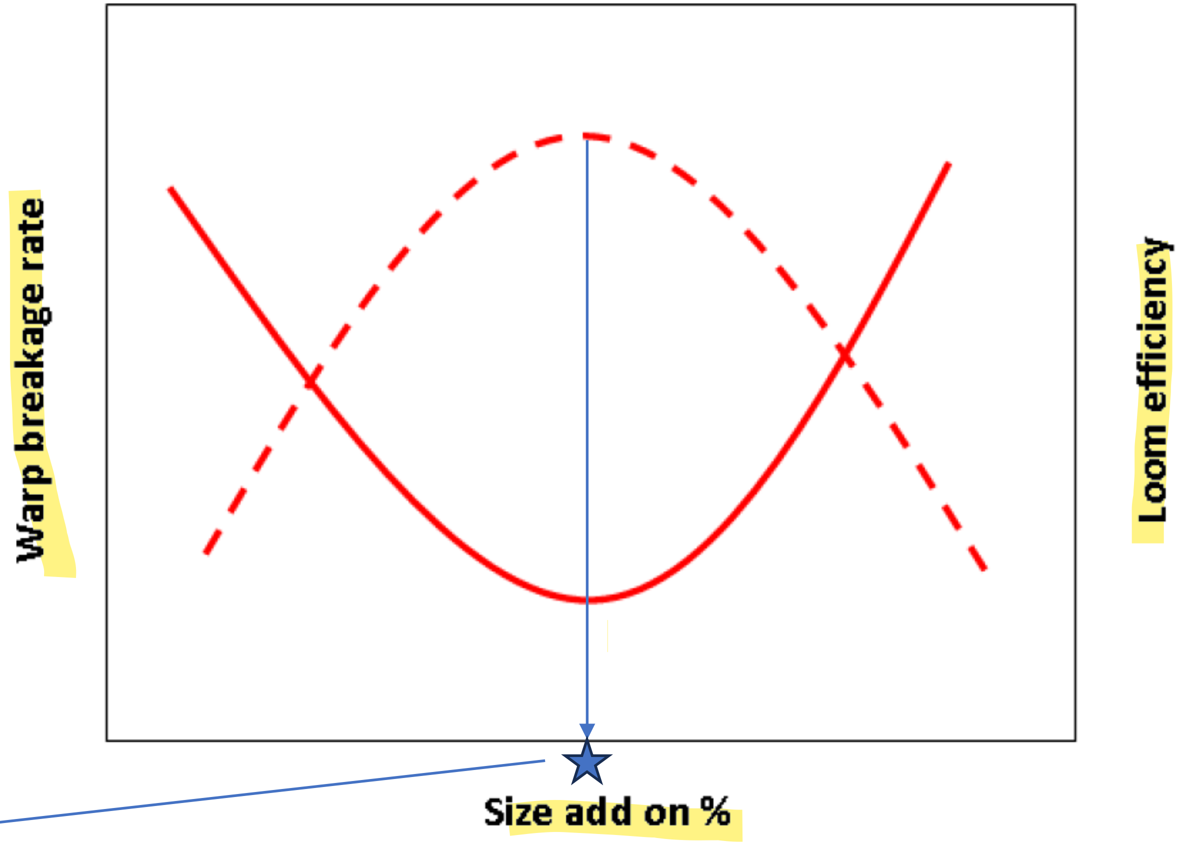
A modern sizing machine can process yarns coming from approximately 25,000 ring spindles and feed 150 projectile looms of 3 m width



(a) unsized and (b) sized yarn

Sizing: Sizing-weaving Curve

The solid line represents the warp breakage rate whereas the broken line implies loom efficiency.

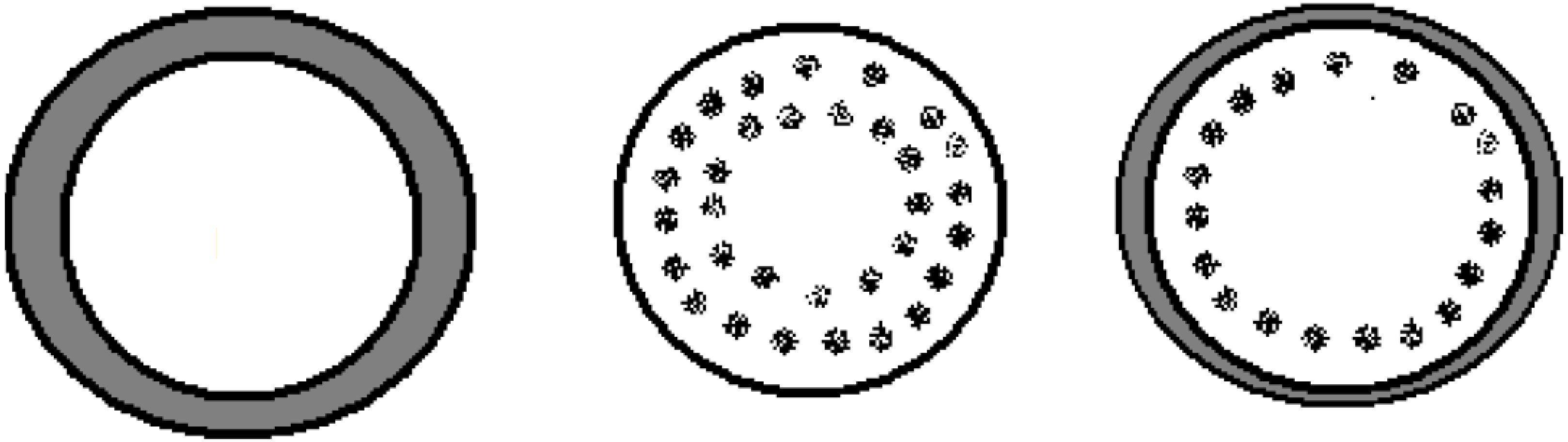


The optimum level of size add-on will depend on the following factors

- ❑ Type of fibre
- ❑ Type of size materials
- ❑ Yarn spinning technology
- ❑ Yarn count and twist
- ❑ Level of hairiness in the yarn
- ❑ Loom type and loom speed

Sizing: Sizing-weaving Curve

Although add-on primarily influences the weaving performance, it is possible to have different weaving performances even at the same level of size add-on, mainly due to differences in Size penetration and Size coating



Size coating — size penetration — optimum coating and penetration

Size coating

- ❑ Uniform coating
- ❑ No hairiness problem
- ❑ Lower adhesion
- ❑ Stiff coating
- ❑ Chances of shedding of sizing material

size penetration

- ❑ No outer coating
- ❑ No abrasion protection
- ❑ Too deep penetration
- ❑ Less binding

optimum coating and penetration

- ❑ Thin but uniform coating
- ❑ Appreciable penetration and binding
- ❑ Penetration distance about 15-20% of radius

Sizing: Sizing Materials

What are the desirable and essential properties of sizing material?

Film forming	Controllable viscosity
Adhesion	Easy removal and recyclability
Optimum penetration	Neutral pH
Film flexibility and elasticity	Non-polluting
Lubrication	Cheap
Bacterial resistance	

Adhesion is the most critical component

- The adhesive part is responsible for forming the film and adhering with the fibres
- Softening agent makes the film flexible so that the film can bend easily without forming cracks
- Antimicrobial agents are added to thwart the mildew to grow on the size film

Sizing: Desirable Nature of Bonds between Adhesives and Fiber Material

In order to hold down protruding fibers onto the yarn body, the number of bonding sites between the sizing material and the fibers constituting the yarn must be sufficiently high. However, a sizing material should ideally have a low bond strength as it has to be disposed of after sized yarns have been woven into a fabric.

What kind of forces we can expect?

- ❑ van der Waals interaction → van der Waals forces are weak forces of attraction. They arise due to momentary dipoles occurring due to uneven electron distribution and/or The weak residual attraction of the nuclei in one molecule for the electrons in a neighboring molecule

- ❑ Hydrogen bonds → Hydrogen bonds occur between molecules that have a permanent net dipole resulting from hydrogen being covalently bonded to fluorine, oxygen, or nitrogen

- ❑ Dipole-dipole interaction → Dipole-dipole interactions are intermolecular forces that are stronger than van der Waals forces. They develop between molecules that have permanent net dipoles as found in polar molecules

Sizing: Desirable Nature of Bonds between Adhesives and Fiber Material

What kind of forces we can expect?

- ❑ van der Waals interaction
- ❑ Hydrogen bonds
- ❑ Dipole-dipole interaction

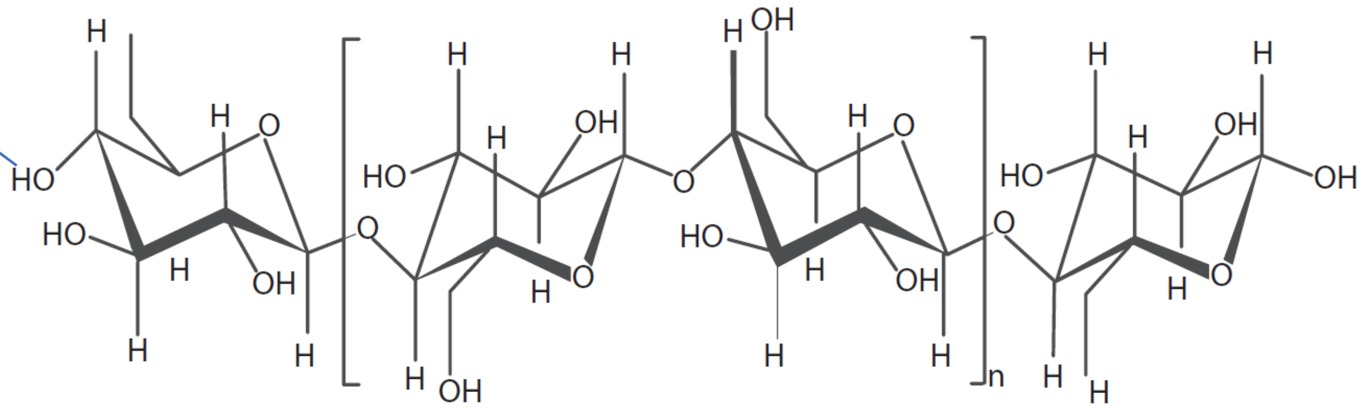
Strength of Different Types of Bonds

Type of Bond	Bond Strength (kJ mol^{-1})
van der Waal's forces	<<50
Dipole–dipole interactions	~50
Hydrogen bond	~100
Single covalent bond	~300

Sizing Material: Starch

Cotton yarns, in general, are sized by the starch which forms the adhesive component of the size mix. The reasons are-

- ❑ Starch is chemically same with cotton and rayon and thus the adhesion is very good.
- ❑ Desizing is easy
- ❑ Relatively cheap
- ❑ Properties can be tuned to cope with the need



Organization of chemical groups in a cellulose molecule of cotton

(*Large number of −OH groups in starch*)

Sizing Material: Starch

- Starches are available from the seed, root or pith of plants. Corn, rice and wheat are the examples of seed starch. Potato and Tapioca starches are obtained from roots. Sago starch is obtained from pith.

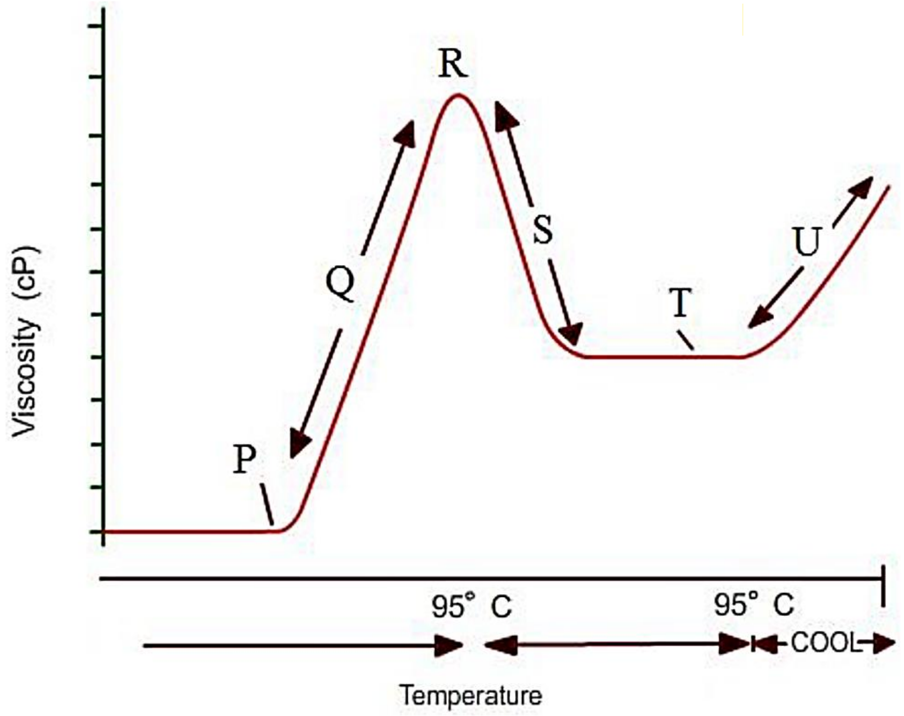
- Starch is usually composed of two components, a straight chain polysaccharide of glucose, called Amylose (low mol. wt) and a branched chain polysaccharide of glucose, called Amylopectin (high mol. wt)

Amylose	Amylopectin
Provides strength	Prevents rapid gelling
Water soluble	Water insoluble
Low molecular weight	Relatively high molecular weight
20-30%	70-80%

- Corn starch is generally preferred for the sizing of coarse and medium count yarns
- Potato starch is preferred for sizing finer yarns

Sizing Material: Cooking of Starch

Starch alone suspended in cold water cannot act as an adhesive because it is tightly bound in granular form. The granules consist of crystalline regions of straight chain molecules and straight chain section of aligned branched chain molecules. The crystalline regions are linked together by more amorphous areas in which the molecules are not aligned. Hence, the granules must be **opened**.



P- gelatinization temperature (crystal structure broken ~60 deg C)

Q- Increase in viscosity due to swelling

R- Maximum viscosity (also aided by stirring), starch granules break

S- The chai molecules of amylose and amylopection come out within the solution causing reduction in viscosity

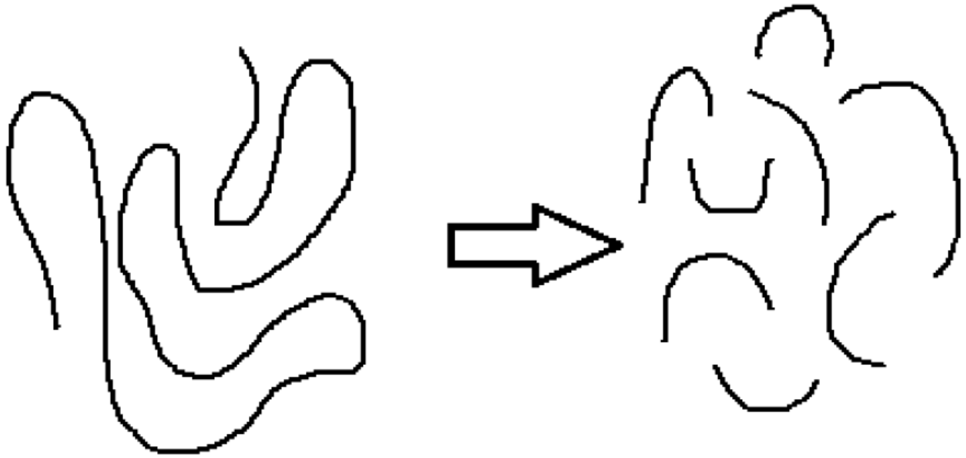
T- When all the granules have burst, the viscosity stabilizes or levels off

U-When the solution is cooled, the starch gels due to the formation of a rigid interlocked micelle-like structure having hydrogen bonding (ready for coating) (retrogradation of starch)

Sizing Material: Acid Treatment (Thin Boiling Starch)

- The viscosity of the sizing paste influences the wet pick-up and resultant add-on %. The viscosity is influenced by the concentration of starch (solid content) and molecular chain length of starch
- Aqueous solution of starch is treated with hydrochloric acids at specified temperature and duration. The acid cleaves the polymer at the glycoside linkage and thus the length of the polymer chain is reduced

Thin boiling starch-the viscosity is reduced and the fluidity increases



Acid treatment of starch to reduce the molecular chain length

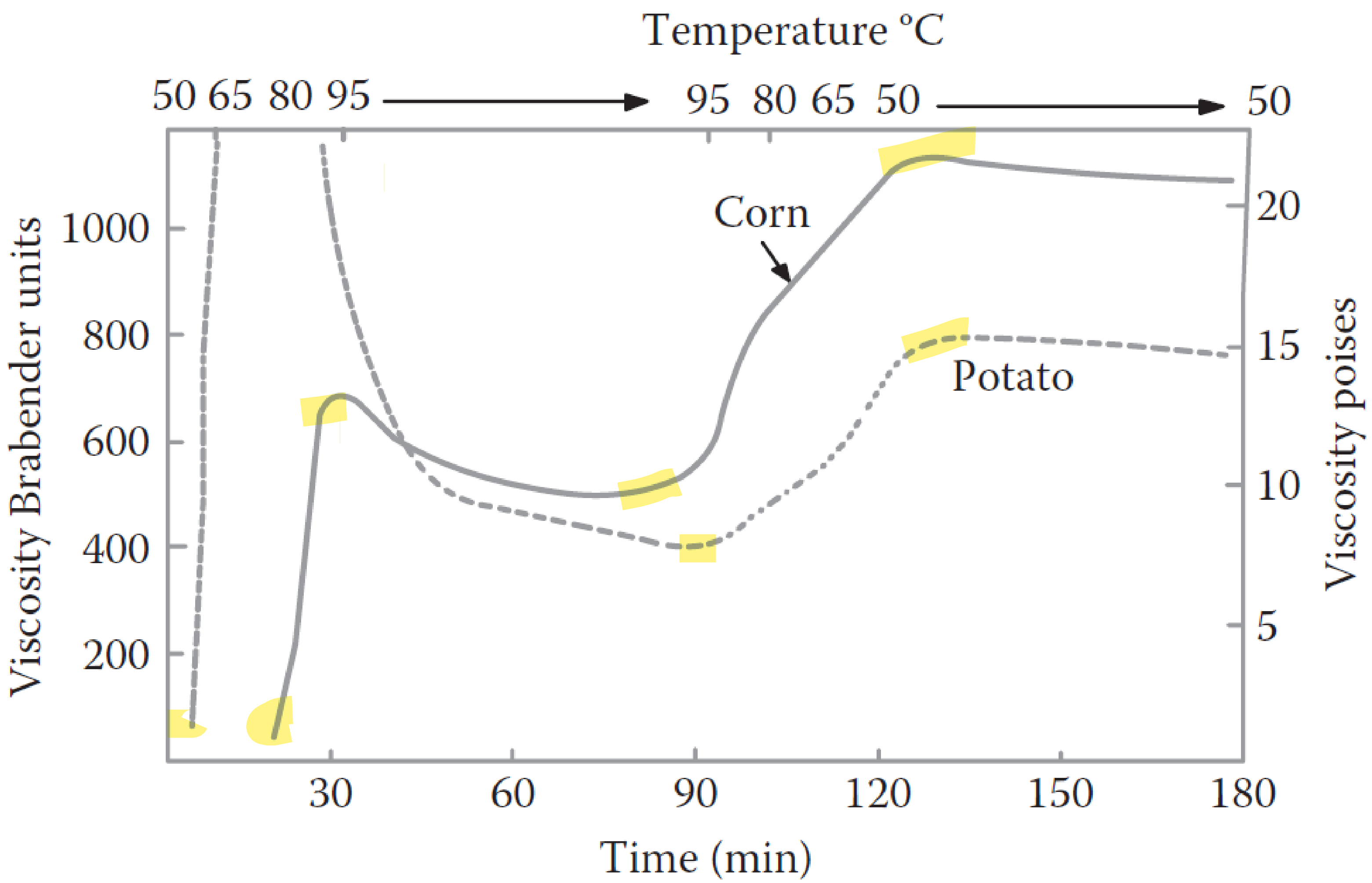
Sizing Material: Alkali Treatment

- Strong bases activate starch-the degree of granule swelling depends upon the nature of the starch; the nature of the alkali; the relative amounts of starch, alkali, and water; the temperature, and the presence or absence of neutral salts.
- Increase in reactivity of starch in aqueous alkali is obtained by addition of neutral salts, especially sodium sulfate

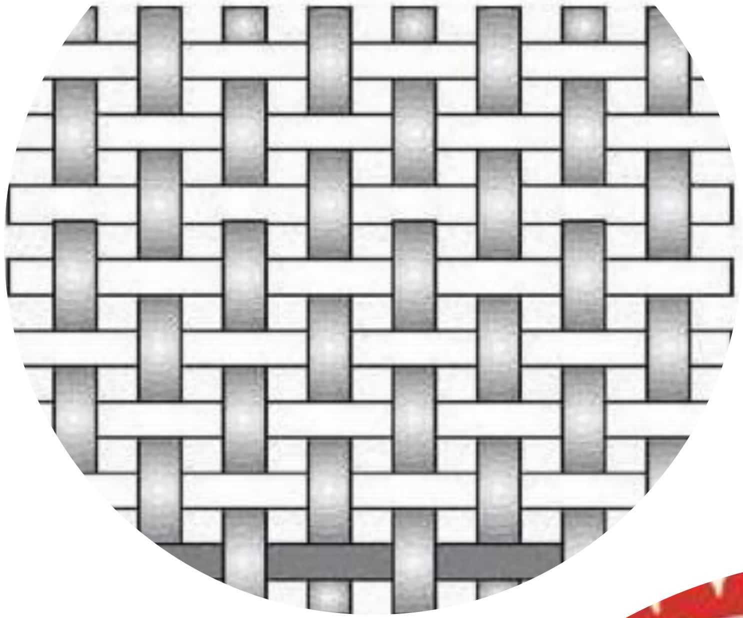
Sizing Material: Oxidation of Starch

Starch granules are oxidized with sodium hypochlorite, which converts some hydroxyls into −COOH groups breaking the ring at that point. Sodium bisulfite is added to destroy excess hypochlorite. The granular structure is retained, and films from oxidized starch are better than those formed from thin boiling starch.

Sizing Material: Starch actual behavior



Fabric Manufacturing I (TXL231)



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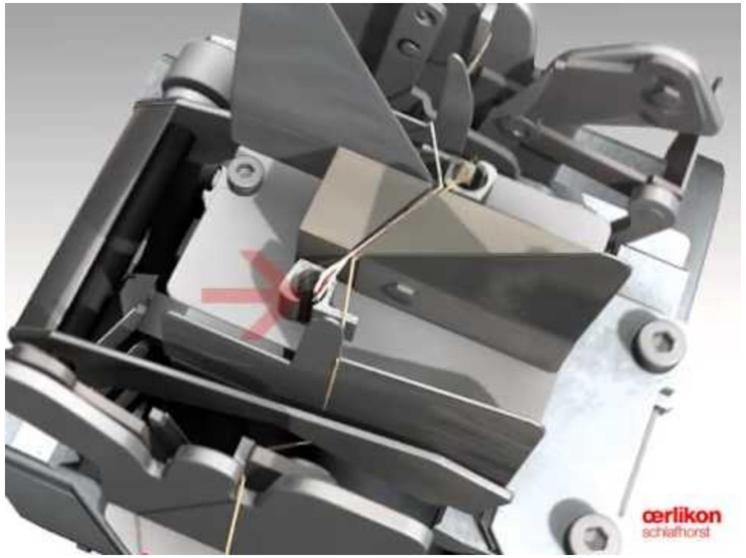
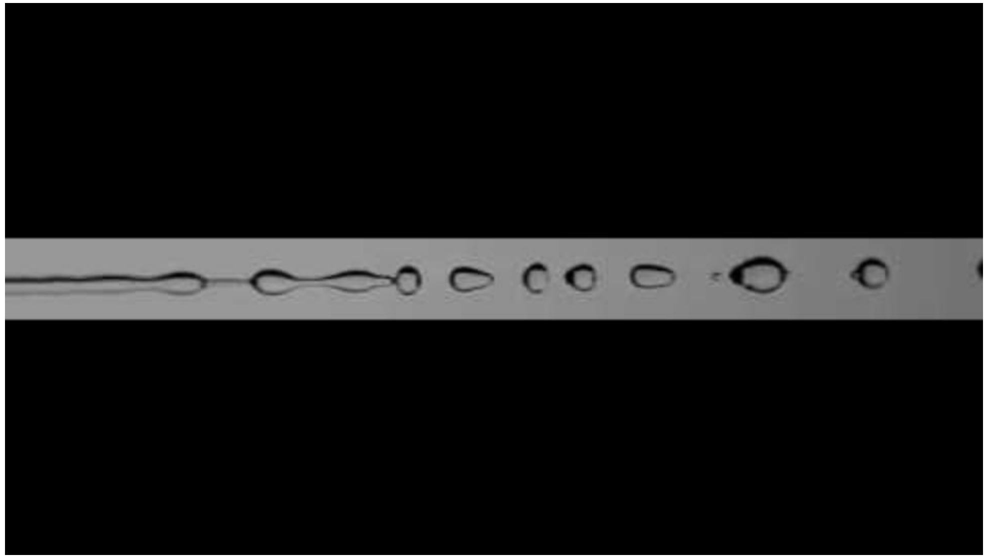


https://www.youtube.com/watch?v=x51KmhTmyRM

Yarn splicing

https://www.youtube.com/watch?v=Fv-2Yl2A_KE

Yarn traverse



https://www.youtube.com/watch?v=X3PdtK5it5o

Capillary instability

https://www.youtube.com/watch?v=e0dJLk3YlFA

Yarn winding

https://www.youtube.com/watch?v=U1u9PM6NOfU

Link to understanding kite flying

Sizing: Recap

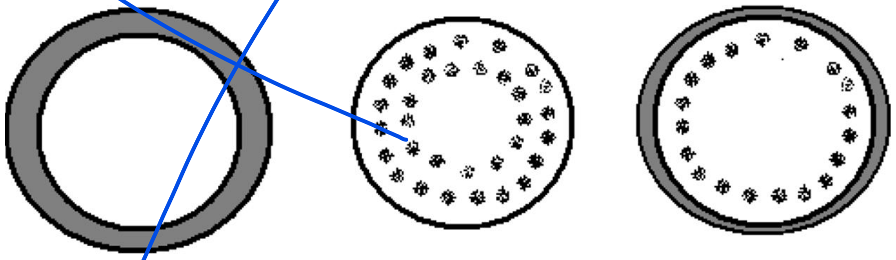
The objective of warp sizing is to improve the weaveability of yarns by applying a uniform coating on the yarn surface so that protruding hairs are laid on the yarn surface

Benefits of Sizing

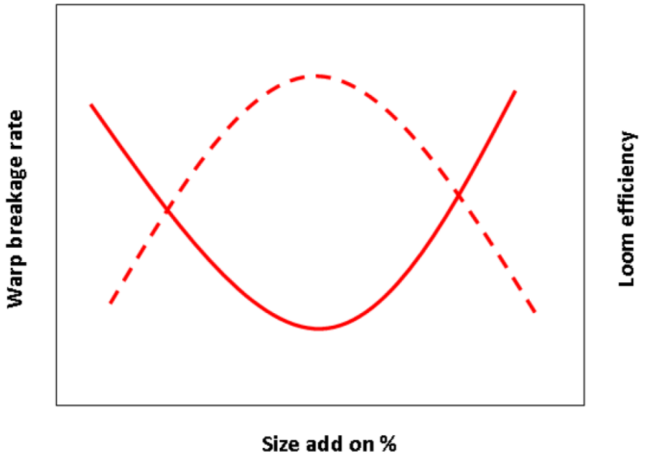
- It prevents the warp yarn breakage due to abrasion with neighboring yarns or with back rest, heald eye and reed.
- It improves the yarn strength by 10 to 20%, although it is not the primary objective of sizing process.

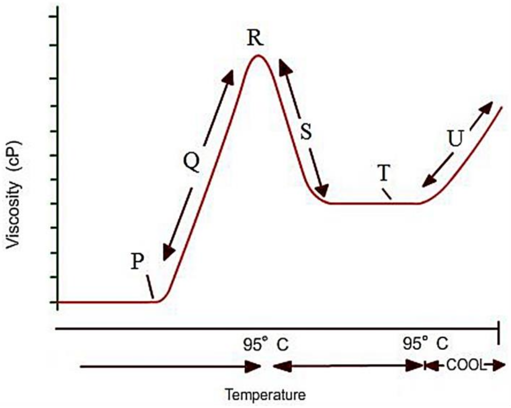
Sizing materials

- Starch
- PVA



Size coating   size penetration   optimum coating and penetration





P- gelatinization temperature (crystal structure broken ~60 deg C)

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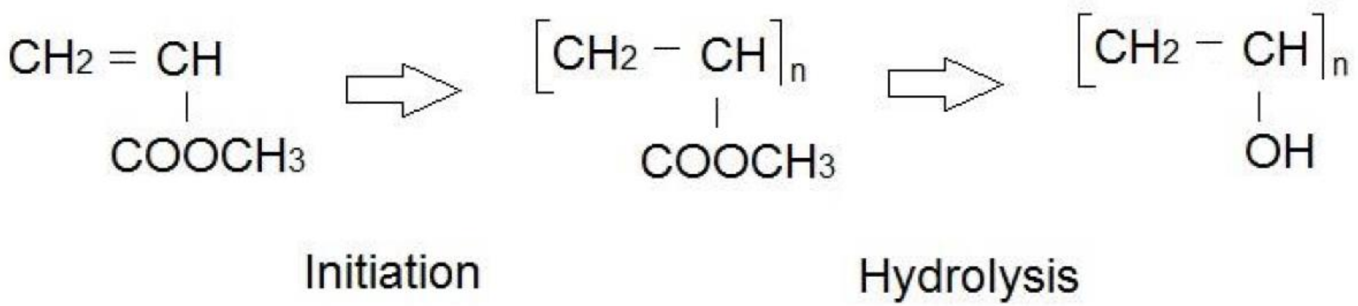
S- The chai molecules of amylose and amylopection come out within the solution causing reduction in viscosity

T- When all the granules have burst, the viscosity stabilizes or levels off

U-When the solution is cooled, the starch gels due to the formation of a rigid interlocked micelle-like structure having hydrogen bonding (ready for coating) (retrogradation of starch)

Sizing: Material-Polyvinyl Alcohol (PVA)

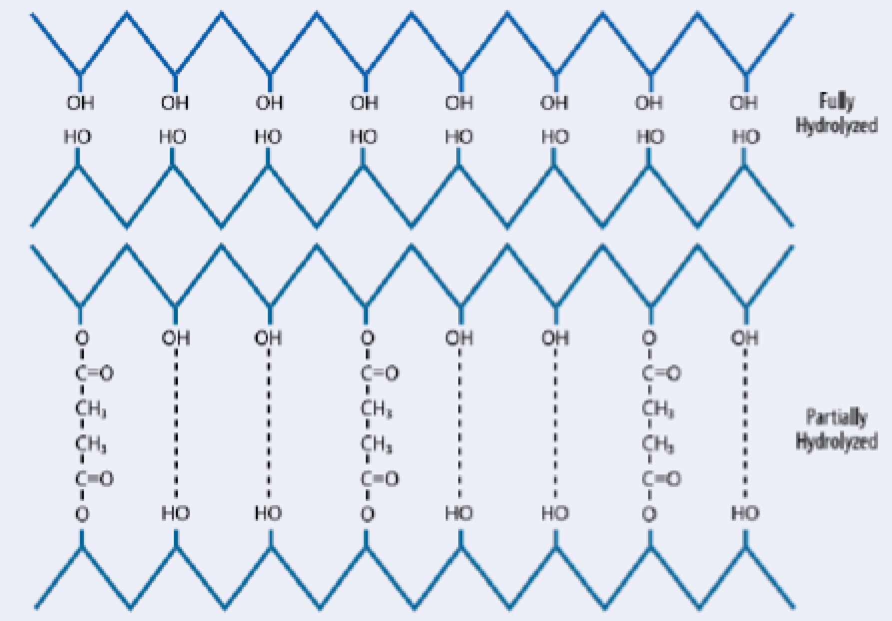
PVA can be used for sizing cotton, rayon, polyester and their blends. It is manufactured by polymerizing vinyl acetate monomers and then substituting the acetate groups with hydroxyl groups by hydrolysis



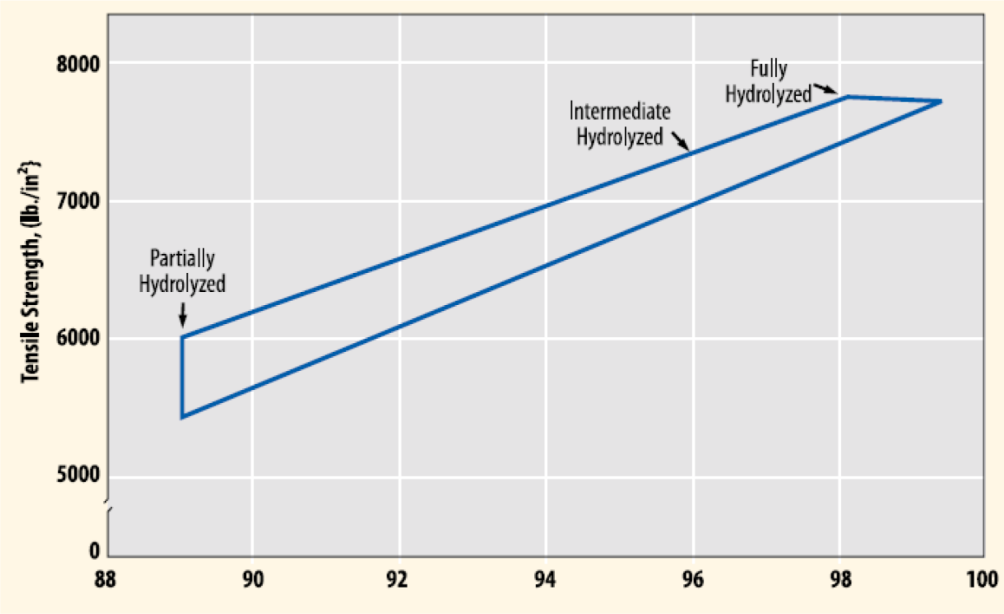
Properties:

- ❑ Hydrolyzation of PVA >99%, leads to formation of intense hydrogen bonding which improves the strength of the PVA film
- ❑ Such PVA is not easily soluble in water and hence requires high temperature, that makes desizing difficult
- ❑ Super hydrolyzed is generally not preferred for sizing
- ❑ Partial hydrolyzed PVA adheres to yarns better

Sizing: Material-Polyvinyl Alcohol (PVA)



Hydrogen bonding in PVA



Effect of hydrolysis on the strength of PVA film

Sizing: PVA properties

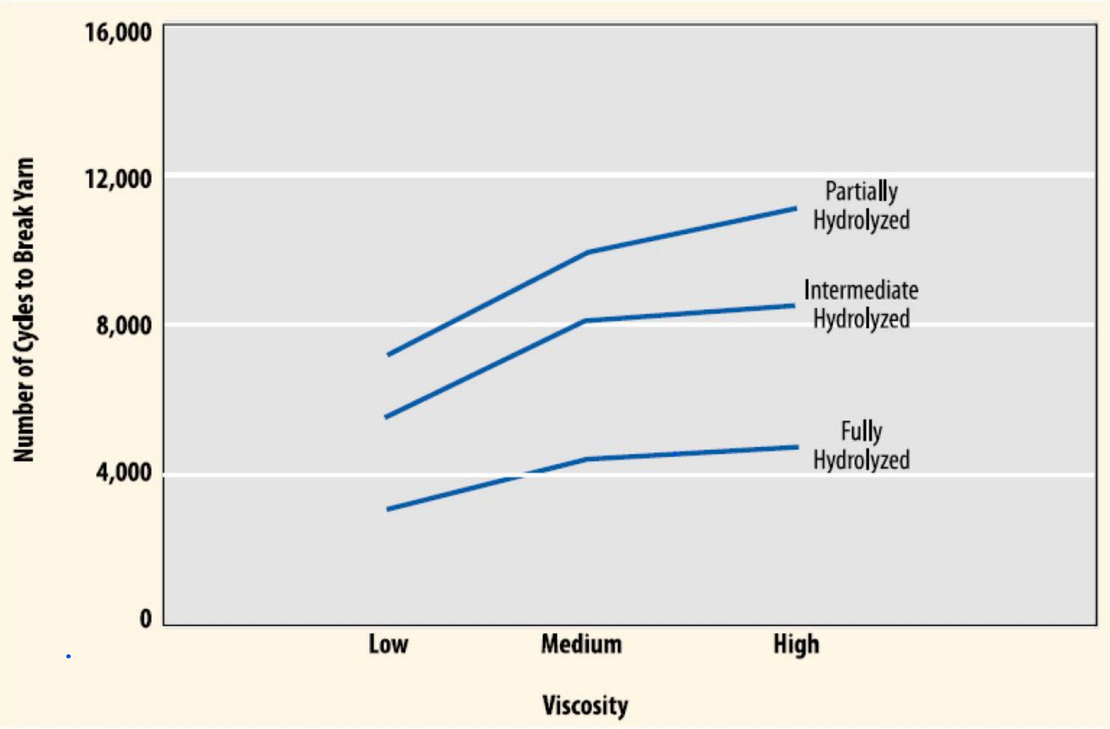
The partially hydrolyzed PVA provides better waving performance in terms of (a) Less shedding or dropping of size (b) Lower yarn hairiness and (c) Lower size add-on

Adhesion Properties

Type of fibre	Adhesion strength (g/mm^2)	
	Partially hydrolyzed	Fully hydrolyzed
Acetate	10	2
Nylon	11	6
Acrylic	9	4
Polyester	7	1

DH and applications

PVA grade	Degree of hydrolysis	Application
Super hydrolysed	>99%	Not a preferred material for sizing
Fully hydrolysed	98-99%	100% Cotton
Intermediate hydrolysed	95-98%	~~Polyester~~ and other synthetic fibres and blends
Partially hydrolysed	87-90	Polyester and other synthetic fibres and blends



Abrasion resistance of yarns sized with PVA

Sizing: Typical Steps Followed in the Industry to Prepare the Size Paste

- Take standard volume (700 litres) of water (normal temperature) into the premixture through water flow meter, start the stirrer.
- Properly weigh all the chemicals required.
- Add modified starch, PVA and then Acrylic binder slowly into the pre-mixture vessel.
- Stir the mixture for 15 minutes.
- Start the stirrer of the cooker, transfer the mixture to the closed cooker from premixture vessel. Close all the open valves of the cooker.
- Heat the cooker mixture with the injection of direct steam, steam will auto cut when the cooker temperature reaches the preset limit (110^{o} C). It takes around 30 to 35 minutes.
- Cook the mixture for another 40 minutes, the temperature of the cooker will reach to around 120 to 125^{o} C depending on the size recipe.
- Start the stirrer of the storage vessel and then transfer the cooked size paste to the respective storage vessels.
- Add lubricant with the size paste at storage.
- Maintain storage temperature at around 80-90^{o} C.
- Paste is ready to transfer to the sow box of sizing machine.

Carded cotton yarn

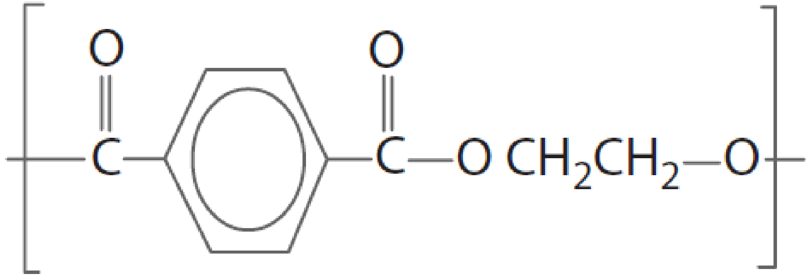
Modified starch	:	10.5 % on the weight of water
PVA	:	2.86 %
Acrylic binder (Liquid)	:	6.6 %
Lubricant	:	0.7 %.

Paste viscosity: 6.5±0.2 second, Solid content: 12-13%

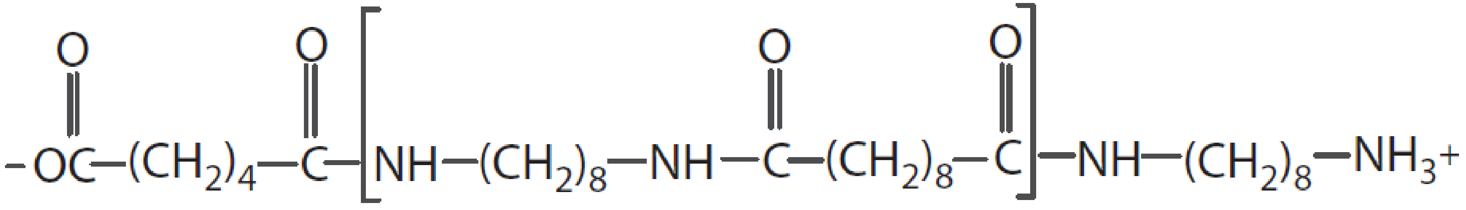
Sizing: Sizing of Synthetic Fibers

The basic problems associated with sizing of synthetic yarns-

- Absence of −OH groups
- Hydrophobicity of material



Molecular structure of a polyester



Molecular structure of a polyamide

For sizing of these hydrophobic yarns, one has to primarily depend on the following forces and some desirable properties-

- van der Waals forces
- Dipole–dipole forces

❖ Adhesive and fiber have to be brought into close proximity.

❖ Adhesive should not contain steric hindering groups.

❖ Adhesive molecules must be as linear as possible.

❖ Adhesive material should have favorable dipole–dipole interacting (polar) groups.

Type of Fiber	Chemical Nature of Size Adhesive
Polyester	Vinyl copolymers
Polyamide and polyacrylonitrile	Polyacrylic acid
Acetate	Polyvinyl alcohol

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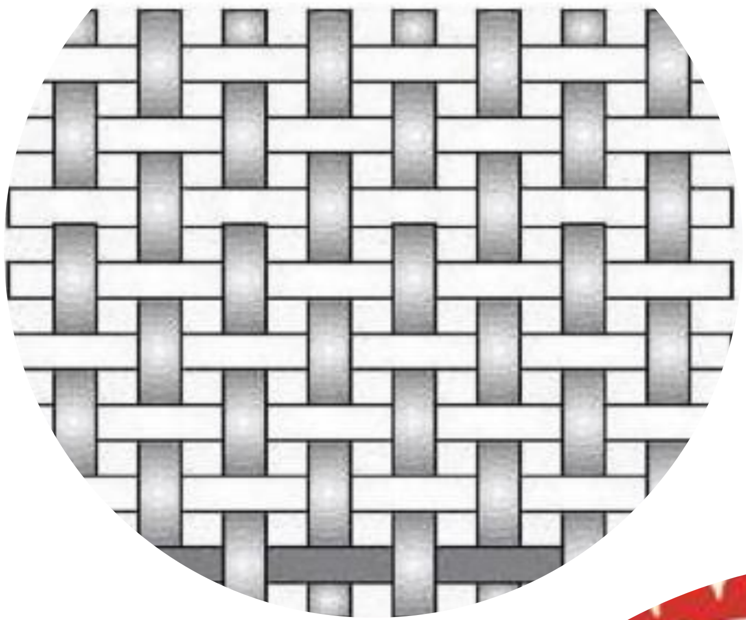

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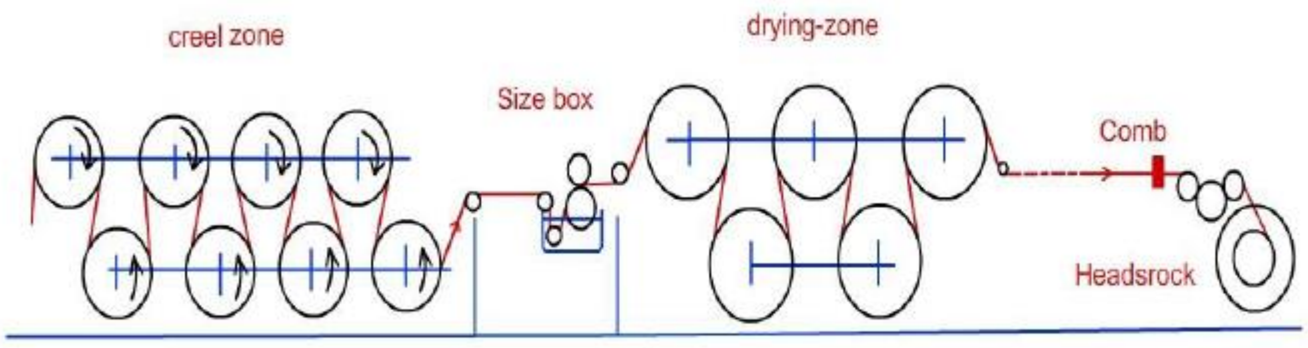
Sizing: Sizing machine

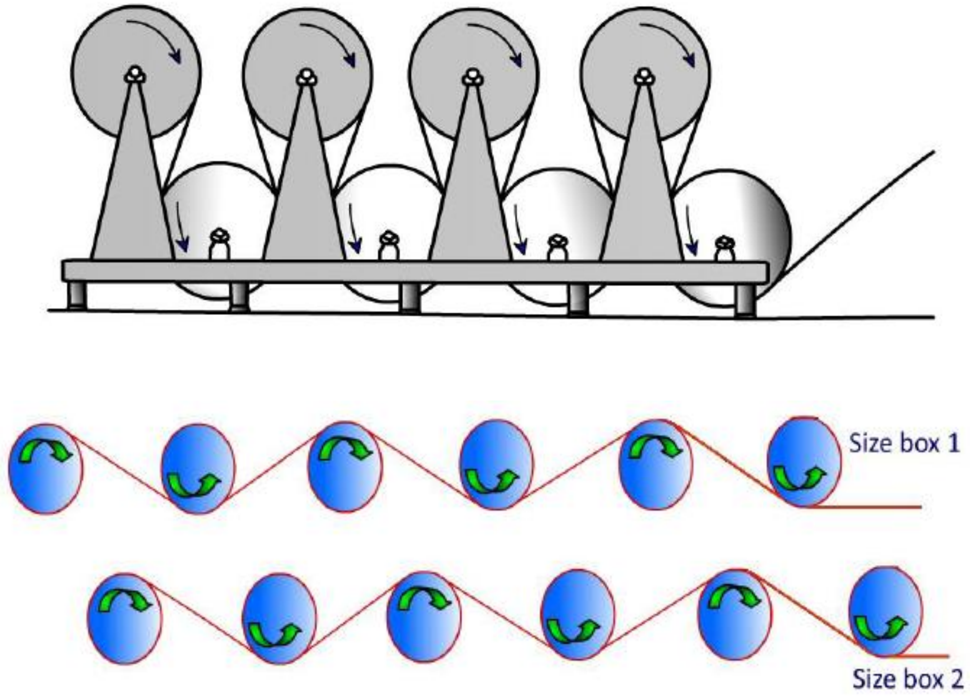


The creel zone contains large number of warper's beam which can be arranged in different fashion depending on the design of the creel. Individual warp sheet emerging from warper's beam are merged together to form the final warp sheet which passes through the size box. During the passage through the size box, the warp sheet picks up size paste and holds a part of the paste after squeezing. Then the wet warp sheet passes through the drying zone and wound on the weavers beam

Sizing: Creel Zone

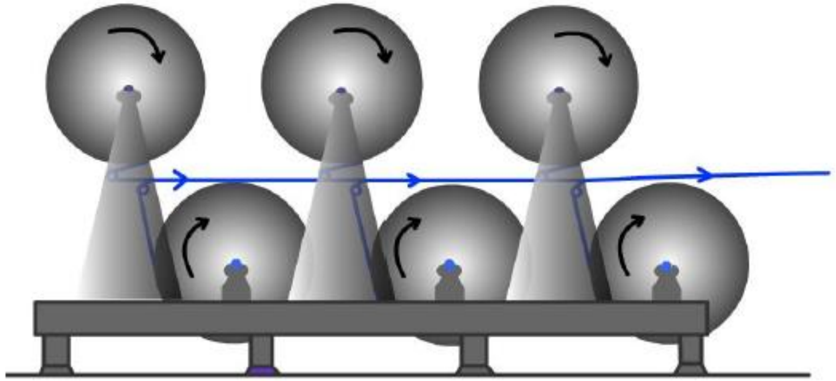
1. An easy withdrawal of warp sheet from each beam
2. Proper assembly of each sheet into the final form in which sizing of the assembled yarn sheet would take place
3. Easy access of the operator to each element of the creel

Over and under creel



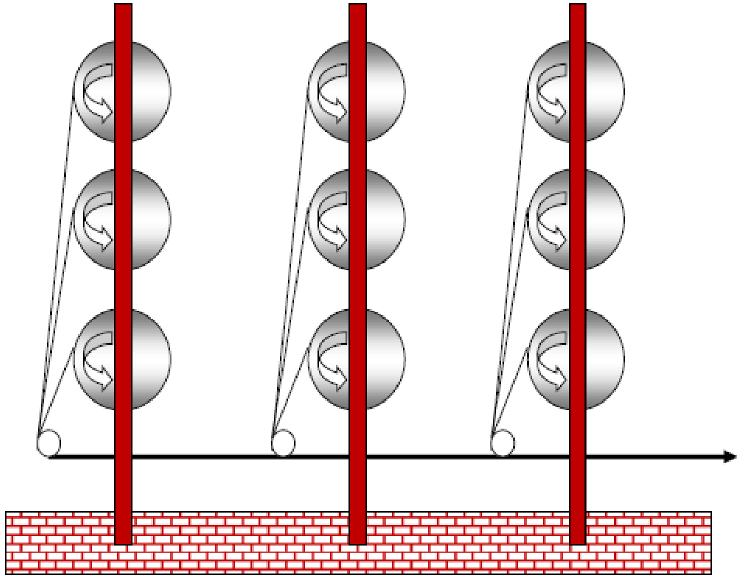
The warp sheet coming from the rearmost beam experiences more tension and stretch than the warp sheet coming from the beam located nearest to the size box

Equi-tension creel



The warp sheets are subjected to equal tension and stretch irrespective of the position of the warper's beam

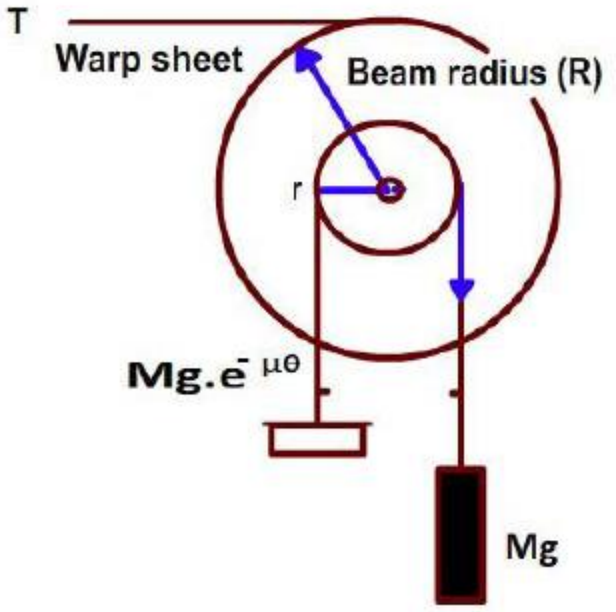
Vertical creel



The beams are stacked vertically to reduce floor space

Sizing: Warp tension

As the sizing process continues, the radius of the warper's beam reduces. Therefore, it is required to adjust the warp tension by adjusting either the dead weight suspended with the rope passing over the ruffles of the warper's beam or by controlling the pneumatic pressure applied on the bearing region of warper's beam



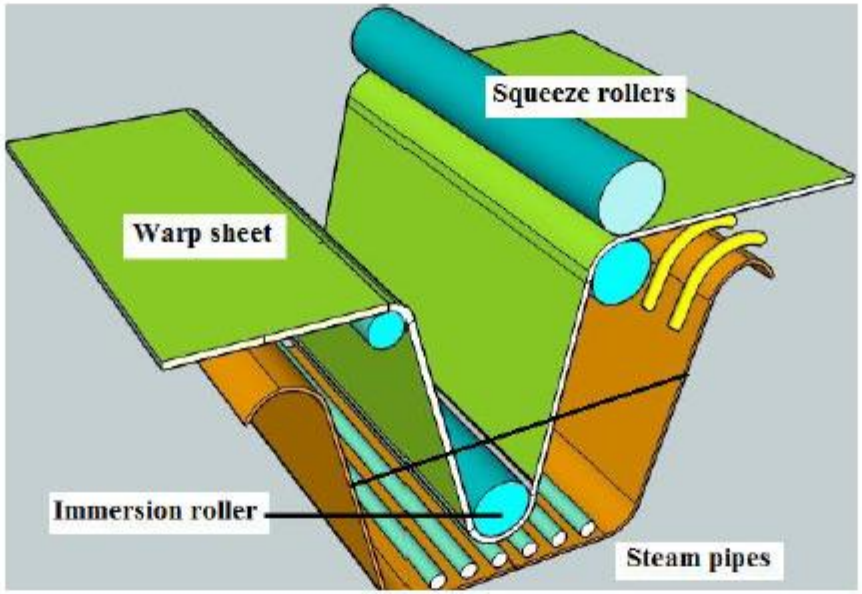
T is the warp tension, R is the radius of warper's beam, r is the ruffle radius, μ is the coefficient of friction between the rope and the ruffle, θ is the angle of wrap (in radian) of the rope over the ruffle, M is the mass of suspended element and g is acceleration due to gravity.

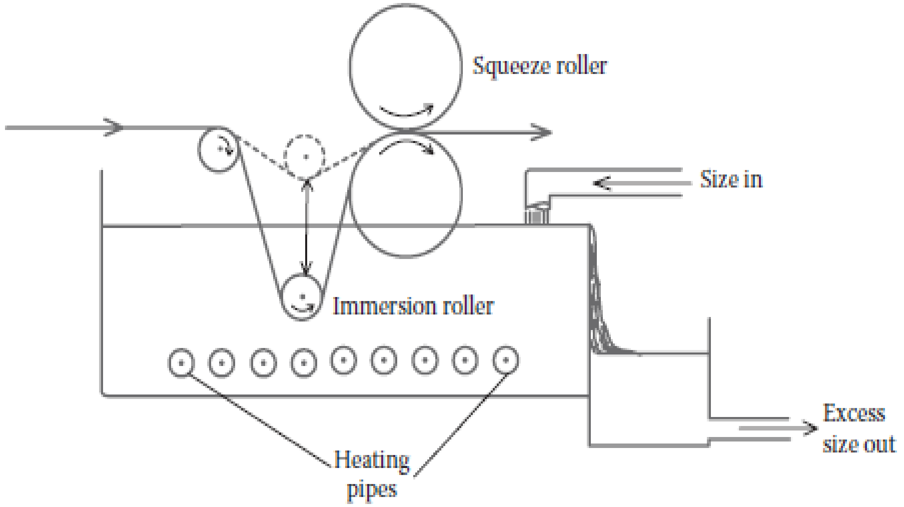
$$T.R = 2.Mg.r.(1-e^{-\mu\theta})$$

In sizing process, the allowable stretch is 1-1.5% for cotton and polyester yarns. The stretch can be higher (3-5%) for viscose and acrylic yarns

Sizing: Size Box Zone

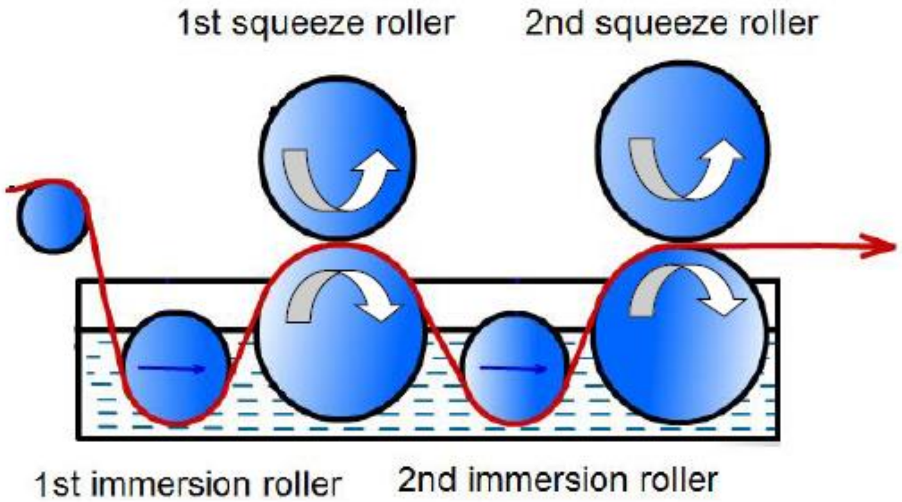
The process of immersion is called ‘dip’ and the process of squeezing by means of a pair of squeezing rollers is called ‘nip’



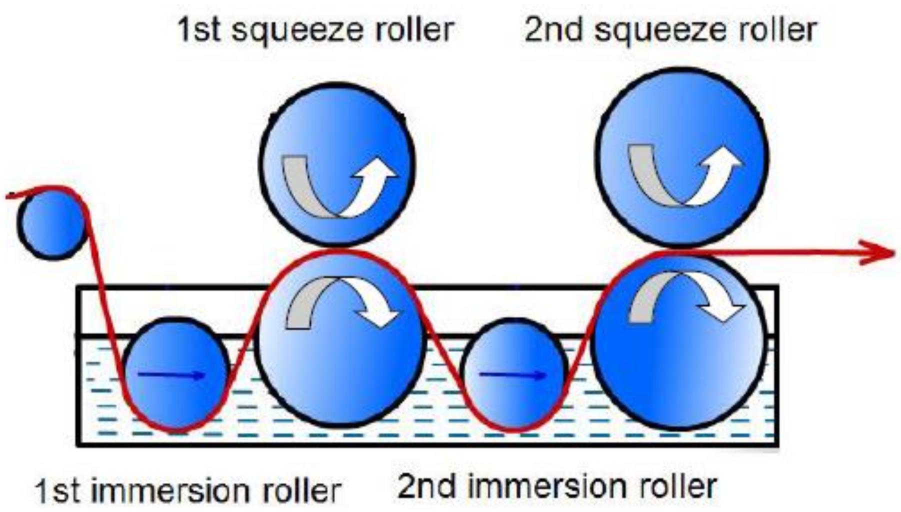


One dip one nip size box

Two dip and two nip process allows grater time for immersion of yarns within the size paste and thus this process forms more uniform coating of size film

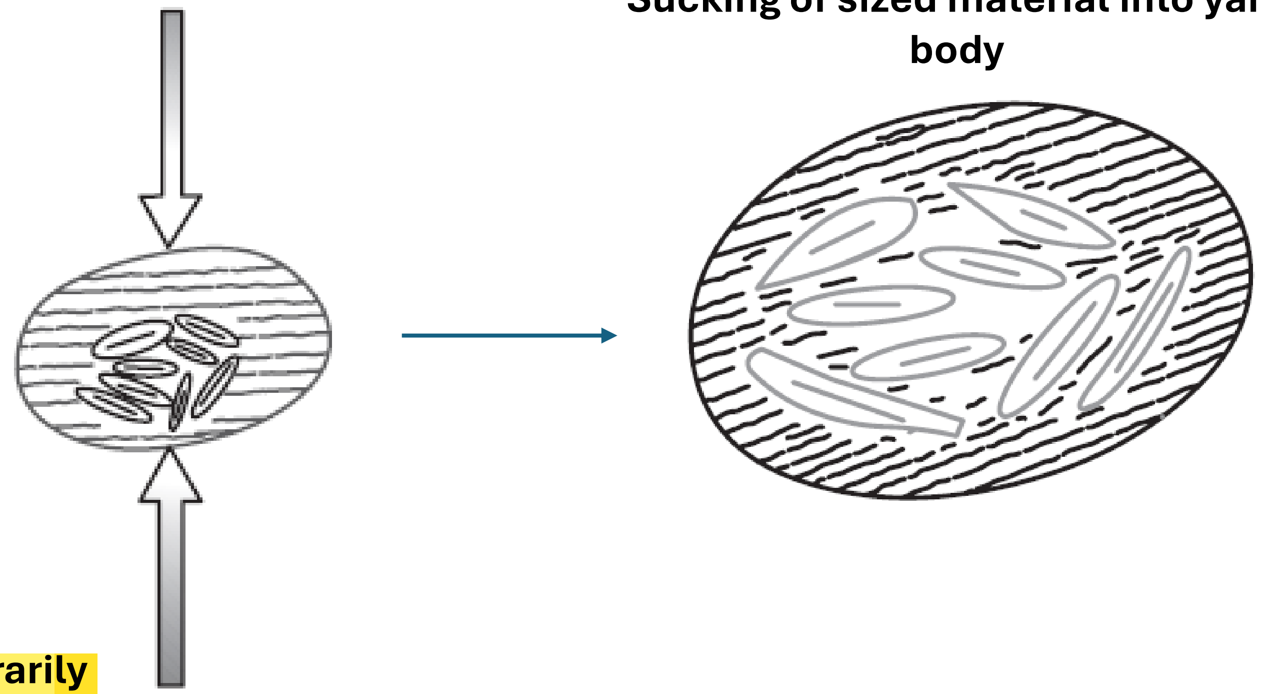


Sizing: Size Box Zone



Two dip and two nip process allows grater time for immersion of yarns within the size paste and thus this process forms more uniform coating of size film

Sucking of sized material into yarn body



Squeezing pressure temporarily flattening sized yarn

Sizing: Size pick up dependence

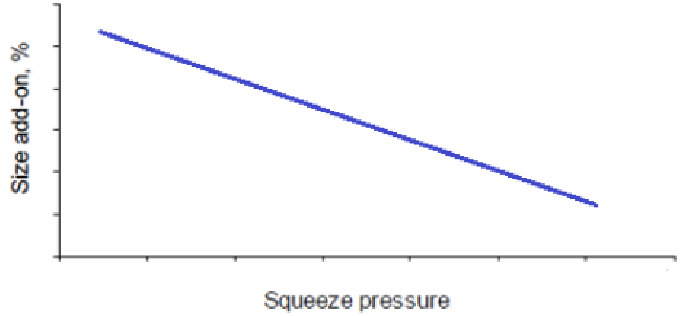
Viscosity of Size Paste

The wet pick-up generally increases with the increase in viscosity. Viscosity also determines the penetration of size paste within the yarn structure. If more penetration is desired then viscosity should be lowered and vise versa.

Squeeze Pressure

The squeeze pressure forces out the excess paste picked up by the warp sheet. Besides, the pressure distributes the paste uniformly over the yarn surface and causes size penetration within the yarn structure

Pressure	Size coating (film thickness)	Size penetration
High	Low	High
Low	High	Low



Hardness of Top Squeeze Roll

If the hardness of the top roller is low, then there will be flattening of the roller. Thus, the contact area increases which effectively reduces the pressure acting at the nip zone. Therefore, the size pick-up increases

Sizing: Size pick up dependence

Thickness of Synthetic Rubber on the Top Roller

If the thickness of synthetic rubber cover on the top roller is greater, then the extent of flattening is more. This will reduce the nip pressure and thus the wet pick-up will increase

Position of Immersion Roller

If the height of immersion roller is lowered, then the residence time of the warp sheet within the size paste increases. This will lead to the increase in wet pick-up if other factors are constant.

Speed of Sizing

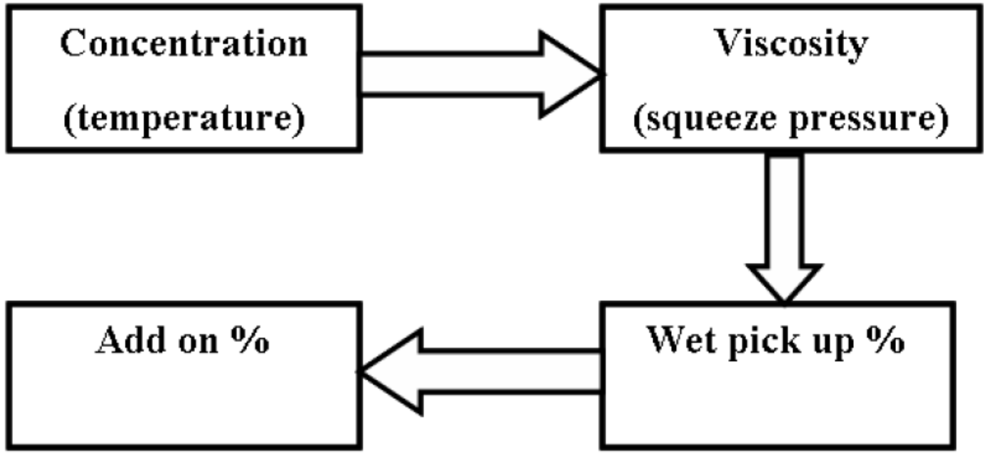
- ❑ Higher speed reduces the residence time of the yarn within the paste which should reduce the wet pick-up.
- ❑ Higher speed increases the drag force between the warp sheet and size paste which should induce more flow of paste with the warp sheet.
- ❑ Higher speed reduces the time of squeezing which should increase the wet pick-up

In modern sizing machine, the practical speed can be around 100 m/min

Sizing: Size pick up

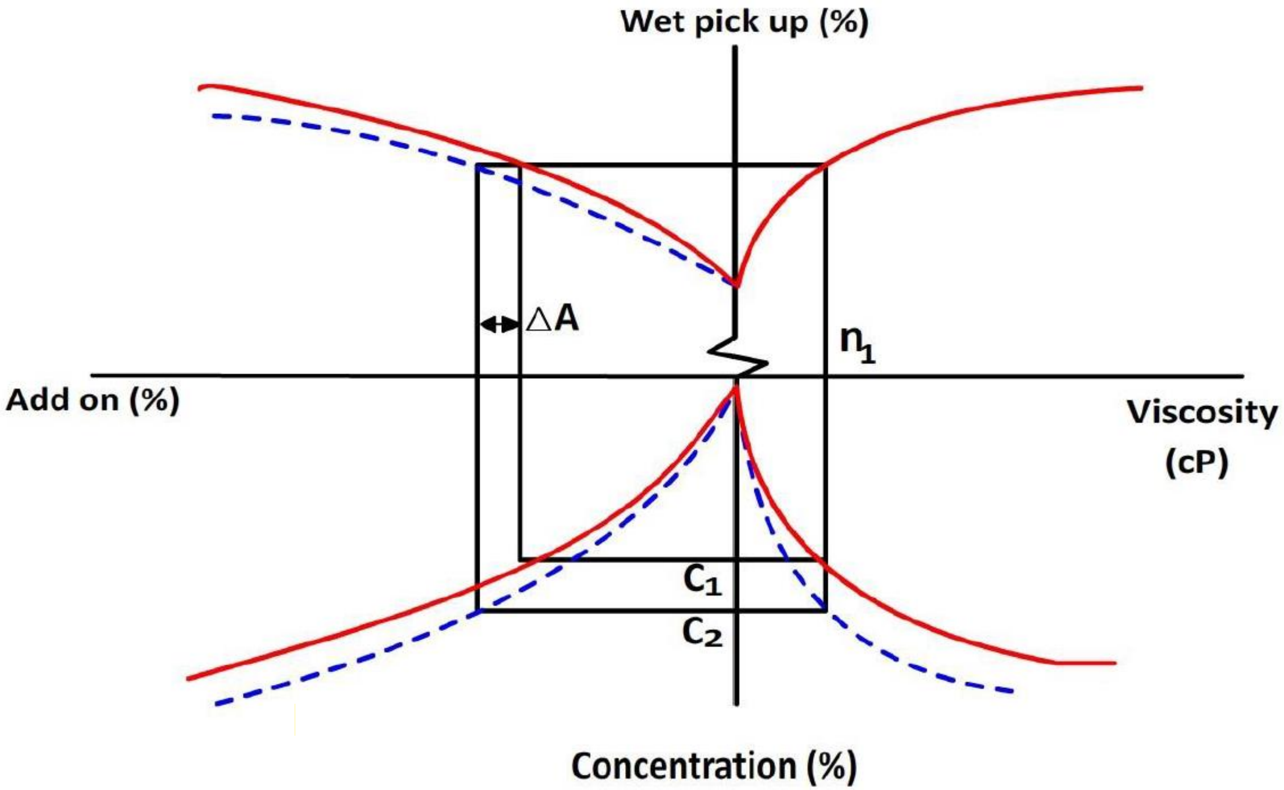
The balance between viscosity and add on

- At a given temperature, concentration of size paste determines the viscosity.
- For a given yarn, squeeze pressure and sizing speed, viscosity of size paste determines the wet pick-up.
- Wet pick-up determines the add-on.
- For a given concentration of size paste, higher wet pick-up leads to higher add-on and vice versa.



Sizing: Size pick up

The balance between viscosity and add on



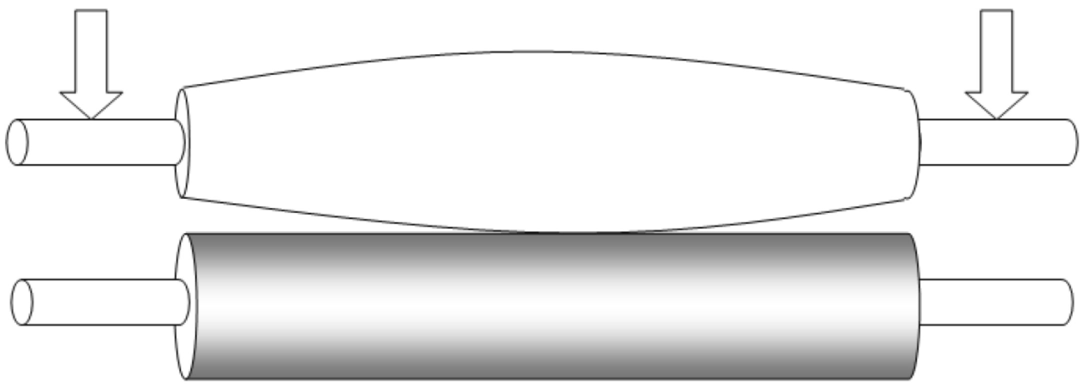
Pressure	Concentration: Low	Concentration: High
High	High pressure Low conc.	High pressure High conc.
Low	Low pressure Low conc.	Low pressure High conc.

The broken line representing the thin boiling starch is positioned below the solid line representing normal starch

Sizing: Some other important factors

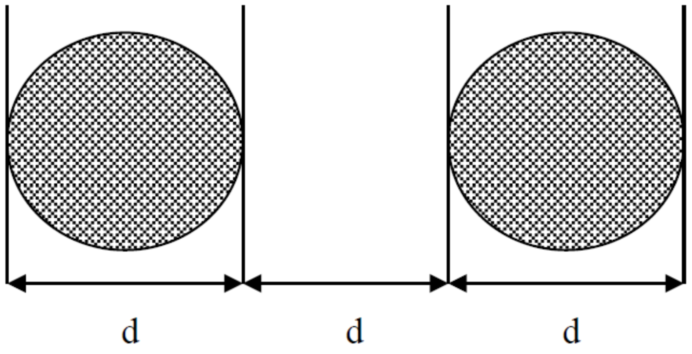
Crowning of Top Roller

To avoid uneven pressure along the nip line



Percent Occupation and Equivalent Yarn Diameter

The relative closeness of the yarns inside the size box is expressed by percentage occupation and equivalent yarn diameter. Equivalent yarn diameter indicates the space between the two yarns in terms of yarn diameter



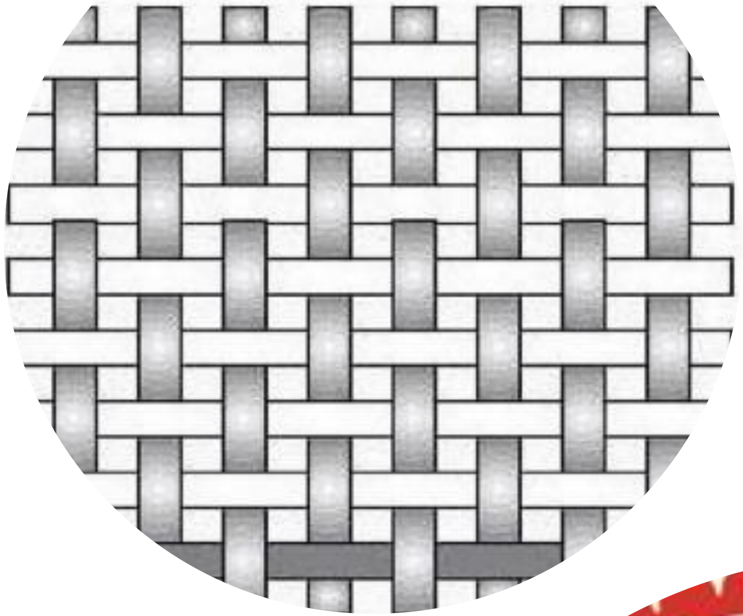
Yarn arrangement for 50% occupation

$$\text{Percent occupation} = \frac{\text{Actual number of yarns in the warp sheet}}{\text{Number of yarns in the warp sheet with 100\% occupation}}$$

$$\text{Percent occupation} = \frac{100}{1 + \text{Equivalent yarn diameter}}$$

If the percent occupation is very high, then the yarn may not be uniformly coated by the size film.

Fabric Manufacturing I (TXL231)



Dr. Sumit Sinha Ray

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Sizing: Drying zone

The drying operation is very crucial because of the following reasons.

- It consumes most of the energy of sizing process
- Inadequate drying will cause sticking of yarns with one another causing problem in weaving
- Over-drying will make the size film brittle and therefore they may fall apart by minimum abrasion.

Mass (kg) of water to be evaporated per unit oven dry mass (kg) of yarn

$$= \left(\frac{\text{Add on \%}}{\text{Concentration \%}}\right) - \left(\frac{\text{Add on \%}}{100}\right)$$

wet pick-up

This equation presumes that there is no residual moisture in the sized yarn after drying

For a running machine it is important to calculate the mass of water to be evaporated in unit time (minute)-

- Sizing machine speed
- Total number of yarns
- Linear density of yarns (Tex)
- Add-on %
- Concentration %

Sizing: Drying zone

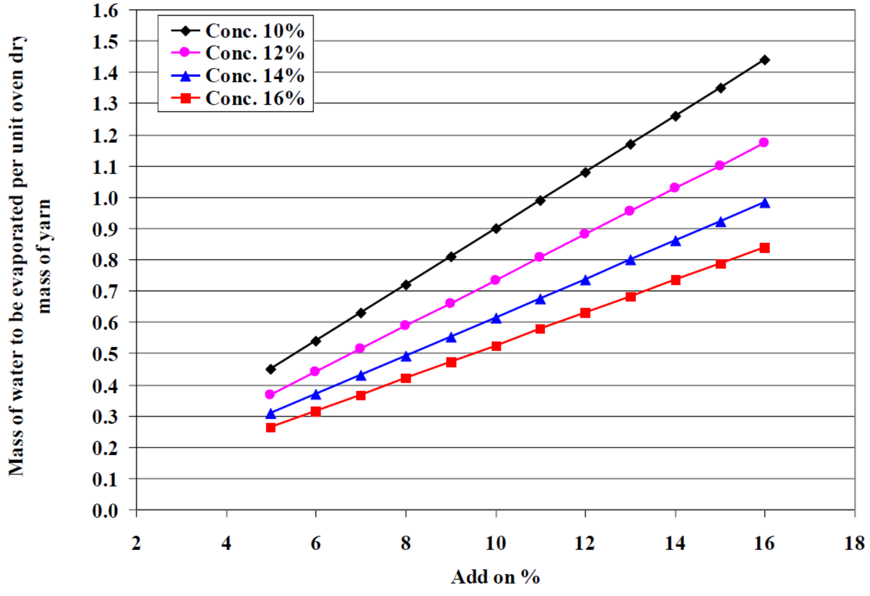
The mass of yarn passing through the machine per minute

$$= \frac{\text{Sizing machine speed (m/min)} \times \text{Total number of yarns} \times \text{tex}}{1000 \times 1000} \text{ kg}$$

The mass of size paste pick up per minute

$$= \left(\frac{\text{Sizing machine speed (m/min)} \times \text{Total number of yarns} \times \text{tex}}{1000 \times 1000} \times \text{wet pick up} \right) \text{kg}$$

$$= \left(\frac{\text{Sizing machine speed (m/min)} \times \text{Total number of yarns} \times \text{tex}}{1000 \times 1000} \times \frac{\text{add on \%}}{\text{concentration \%}} \right)$$



The mass of water to evaporated per minute

$$= \frac{\text{Sizing machine speed (m/min)} \times \text{Total number of yarns} \times \text{tex}}{1000 \times 1000} \times \frac{\text{add on \%}}{\text{concentration \%}} \times \left(1 - \frac{\text{Concentration \%}}{100} \right) \text{kg}$$

Both sensible heat and latent heat to be considered here-

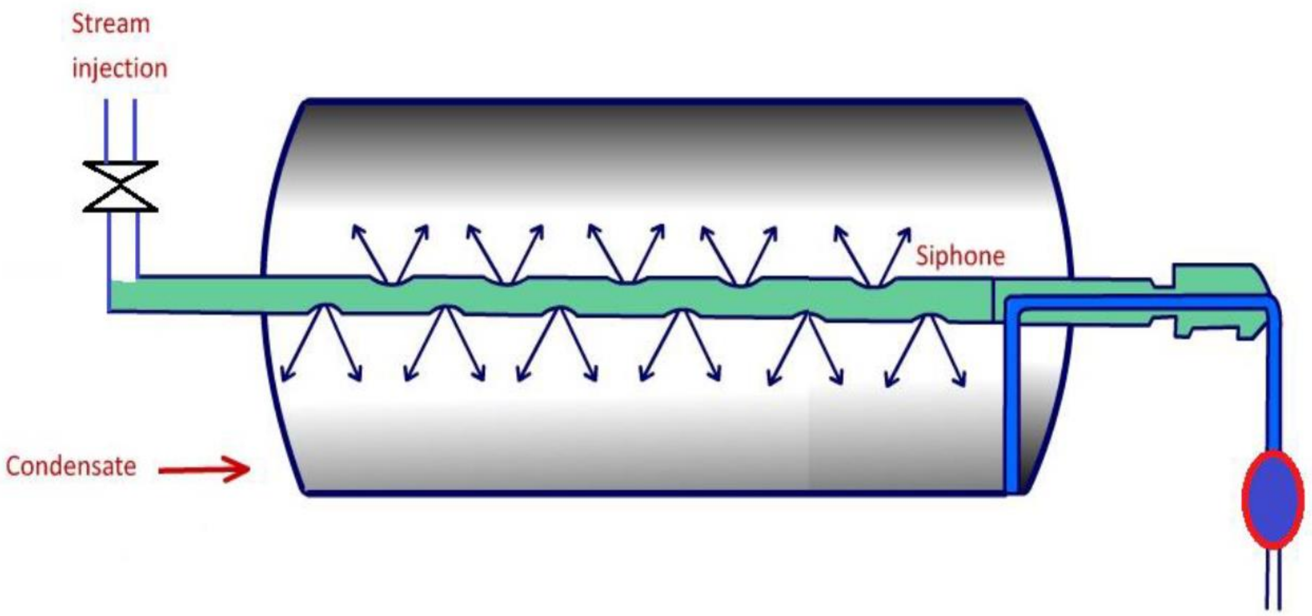
1. **Sensible- to raise the yarn temperature up to water evaporation**
2. **Latent- For the actual evaporation**

Sizing: Drying zone

The methods of drying in sizing process can broadly be divided in two categories-

1. Conduction
2. Convection

In **conduction method** the warp sheet is passed over a metallic cylinder which is heated by using superheated steam. Heat exchange takes place between the wet warp sheet and heated cylinders and in the process the warp sheet is dried

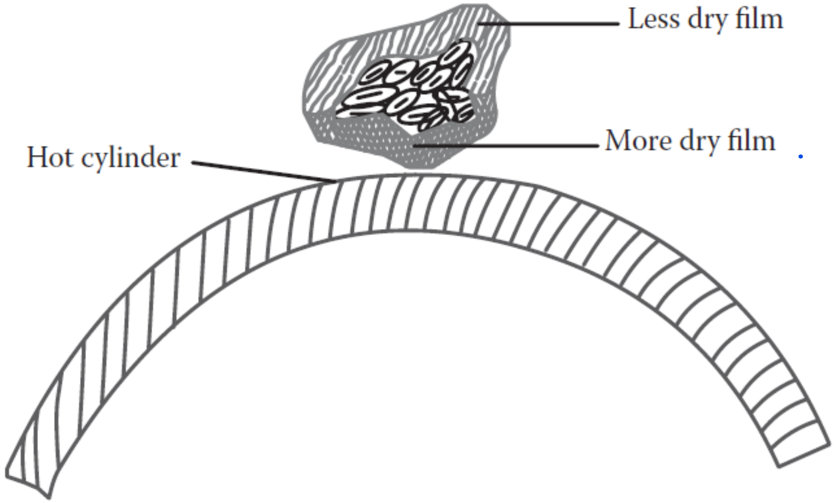


Q'= kA(dT/dx)

Sizing: Drying zone

Some issues with this method-

- Part of the heat energy of steam/gas is spent in heating the metallic cylinder up to the required temperature
- Direct contact between a size film– coated yarn sheet and the hot cylinder causes a localized instantaneous drying of the portion touching the cylinder. This causes a moisture gradient



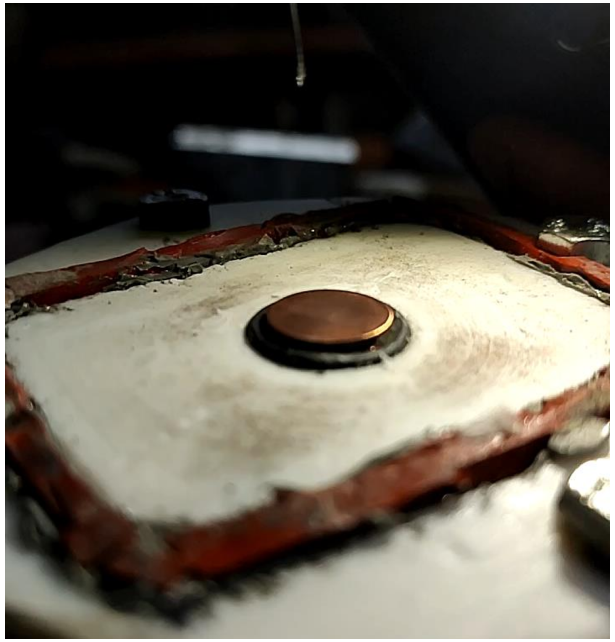
Alternative-

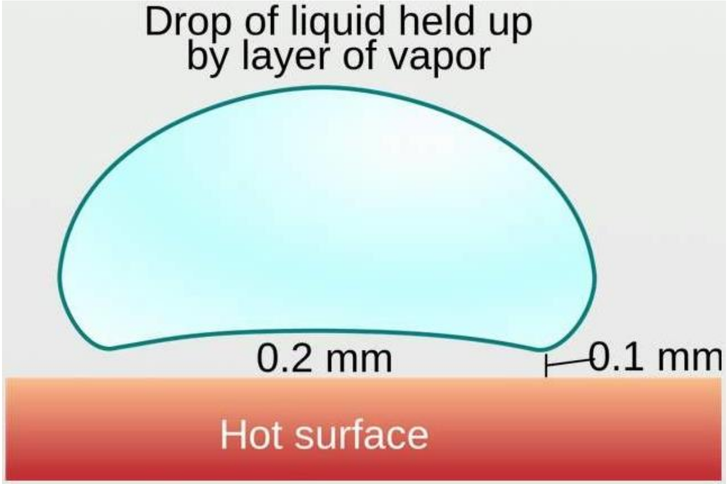
- Dry the two sides of yarn alternately in many small steps, a strategy adopted in multicylinder drying systems (eight cylinders arranged in two blocks of four)
- The wet yarn sheet is initially split into two layers while entering the first block (pre-drying) and then rejoined again in next block)

Sizing: Drying zone

Wet-splitting is preferred, because-

- A continuous coat of size film develops around each yarn
- If the yarns are fully dried in this state, then the subsequent splitting zone would become redundant
- Sufficient space between two adjacent yarns lowers the vapor pressure, thereby facilitating evaporation and helps in avoiding steam blanket





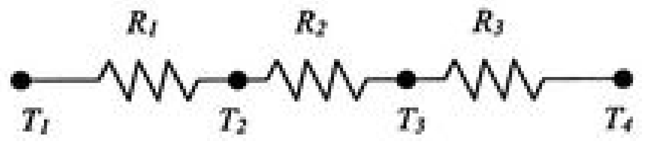
Sizing: Drying zone

At the instant of detachment of the warp sheet from the first drying cylinder, the size film surrounding each yarn would still be wet and soft, else it will get brittle locally and peel off.

The first few drying cylinders are coated with PTFE (polytetrafluoroethylene), because-

1. Very low coefficient of friction of PTFE
2. High thermal stability
3. Low thermal conductivity (1/100th of steel but 10 times of air)

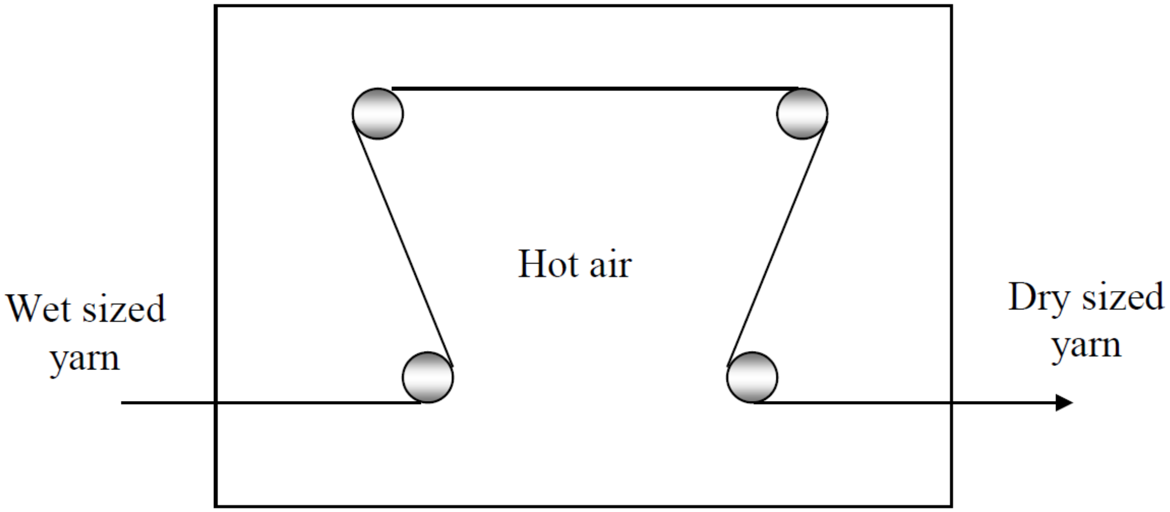
But the thermal energy of steam injected into the cylinder is wasted considerably in overcoming the combined resistance of a layer of condensate on the inner wall of the cylinder, the wall of the cylinder itself, and the layer of PTFE.



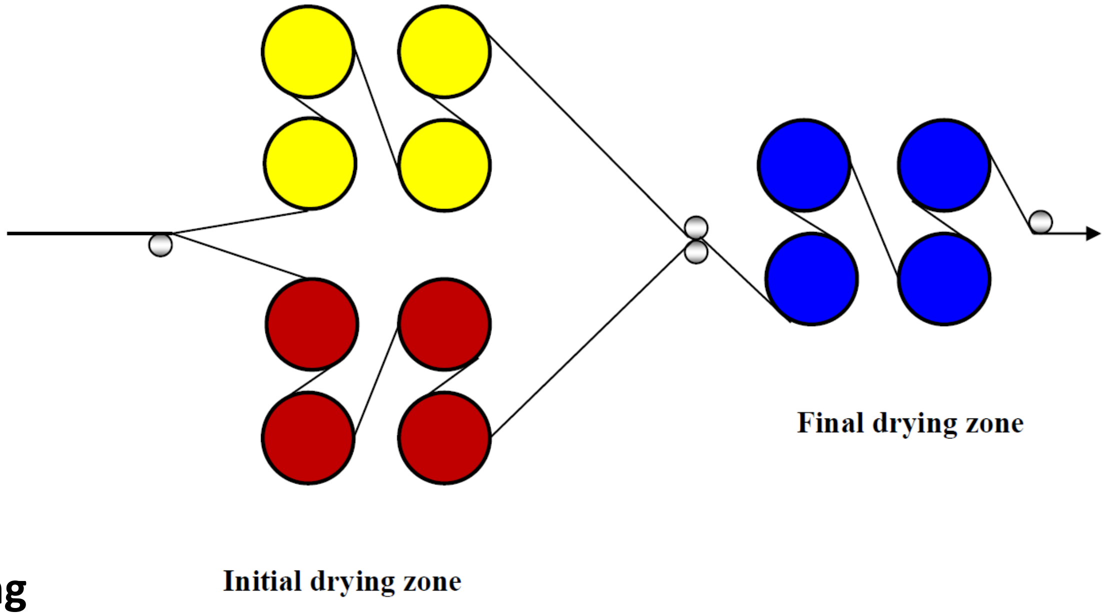
Can be overcome with hot air

Sizing: Drying zone

Convection system



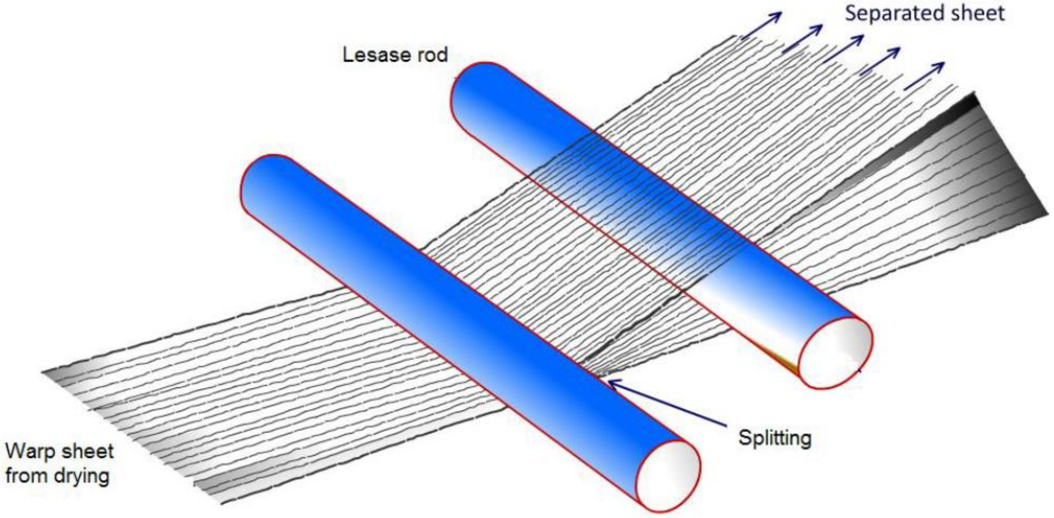
Q'= hAdT



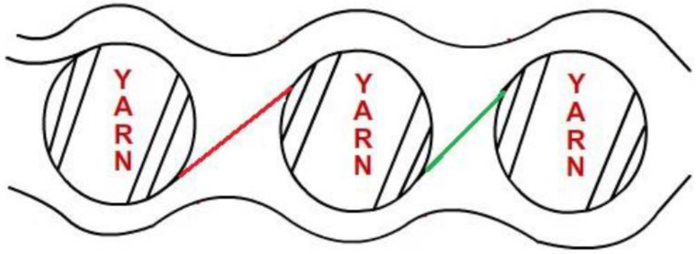
Two-zone drying

Sizing: Splitting

Splitting of warp sheet



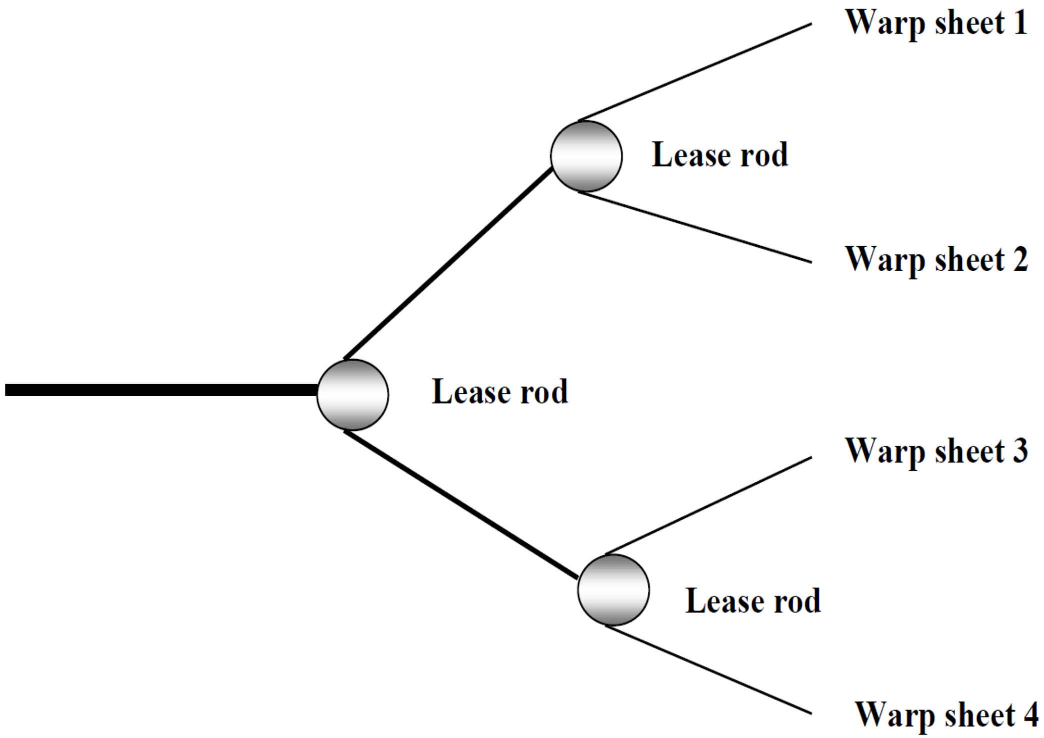
Function of lease rods is to separate the individual yarns which are stuck together by dried size. During the splitting some amount of size film would be dropped as waste. However, many longer fibres, bridging two adjacent yarns would also get broken into smaller pieces.



Before splitting

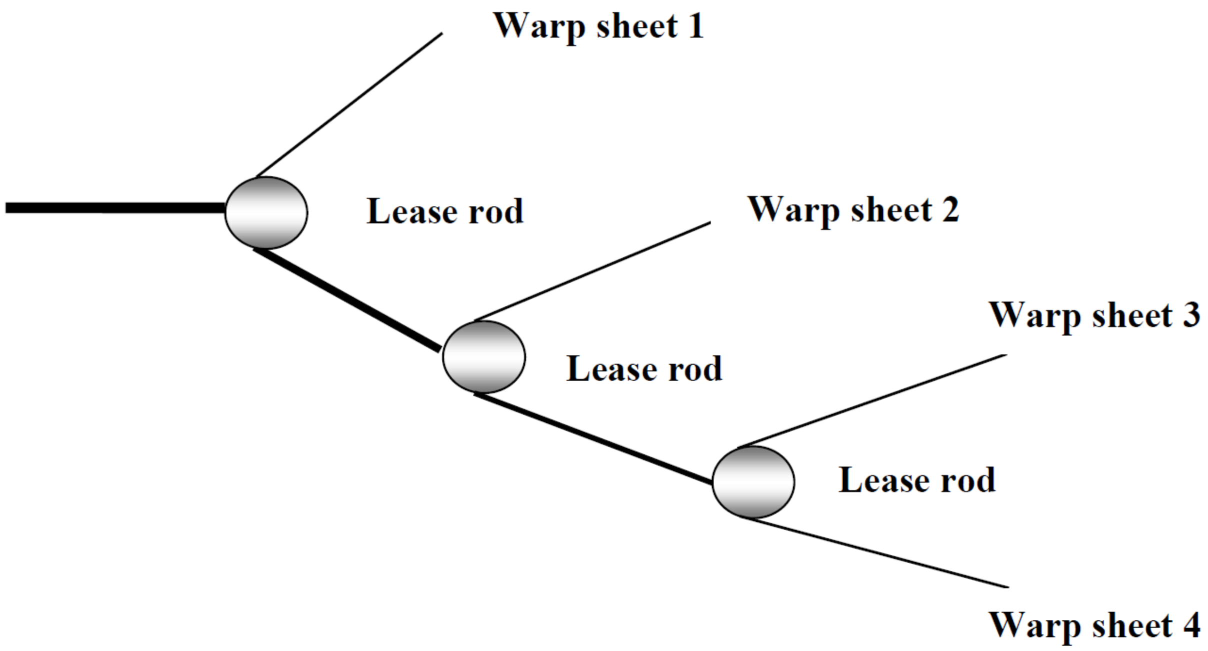
After splitting

Sizing: Splitting



Splitting of sized warp sheet into equal parts

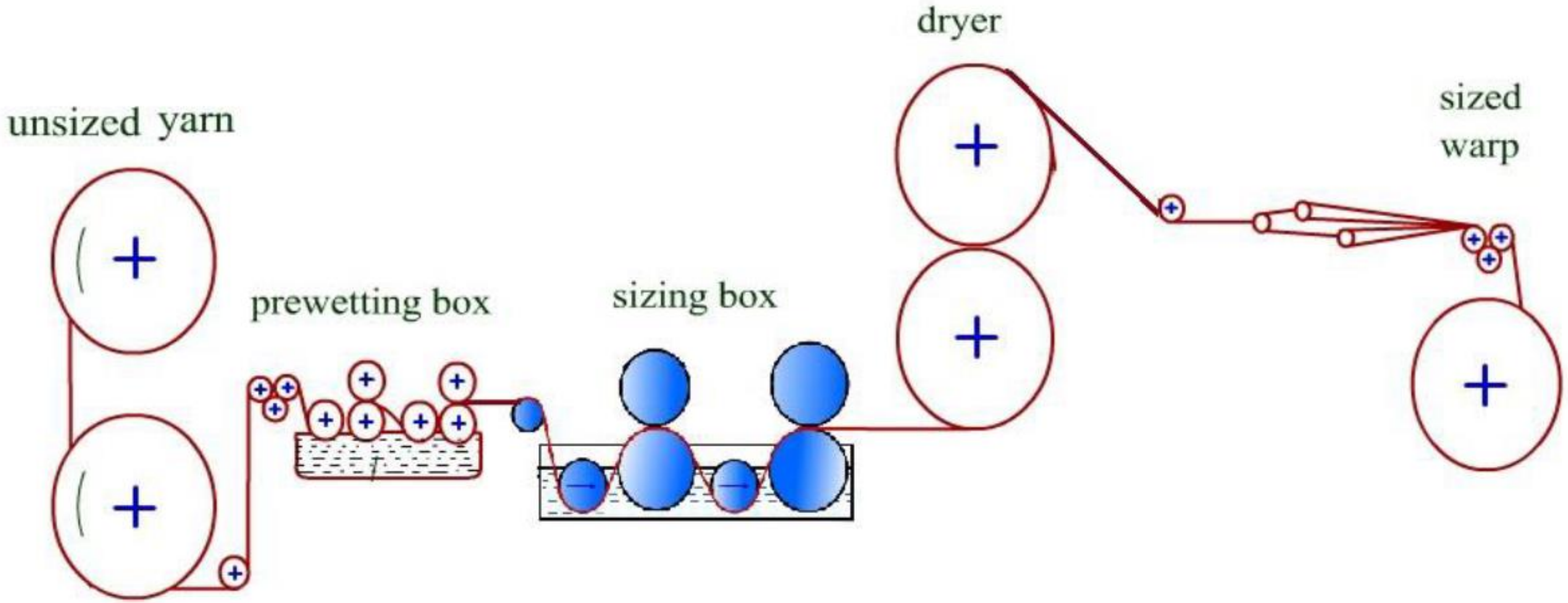
Splitting of sized warp sheet into unequal parts



Sizing: With pre-wetting

The advantages of pre-wetting are-

- Reduction of size ingredient consumption up to 50%
- Increase in yarn strength
- Reduction of yarn hairiness
- Improvement of loom efficiency



Sizing: Example problem

A 40 tex cotton yarn has add-on of 8%. If the moisture regain of the warp is 10% then determine the oven-dry mass of the size added per kg of the unsized warp.

Size add-on = 8%, Moisture regain = 10%

So, $\frac{W}{D} \times 100 = 10$, where W= mass of water and D = oven dry mass of yarn

or, $W = 0.1D$

Let, total mass of unsized yarn = 1 kg

So, $D+W$ = 1 kg, or, $D+0.1D$ = 1 kg

or, D = 0.909 kg

Now, add-on is 8%.

So, $\frac{\text{Oven dry mass of size}}{\text{Oven dry mass of yarn } (D)} \times 100 = 8$

or, Oven dry mass of size = D x 0.08 = 0.073kg = 73 g.

So, oven dry mass of size per kg of unsized warp is 73 gram.

Sizing: Example problem

A sizing machine is running at 150 m/min with 6000 ends. The add-on requirement is 12% and concentration of the size paste is 18%. If yarn count is 20 tex (without any moisture) and residual moisture content in the sized yarn and film after drying is 10%, then calculate the number of drying cylinder required. One drying cylinder can evaporate 4 kg water per min.

$$\text{Oven dry mass of warp passing through the machine / min} = \frac{150 \times 6000 \times 20}{1000 \times 1000}\ \text{kg} = 18\ \text{kg}$$

$$\text{Wet pick up } (WPU) = \frac{\text{Add on \%}}{\text{Concentration \%}} = \frac{12}{18} = 0.667$$

Total mass of size paste picked up by the warp= $WPU \times$ Oven dry mass of warp

$$= \frac{12}{18} \times 18\,\text{kg} = 12\ \text{kg}$$

Oven dry mass of size = Mass of size paste ×concentration = 12 ×0.18

Total oven dry mass of warp and size = (18 + 12×0.18+) kg = 20.16 kg

For moisture content of 10%, mass of water to be retained in warp and size film

$$= \frac{1}{9} \times 20.16\,\text{kg} = 2.24\ \text{kg}$$

$$\text{Mass of water in picked up size paste of 12 kg} = 12 \times \left(\frac{\text{100-Concentration\%}}{100}\right) = 9.84\ \text{kg}$$

So, water to be evaporated per minute = (9.84 - 2.24) kg = 7.6 kg

Drying capacity of one cylinder = 4 kg/min.

Number of cylinders will be = 7.6/4 ≈ 2.

Quiz 1: TXL 231- Fabric Manufacturing I **Date: 05.02.2024** **Time: 30 minutes**

Name: **Entry No.:**

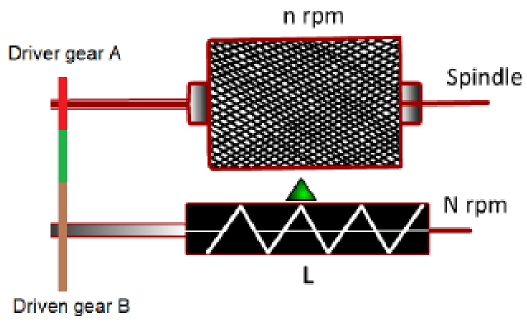
Use your own calculator
Unfair means will result in cancellation of examination
Answering any question without justification/necessary calculation will fetch no points
Every unit mistake will result in 0.5 mark deduction every time

Q1. As a rule of thumb, we expect that diameter of a cotton yarn, with packing factor of 0.6, d= $1/28(Ne)^{0.5}$ [where, Ne= 840 yards or 30240 inches in 1 pound or 453.6 gm]. If the cotton yarn has a packing factor 0.55, amend the above-mentioned relation (density of yarn 1.5 g/cm^3] (2)

Q2. Considering the new relation, find the fabric cover factor including warp (K_1) and weft (K_2) cover factors. (2)

Q3. What are the basic principles of yarn clearing instruments during winding processes? Differentiate them based on two areas where one should use a particular mechanism. (2+1)

Q4. Show that for spindle driven winder, the traverse ratio remains constant. (3)



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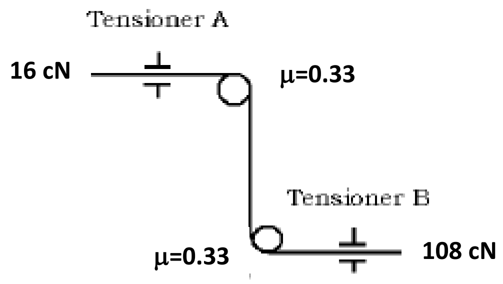
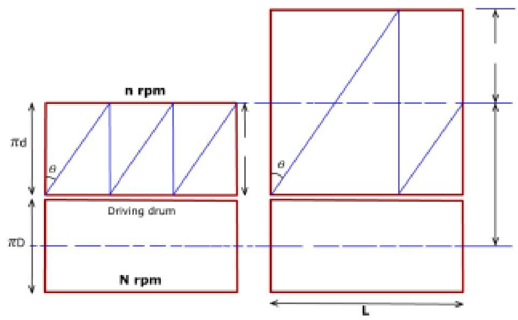
Q2. The tensioning system shown in the bottom Figure is being used in a winding system. The input and output tensions are 16 cN and 108 cN respectively. If disc (additive) type tensioners A and B are identical then calculate the weights used in tensioners A and B. (3)



Q3. Show that for drum driven winder, the traverse ratio reduces with the increase in package diameter. (3)



Q4. Differentiate between direct and sectional warping (use 4 points) (2)

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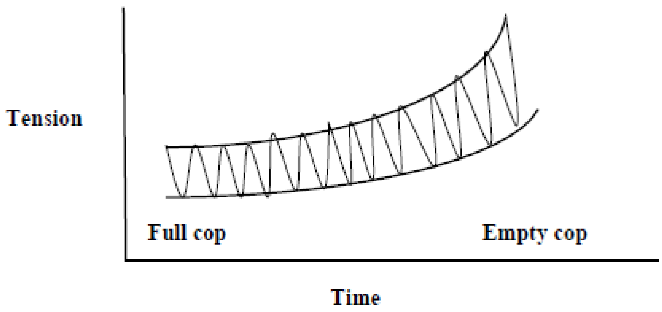
Q2. During Pirn unwinding we get to see a short- and long-term tension variation as per the image given. Provide the rationale for both kinds of tension variation in the pirn. [Use the tension variation relation to justify your answer] (1+1+1)



Q3. The empty diameter of a spindle-driven cylindrical package is 5 cm. The spindle speed is 1500 r.p.m. and traverse velocity is 100 m/min. Determine-

a) Winding speed and angle of wind at the start

b) Winding speed and angle of wind when package diameter becomes double (1.5+1.5)