Fibre

Any raw material that has hair like appearance or has a tapered elongated shape is called as a fibre. The fibre has a length that is at least one thousand times than its thickness. This high ratio of length to its thickness is responsible for its peculiar hair like appearance.

Fibres occur naturally or they can be artificially produced by using chemicals. Not all the fibres are suitable for the production of textile goods i.e. yarns and fabrics.

Textile Fibre

A textile fibre is the basic unit of raw material for making a yarn. The textile fibres must have a suitable length, pliability, fineness and strength that is necessary for their conversion into yarns and fabrics. A fibre having an extreme length is called as a filament.

Yarn

Yarn is a continuous strand composed of either natural or manmade fibres or filaments and is used in weaving and knitting to produce a cloth.

OR

A yarn is defined as a product of substantial length and relatively small cross-section consisting of fibres and / or filament(s) with or without twist.

(Textile Institute)

Spinning

Spinning may be defined as the process of converting fibres and / or filament(s) into a yarn.

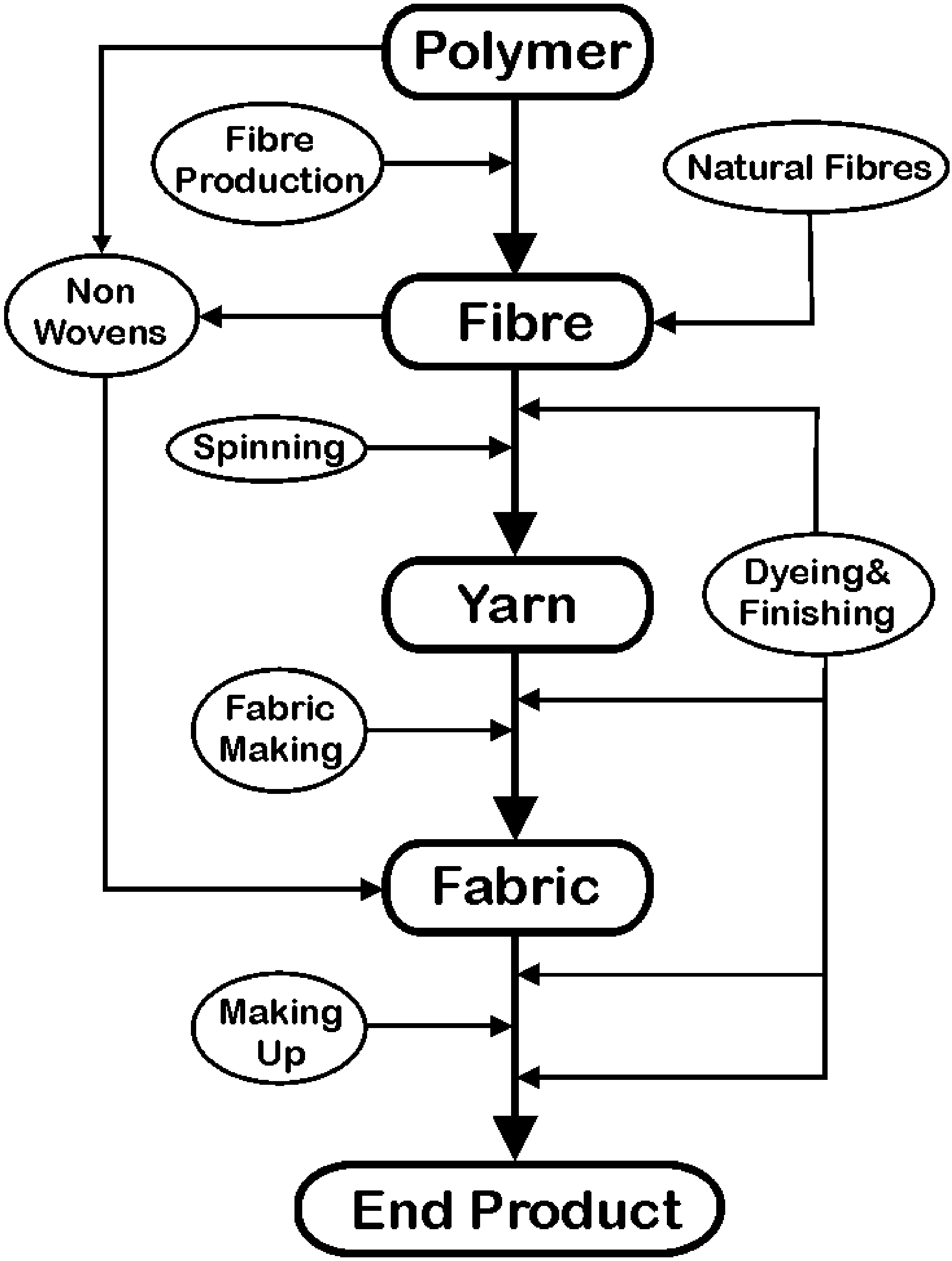
In the production of manmade fibres, the extrusion of the fibre forming liquid through the spinnerets followed by hardening of these liquid jets into solid filaments is called as the process of spinning.

The meaning of the term spinning in this case may be completely different from that used for natural fibres. Generally we can define spinning as a process that produces a yarn as its final product. The spinning of manmade fibres can be carried out by three different methods:

(i) Wet Spinning.
(ii) Dry Spinning.
(iii) Melt Spinning.

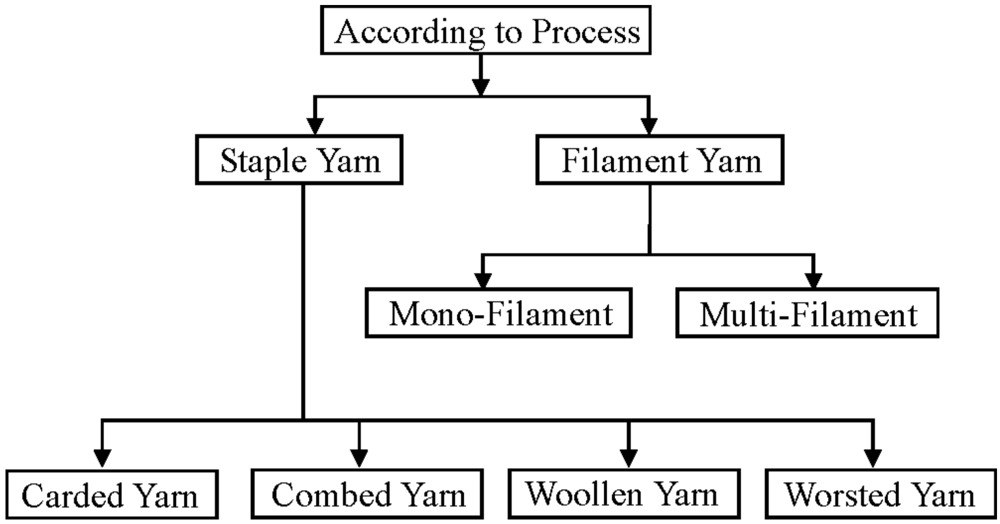
These different types of spinning methods are used based on the properties of the fibre forming substance. For example in order to spin Viscose Rayon, wet spinning is used and for Nylon we use the melt spinning. Some fibre forming substances can be spun by using more than one type of the above mentioned spinning techniques.

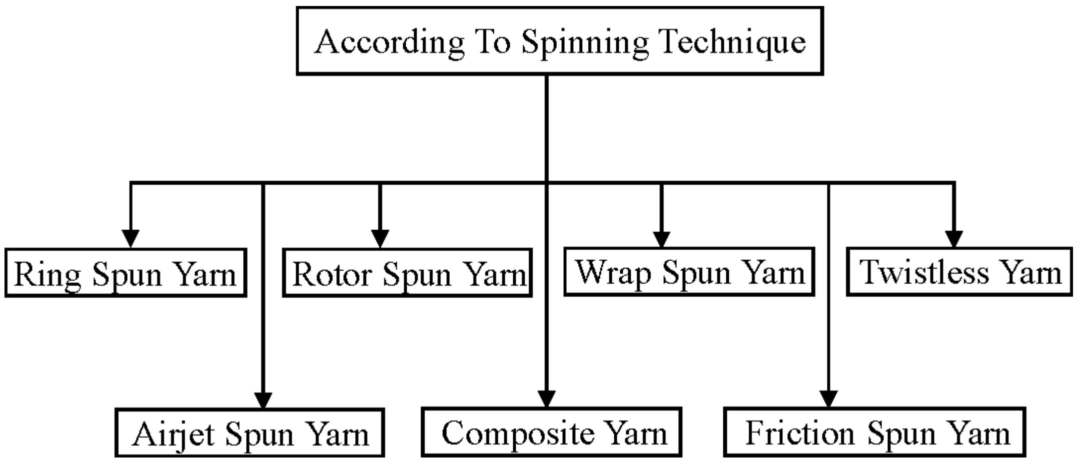
The Making of a Textile Product

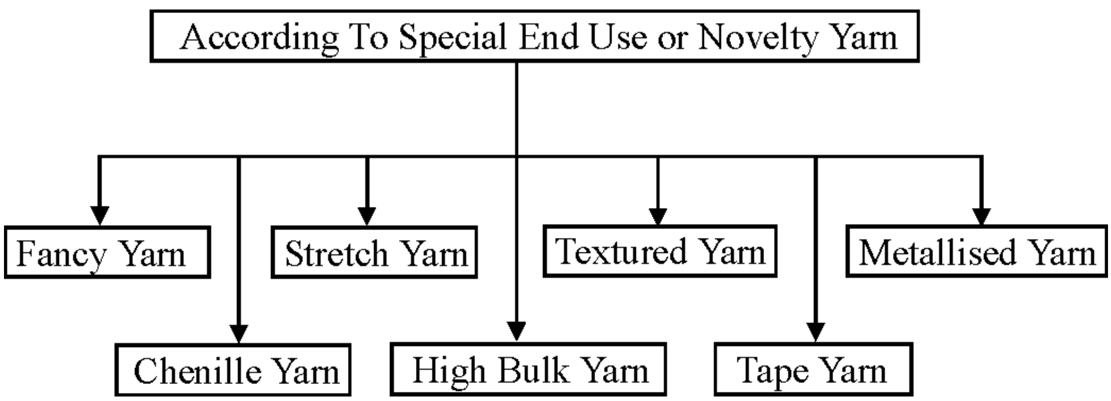


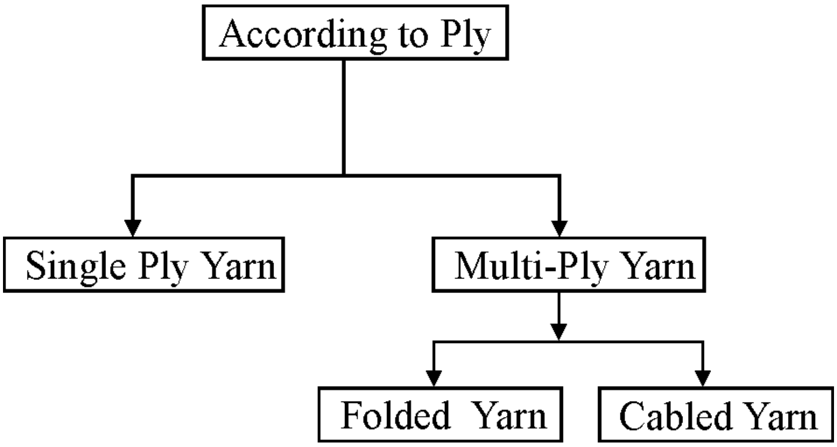
Yarn Classification

There is no limit of the range of yarns that can be produced by various types of spinning processes. So it is difficult to classify various types of yarns on a single basis. Yarns can be classified on various grounds.









<u>Fibre Properties That Can Influence Spinning</u>

In general there are numerous fibre properties that are important to consider as these properties have a large influence on the final end product produced from it. It is also important to know every detailed fibre property because it helps us to decide the type processes that should be used for a particular fibre. However strictly speaking from spinning viewpoint the most important fibre properties that determine the spinning ability are:

(1) Fibre Staple Length
(2) Fibre Fineness
(3) Fibre Strength

(1) <u>Fibre Staple Length</u>

Length of the fibre is the most important property that determines the quality and value of the fibre and it also determines its spinning ability. Most natural fibres have a length ranging from ¼″ to about 3″. But the silk fibre made by silkworm is in a continuous filament form that can have a length of up to 2 kilometres. Apart from silk the all the natural fibres are valued from their staple length, greater the staple length greater will be their value. The staple length of the natural fibres obtained from a same source can vary. So the actual staple length given to the fibre is the length of the majority of the fibres in a lot.

On the other hand the synthetic fibres can have unlimited length in a filament form or they can be cut into a desired staple length. This is true because they are produced chemically in laboratories. Synthetic fibres either in filament or staple form will have perfect uniformity of length among themselves.

Staple length of fibres play important role in their conversion to a yarn. In general the longer the individual fibres easier it is to convert them to yarn due to the fact that long fibres will have to overlap at less frequent points as compared to short fibres and that is the reason that longer fibres can easily be spun into a yarn with less twist. Furthermore it takes less twist to convert long fibres into a yarn as compared to short fibres.

(2) Fibre Fineness

The fineness of the fibre is also an important parameter that controls spinning ability of the fibres to be converted into a yarn. Finer the individual fibres are, the finer the yarn can be made out of it. A yarn spun with finer fibres will have more number of fibres per unit cross-section as compared to a yarn having coarse fibres. This considerably increases the cohesion among the fibres within the yarn. Also the fine fibres tend to be more flexible and pliable than the coarse ones, which enables them to be spun more effectively into a yarn.

The measure of fineness of the fibres that is how thick or thin they are, is expressed in terms of fibre count. The direct method of measuring fineness or the count of the fibre is to express the thickness or diameter of the fibre in terms of microns, where 1 micron = 0.001 mm.

More practically, the count of the fibre is expressed in terms of mass per unit length i.e. the linear density. The linear density is expressed in terms of milligrams per kilometer (millitex unit), grams per kilometer (Tex unit), grams per 9000 metres (denier unit). Sometimes the mass per unit length is also expressed in grams per centimeter (usually in 10^{-8} grams / cm).

(3) Tensile Strength

The tensile strength of a textile fibre is the ability of a fibre to resist a stretching load when applied in the longitudinal direction. Whenever a pulling or a stretching load is applied to a textile fibre, it starts elongating. As the load applied to it gradually increases, a point comes when the fibre is no longer able to resist that load and it breaks. In this way the tensile strength of a fibre is found out. The tensile strength of a fibre is also called as the breaking load i.e. the load under which the fibre breaks.

In case of a single fibre, the strength of the fibre is better expressed in terms of tenacity. Tenacity can be defined as the ratio of the breaking load to the mass per unit length and is also a measure of specific stress at break.

$$\text{Tenacity} = \text{Breaking Load} / \text{Mass per unit length}$$

Tenacity is usually expressed in grams per tex, grams per decitex, grams per denier, centiNewton per Tex (cN/Tex).

It may be noted that two fibres with the same tenacity can have different tensile strength depending upon their densities or cross-section area.

The maximum achievable strength of the yarn is dependent upon the strength of individual fibres.

Yarn Dimensions

There are number of parameters that can describe a yarn, however following are the most important yarn properties:

(1) Yarn Count
(2) Yarn Twist
(3) Yarn Strength

(1) Yarn Count

The yarn count or the yarn number is the relationship between the mass and the length of the yarn. Yarn count or yarn number actually describes the linear density of a yarn i.e. mass per unit length. In simpler words, the yarn number is the measure of thickness of yarn. There are two types of yarn numbering systems :-

(i) Indirect System
(ii) Direct System

(i) Indirect System

The indirect counting system is also known as the English counting system. It is an old system of yarn counting or numbering and is only used for natural fibres like cotton, jute, wool, flax, etc.

This system is called as indirect because here the yarn count has an indirect relationship with its weight. Which means that as the count increases, the yarn becomes finer.

In this system, the weight is kept constant while the length is variable and the number of hanks that weighs a unit weight gives the indirect count.

Indirect Count = Length / Weight

The most commonly used Indirect numbering systems are :-

(a) Cotton System
(b) Metric System or Continental System

(a) Cotton System

The Cotton count may be defined as the number of hanks per pound. Where one hank is a specific length of a yarn, for cotton fibres, it is 840 yards.

Cotton Count = Number of Hanks / 1 Pound

Although this Counting system can be used for many natural fibres, but still it is known as cotton system because it is mostly used for cotton fibres.

The hank length for different fibres is different depending upon the nature of the fibre. Different hank lengths for different fibres are given below :-

Nature of Fibre	Hank Length
Cotton	840 Yards
Spun Silk	840 Yards
Wool	256 Yards
Worsted	560 Yards
Linen	300 Yards
Jute	14400 Yards

(b) Metric System or Continental System

The Continental system is similar to cotton system and can be defined as the number of hanks per kilogram. Here the hank length is fixed at 1000 metres.

Continental Count = Number of Hanks / 1 KG

(i) Direct System

The direct numbering system is also called as French numbering system. It is a modern counting system which can be used for both natural and manmade fibres. This system is called as the direct system because here the yarn count has a direct relationship with its weight and is given by :-

Direct Count = Weight / Length

In the direct system, the length is kept constant, while the weight varies. Since the yarn has a direct relationship with its weight therefore, as the count increases, the yarn becomes coarser.

There are many direct numbering systems, the most widely used are :-

(a) Denier
(b) Tex
(c) Grex

(a) Denier

Denier count is the number of grams per 9000 metres of a yarn.

Denier Count = Number of Grams / 9000 Metres

It means that the weight of 9000 metres of yarn gives the Denier count.

(b) Tex

Tex count is the number of grams per 1000 metres of a yarn.

Tex Count = Number of Grams / 1000 Metres

It means that the weight of 1000 metres of yarn gives the Tex count.

(c) Grex

Grex count is the number of grams per 10,000 metres of a yarn.

Grex Count = Number of Grams / 10,000 Metres

It means that the weight of 10,000 metres of yarn gives the Grex count.

Conversion Factor

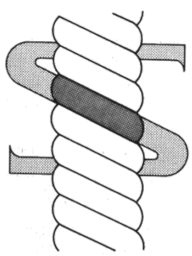
The indirect or English number can be converted into direct or French number by using the following relations :-

(1) Cotton Count x Tex Count = 590.5
(2) Cotton Count x Grex Count = 5905
(3) Cotton Count x Denier Count = 5315
(4) Denier Count = 9 x Tex Count

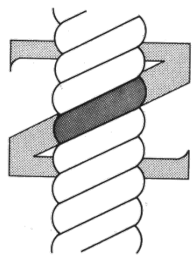
(2) Yarn Twist

The short staple fibres are always twisted together during the process of spinning to produce a yarn. The twist is actually given to bind the fibres together as a yarn and to give yarn strength. The amount of twist not only directly affects the strength of the yarn; it also affects lustre, abrasion resistance, handle, absorbency and flexibility.

The twist during spinning is inserted by rotating the fibre strand in either clockwise or counter clockwise direction. The direction of the twist is defined by using the letters 'S' and 'Z'. The 'S' twisted yarn is the one in which the direction of the twist or the spiral of the yarn is parallel to the centre bar of the letter 'S'. Similarly the 'Z' twisted yarn has its twist direction parallel to the centre bar of the letter 'Z'. A spindle rotating counter clockwise will produce 'S' twist while the spindle rotating clockwise will result in 'Z' twist.



S-Twisted Yarn



Z-Twisted Yarn

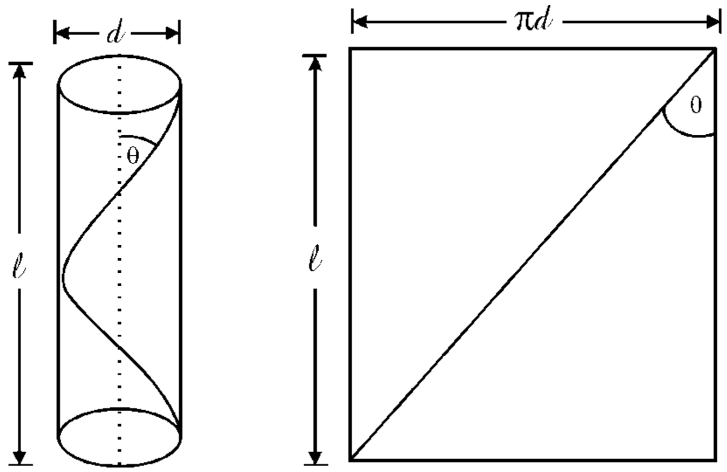
The direction of the twist is very important in folded and cabled yarn where the direction of the twist of the individual thread and the direction of twist of folding and cabling affects the properties of the resultant yarn. The direction of twist of the yarn can also affect some woven fabric structures like twill weaves.

The majority of the cotton spun yarns are 'Z' twisted this is due to the fact that most of the spinning equipment are designed for producing 'Z' twisted yarns because such an equipment will favour a right-handed person as he does the necessary repairing and maintenance of machine parts.

The amount of twist in a yarn is expressed in terms of turns per unit length usually in turns per inch (tpi), turns per centimetre and turns per meter. The yarn with a low twist will be weaker, softer and bulkier. In general to hold and to give strength to short fibres more twist is required.

As the degree of twist in a yarn increases the strength of the yarn also increases. However when the amount of twist is further increased beyond an optimum value then on further increase of twist, the strength of the yarn decreases. This is due to the fact that with an excessive twist, the fibres tend to be more perpendicular than parallel to the length of the yarn i.e. they loose their linear orientation and also because with an excessive twist fibre breakage occurs.

Assuming the yarn as a perfect cylinder, consider a yarn having a length (ℓ) and diameter (d) with only one turn of twist inserted into it. If the yarn is cut from the centre and is laid flat then it would look like a rectangle as shown below:



It is very important to establish a relationship between the helix angle (θ) and the tpi inserted in a yarn. The helix angle (θ) depends upon the amount of twist present in a yarn. With a change in the value of tpi, the helix angle (θ) will also change.

From the above figure:

$$\text{Tan}\ \theta = \pi d / \ell$$

But

$$\ell = 1 / \text{tpi} \quad \text{and} \quad d = \frac{1}{28\sqrt{Nc}}$$

So

$$\text{Tan}\ \theta = \frac{\pi}{28} \times \frac{\text{tpi}}{\sqrt{Nc}}$$

This equation shows that the helix angle (θ) is also related to the count of the yarn. If the helix angle (θ) is to be kept constant, the ratio of tpi and yarn count should also be kept constant. In other words to spin yarns of various different counts but with the same twist characteristics this ratio should remain the same. Which means that twist or tpi in a yarn is directly related to the fineness or count of the yarn. Fine yarns would usually require a higher value of tpi than coarse ones.

To calculate the amount of optimum tpi required for various counts of yarns a term called as twist multiplier comes into play. Twist multiplier (TM) is defined as the ratio of the tpi to the square root of the cotton count.

$$\text{Twist Multiplier} = \text{TM} = \frac{\text{tpi}}{\sqrt{\text{Nc}}}$$

Different types of yarns according to the end usage are spun with different values of TM. For example knitted yarns or hosiery yarns are spun with a TM of 2 to 3, weaving yarns with a TM of and hard twisted crepe yarns are twisted with up to a TM of 7. Too much twist makes the yarn hard, brittle and cause snarls in the yarn and becomes hard to knit and weave.

(1) **<u>Yarn Strength</u>**

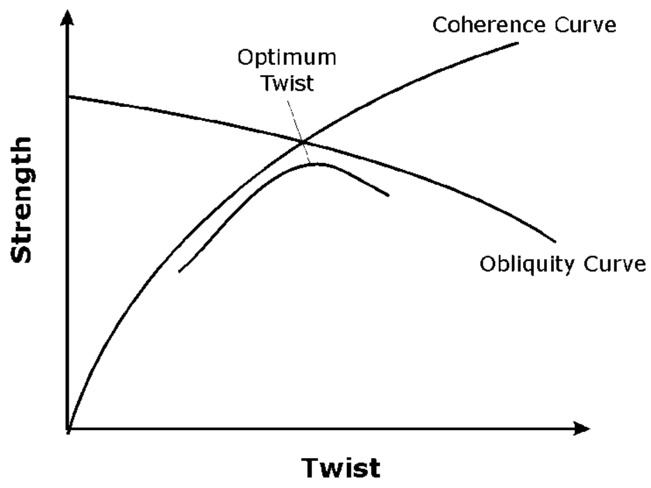
All the staple yarns consist of fibres twisted together. The purpose of twisting is to bind the fibres together so as to strengthen the yarn. If a load is applied to a yarn with a low twist then that yarn may break easily. This breakage may not be due to the breakage of fibres but because of the slippage of the fibres. As the amount of twist increases, the level of cohesiveness among the fibres will also increase making the yarn stronger and more compact. Such a yarn would require a bigger load to break it.

So the major source of strength to the yarn is provided by the twist. As the twist increases, the strength of the yarn also increases. However this is only true up to a certain limit of twist called as the optimum twist. Beyond the optimum twist, on further increase in twist will reduce the strength of the yarn. This is because of the two factors:

(i) Excessive twist causes obliquity in the fibres and the fibres tend to lie more perpendicular than parallel to the length of the yarn i.e. they loose their linear orientation.

(ii) Secondly with an excessive twist fibre breakage occurs.

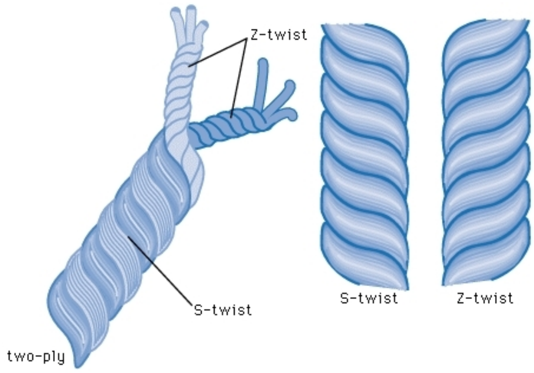
The relationship between the yarn strength and the twist is shown by the following graph:



Folded & Cabled Yarns

Folded Yarns

Folded or plied yarns are spun from two or more single yarns by twisting them together. Two fold or two ply yarn for example is composed of two single yarns and three ply or three fold yarn is composed of three single yarns. Depending upon twist direction two methods are used to make a plied yarn:



(i) All the individual single yarns are twisted in one direction and are then combined and twisted in the opposite direction to form a uniform and soft folded or plied yarn.

(ii) All the individual single yarns are twisted in one direction and are again combined and twisted in the same direction to form a hard and less flexible folded or plied yarn.

Uses of Folded Yarns

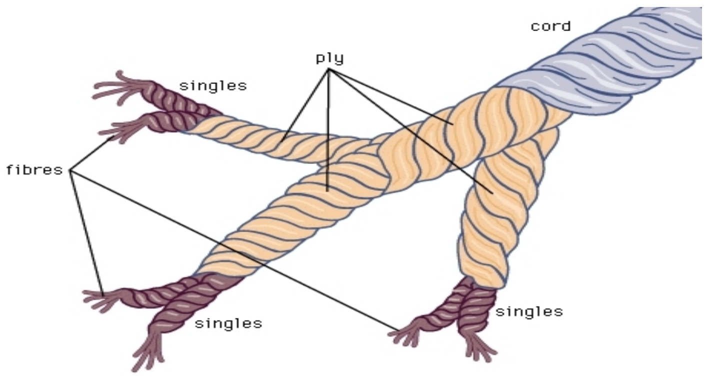
(i) Folded yarns are used for heavy industrial fabrics where extra strength is needed.

(ii) By the process of folding, a very coarse yarn that is impossible to make on ordinary spinning machines can be made.

(iii) Folded yarns made from very fine fibres are used in delicate looking sheer fabrics.

Cabled Yarns

Cabled or Corded yarns are produced by twisting two or more plied or folded yarns together.



Cabled or Corded yarns can be produced by different combinations of twist directions:

(i) Usually cabled yarns are made with the final twist usually applied in the opposite direction of the ply twist.

(ii) Cables or cords may follow an SZS form, with S-twisted singles made into Z-twisted plies that are then combined with an S-twist, or may follow a ZSZ form.

(iii) Cabled or corded yarn may also follow an SSZ or a ZZS pattern.

Uses of Cabled or Corded Yarns

(i) Corded yarns may be used as rope or twine.
(ii) They may also be made into very heavy industrial fabrics
(iii) Cables made from extremely fine fibres are used to make sheer dress fabrics.

Count of Folded and Cabled Yarns

In order to find out the count of the folded and cabled yarns we use the following formula :-

For Direct Numbering system :-

$$\textit{Final Count} = C_1 + C_2 + C_3 + C_4 + \ldots\ldots\ldots$$

Where, C_1, C_2, C_3, C_4, ... are the counts of the threads out of which the folded yarn or cabled yarn is made.

For Indirect numbering system :-

$$1/\textit{Final Count} = 1/C_1 + 1/C_2 + 1/C_3 + 1/C_4 + \ldots\ldots\ldots$$

Where, C_1, C_2, C_3, C_4, ... are the counts of the threads out of which the folded yarn or cabled yarn is made.

For using these formulas, the count system of each yarn in the folded or cabled yarns must be the same.

Variables in Yarn Production

Most generally yarns can be classified into continuous filament yarns made out of manmade raw material and short staple yarns produced from natural fibres. However within these two categories endless varieties of yarns can be produced because there are so many variables involved in yarn production. Some of the variables are listed below:

(1) Type of fibre(s) and / or filament(s) used in an individual yarn.

(2) Dimensional and physical characteristics of the fibre or filament used in a yarn e.g. fineness, cross-sectional shape, crimp, density, etc.

(3) The mechanical properties of a fibre or filament e.g. tensile strength, tenacity, extensibility, elastic properties, etc.

(4) The general properties of a fibre or filament e.g. frictional properties, moisture regain, thermal properties, dimensional stability, resistance to micro-organisms, static properties, electrical properties, colour, ageing etc.

(5) Chemical properties of a fibre or filament e.g. resistance to acids, alkalis, dry cleaning agents and other chemicals.

(6) The method of yarn production e.g. carded system, combed system, woollen system, worsted system, etc.

(7) Method of final yarn formation e.g. ring, rotor, wrap, core, air jet & friction spinning, etc.

(8) Component of the yarn e.g. 100% natural fibres, 100% manmade fibres, blend of natural fibres with manmade fibres, blend of natural fibres with filaments, etc.

(9) The linear density i.e. the count of the yarn and the level of twist (twist multiplier).

(10) Cross-section of the yarn e.g. circular, elliptical, flat, textured, etc.

(11) Ply of the yarn whether the yarn is single-plied or multi-plied.

As far as natural fibres are concerned, they have typical properties depending upon the group to which they belong. For example cotton, flax, jute, etc all are cellulosic fibres on the other hand wool, silk, mohair, etc all belong to proteinic fibres. There is nothing much can be done to alter the basic properties of these fibres. These properties also vary from lot to lot within the same category. On the other hand in manmade fibres, most of the properties can be controlled to a great extent and precision. They can both occur in filament and short staple form of desired length.

Consequently the yarn properties made of natural fibres are dependent on the basic natural properties of the fibre. However in case of manmade yarns properties of the fibres can be modified to meet the requirements of the end use of the yarn.

General Principles of Short Staple Spinning

All short staple yarn spinning systems make use of the following basic principles:

(1) Mixing

The term mixing is applied for combining or blending more than one mass of fibres into a single homogenous mass. Since all the natural fibres vary from one another from region to region, field to field and even from bale to bale, it is necessary to mix them well so that the final end product i.e. the yarn may be homogenous and of consistent quality.

(2) Blending

Usually blending refers to the mixing and combining two or more than two fibres of different origins. For example cotton fibres with polyester. The purpose of blending is to achieve desired properties of both the components of the fibres in a yarn which otherwise is unobtainable from a single component. For example strength, crease resistance, colour, price, moisture absorption, drying properties, etc.

Just as mixing, blending should also be done thoroughly so that a homogenous yarn may be produced out of the component fibres.

(3) Opening

The raw fibres for easy transportation are highly compressed into bundles called as bales. Before effective spinning can be carried out, this compressed form of fibres must be separated from one another. Opening refers to mechanical separation of fibres from one another. The opening is carried out gradually in steps. In the first step the bale of fibre is broken down into small tufts then later on at various stages of spinning these tufts are further broken down into individual fibres.

(4) Cleaning

All the natural short staple fibres have some amount of natural impurities in it. These impurities have to be removed before fibres are converted into a yarn. On the other hand the short staple manmade fibres just require opening but no cleaning.

The amount and type of cleaning required for a particular lot of fibres depends upon size and amount of impurities present in it. Greater the trash content in fibres greater number of cleaning points are used during various stages of the spinning process. Typically cotton bale contains about 5 to 10% impurities and about 3.5 to 7 % cleaning is obtained during initial opening and cleaning.

Cleaning is generally associated with opening. As the fibre opening takes place, the impurities also get separated and removed. Greater the degree of opening, greater cleaning may be carried out.

(5) Fibre Separation

The fibre separation is the further opening of the small tufts that have been initially opened up into an individual fibre form. This happens at the carding machine. By fibre separation a further up to 1% waste can be removed.

(6) Fibre Regularising

Fibre regularising means the reduction in the variation of the mass per unit length of the fibre material. Regularising is very important to produce a regular and a more consistent quality of a yarn. Fibre regularity takes place at the drawing frame.

(7) Fibre Alignment

Along with the improvement of the fibre regularity, the alignment of the fibres also improves at the draw frame. Fibre alignment means the straightening of the fibres and making them parallel to the axis of the sliver.

(8) Drafting

Drafting is drawing out or attenuation of the fibre material into a desired fineness or count of a yarn. In ring spinning system drafting is done in two stages one at the roving frame and other at the ring frame.

(9) Twisting

Twist plays a vital role in the final formation of the yarn. The purpose of giving twist is to bind the fibres together as a yarn and to give strength to the yarn. The major twisting takes place at the ring spinning frame or at the final stage of spinning.

Cotton Impurities

Any foreign material other than fibres is classified as impurities. Not only the quality and the price of fibres depend upon the amount of impurities present in the fibres, also the subsequent processes depend on it. Greater the impurities are more efforts have to put in to remove it. The removal of the impurities also results in the loss of useful fibres. Impurities are also found in the manmade fibres however the level is significantly low as compared to impurities in natural fibres.

The impurities in cotton fibres can be classified into:

(1) Seed

Seed impurity is the largest type of impurity present in raw cotton and it includes un-ginned seeds with fibres attached to it, ginned seeds and parts of seeds.

(2) Chaff

The chaff is the vegetable fragments consisting of leaf particles, bract, shale and stalk of the cotton plant. Bract is a small type of a leaf that grows beneath the cotton boll and shale is the silvery interior lining of the cotton boll.

(3) Dirt

The dirt impurity includes soil and sand particles that may be added from the cotton fields due to mishandling of the fibres and also the cotton fibres pick up dust and sand if they are transported by open trucks.

(4) Micro-dust

The micro-dust includes very fine particles of chaff, dirt, small fibre fragments and spores of mildew. These particles are extremely small and are often a fraction of the fibre diameter. They generally gets embedded around the natural wax of the cotton fibre.

(5) Abnormal Impurities

The abnormal impurities are very rare however when found in the cotton fibres, they can cause serious problems. These impurities include pieces of stones, pieces of iron, cloth fragments, foreign fibres such as jute, polypropylene, etc (that may be included due to the bagging of cotton fibres made up of these fibres), grease and oil (from machine harvesting or ginning), tar and coal (from the air while the cotton fibres are transported openly), small pieces of wood, etc.

The term trash is applied to all of these impurities present in the raw cotton. The total trash content of cotton fibres ranges from 1% to 10% of the total weight of the cotton fibres. The amount of trash content directly determines the amount of cleaning required.

Removal of Impurities

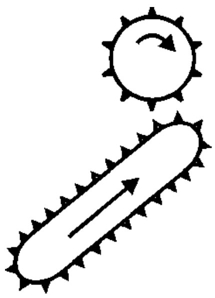
The removal of impurities is associated with the opening of the fibres and is carried out in stages during the spinning process. Initially the impurities are removed in the blow room with the very basic opening of the larger tufts of fibres into smaller tufts. Then further at the carding machine due to fibre separation, more impurities are removed. The blow room mostly removes the seed and chaff while the carding removes the dirt and microdust. Greater the impurities present in fibres more opening and cleaning is required. However with more severe opening and cleaning, expensive fibres can be damaged or they can be lost during the process.

Methods of Opening & Cleaning

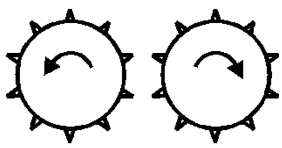
The mechanical techniques or methods used for the opening and cleaning of the cotton fibres are:

(1) Spiked Surfaces

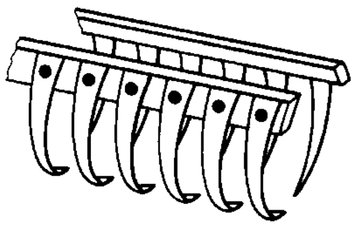
This action consists of plucking and gripping the mass of cotton fibres between two sets of spiked surfaces moving in opposite directions. This action opens the fibres and does some cleaning as well.



Tearing Up



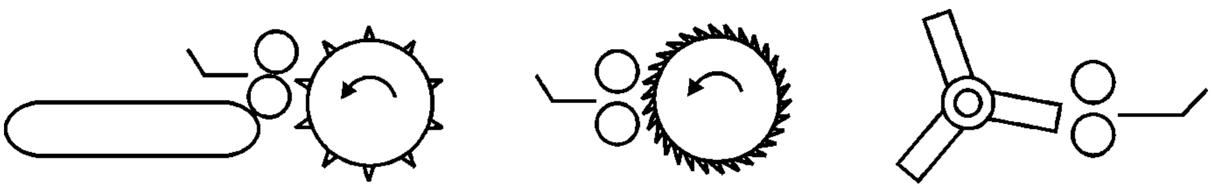
Plucking Up

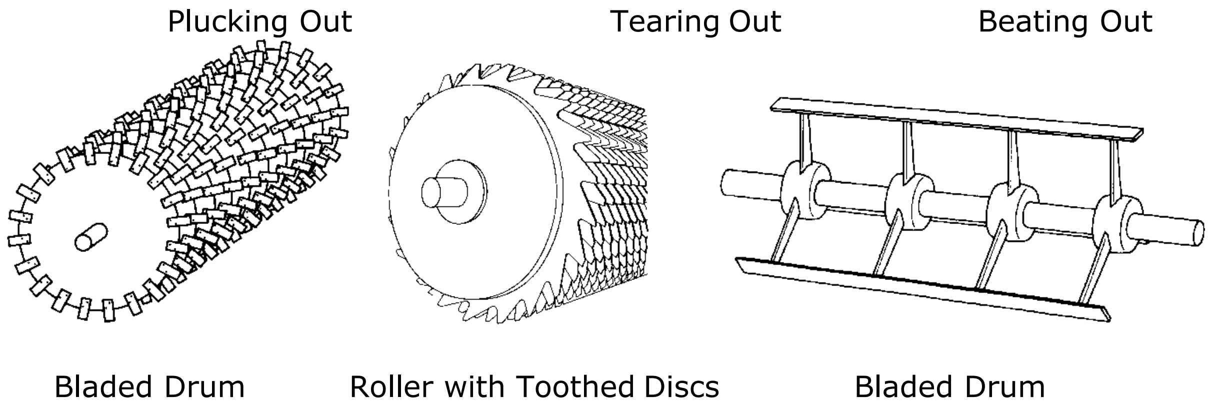


Plucking Out

(2) Beaters

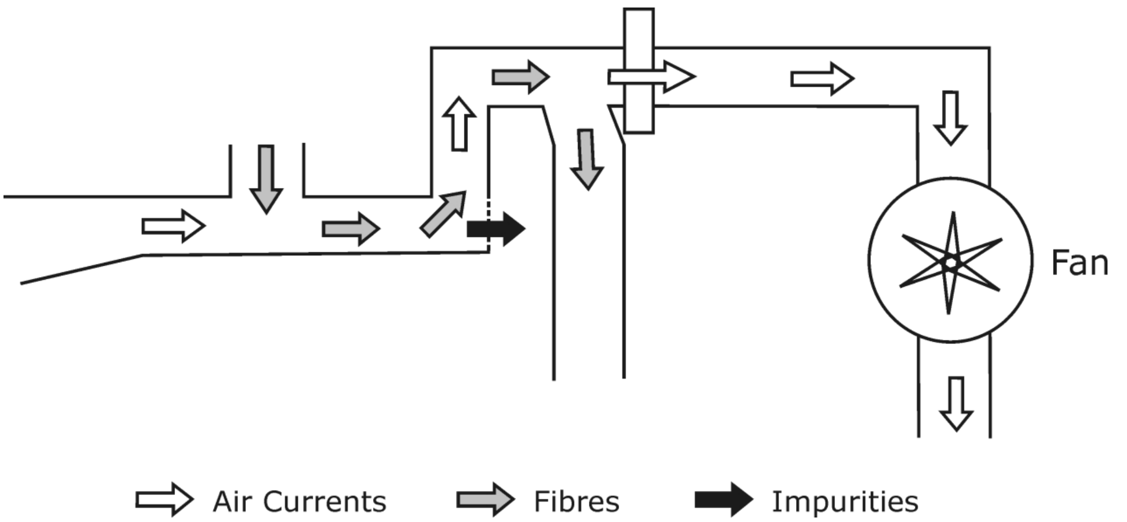
The term beater in spinning is generally referred to a revolving drum having blades, spikes or pins mounted on it surface. The fibres are fed and subjected to the surface of the beater with the help of air currents or by using pair of rollers. When the surface of the beater strikes the fibre mass, it plucks or tears the fibres and transports the opened fibre to next stage. During this opening, the trash being heavier falls down and is collected below the machine.





(3) <u>Air Currents (Pneumatic Action)</u>

Lighter impurities like dust and micro-dust can not be effectively removed from the fibres by using either the spiked surfaces or beaters. These impurities can be removed by passing the fibres over the perforated grids where the air currents can draw off the dust in the fibres.

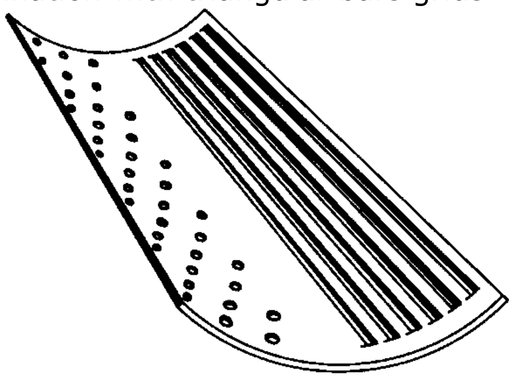


All the above and majority of the operating devices in the blow room machinery are opening devices when they are used alone. However these very same opening devices can also work as cleaning devices if they are worked in cooperation with cleaning apparatus such as grids and special machine covers.

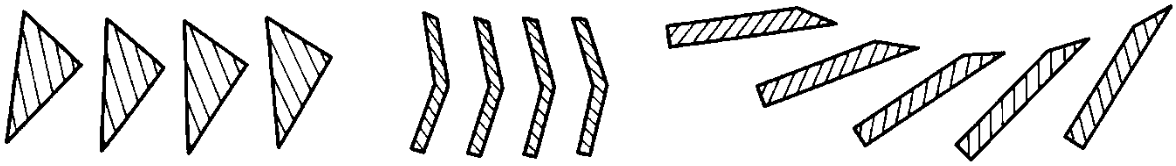
The following elements can be used in grids:

- (i) Slotted Sheets
- (ii) Perforated Sheets
- (iii) Triangular Section Bars
- (iv) Angle Bars
- (v) Blades

These elements can either be used alone or in combination with each other. For example, the perforated and slotted sheets were widely used and placed under the cards but now there use is diminishing. Same is the case with the blade grids that were used in combination with triangular bars grids.



Perforated Sheet Slotted Sheet



Triangular Bars Angle Bars Knife Blades

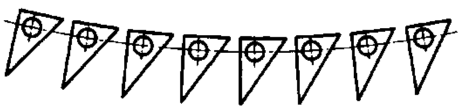
The angle bars are very robust but they tend to create fibre blockages. So Today in the modern cleaning techniques, either the triangular grid bars or knife blades are used alone for the most efficient waste removal.

The impurities and the fibres fall through the gap of the grids and are collected in a special waste chamber of the machine which is placed under the grid. In old machinery this waste has to be manually removed periodically however in the latest opening and cleaning systems pneumatic waste removal systems are used.

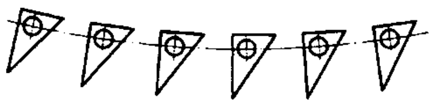
Grid Adjustments

The grids can be in one, two or three parts so it can be adjusted as a unit or in individual sections. Three basic adjustments are possible.

(i) Distance of the complete grid to the beater.
(ii) The distance or the gap between the adjacent grid bars.

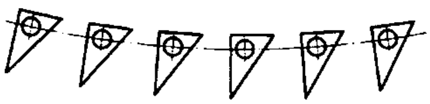


Closed Gap Setting

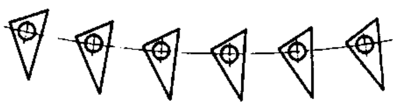


Open Gap Setting

(iii) Angle relative to beater blade



Oblique Angle



Aggressive Angle

It is seldom possible to make all these three adjustments, generally machines are so designed that only two adjustments are possible.

Cleaning Efficiency

All openers & cleaners along with foreign matter also remove a certain amount of short fibres (also called as lint). The composite of trash, dust, fibre fragments and fibres removed is called as waste. The amount of waste removed at each stage of cotton cleaning stage should be known for evaluation and can be found out as:

$$\text{\% age Waste Removal} = \frac{\text{Waste Removed (Kg)}}{\text{Total Fibres Processed (Kg)}} \times 100$$

The effectiveness of a machine or series of machines in a blow room to remove the trash in the fibres is expressed as its cleaning efficiency and is given by:

$$\text{\%Cleaning Efficiency} = \frac{\text{\% trash in raw fibres - \% trash in processed fibres}}{\text{\% trash in raw fibres}} \times 100$$

Factors Influencing Opening & Cleaning

The degree of opening, the degree of cleaning and the fibre loss are primarily dependent on the following factors:

(1) The type of opening devices used.
(2) The speed of the opening devices.
(3) Type of feed
(4) Degree of penetration.
(5) Spacing of feed from the opening devices.
(6) Type of grid used.
(7) Area of grid surface.
(8) Grid Settings.
(9) Airflow through the grid.
(10) Condition of pre-opening.
(11) Position of the machine in the machine sequence.

THE BLOW ROOM

The blow room is the first stage or the first process in the short staple spinning. The name 'Blow Room' is given to this stage because of the air currents that are commonly used during the processing of fibres. the blow room the fibre mass is progressively opened, cleaned and mixed. This is done by using a large number of machines. In each of these machines used in blow room if the actions are too severe of sudden then fibre damage will occur.

Functions of Blow Room

(1) **Fibre Opening**: The tightly packed fibre bales received from the ginning mills have to be opened by converting the larger fibre tufts into smaller ones and ultimately converting the smaller tufts into individual fibre form.

(2) **Cleaning:** All the natural fibres including cotton have considerable amount of impurities in them which have to be removed to produce a clean yarn.

(3) **Mixing/Blending:** The properties of the cotton fibres differ from each other from bale to bale and from fibre to fibre so in order to obtain a homogenous and consistent quality yarn, they need to be thoroughly mixed together. Sometimes in order to have a desired quality at the right price high quality cotton fibres are mixed with low quality fibres.

(4) **Preparation of feed for the next stage:** The end product of the blow room should be compatible with the next stage of spinning i.e. carding. The feed to the carding can be either given in the form of lap or in direct chute form.

Blow Room Machinery

In the blow room all the above functions have to be fulfilled for this purpose various different types of machines are used. Based on the functionality of these machines they are classified into five types:

(1) Bale Opening Machines
(2) Mixing Machines
(3) Cleaning Machines
(4) Dust Removing Machines
(5) Recycling Machines

For these machines to perform optimally, they must be located at specific positions in the blow room line. The modern cotton blow room line can be divided into six distinguished zones.

(1) Bale Opening Zone
(2) Coarse Opening & Cleaning Zone
(3) Mixing/Blending Zone

(4) Fine Opening & Cleaning Zone
(5) Intense Opening & Cleaning Zone
(6) Card Feed Preparation Zone

In case the cotton has less impurities then the Zone 5 (intense opening & cleaning) may not be necessary. Furthermore the Zone 4 (fine cleaning) or the Zone 5 (intense opening & cleaning) and the Zone 6 (card feeding) can form a single unit.

The additional operation of dust removal is not associated with any single zone; in fact dust removal is carried out at a greater or lesser extent at every machine of the blow room.

Bale Conditioning

The cotton fibres from the ginning factories are received by the spinning department in form of highly compressed bales that are wrapped by metal or plastic straps. As the bales are received these straps are cut off and the bales are allowed to condition for 24 hours in controlled temperature and between 60% to 80% relative humidity. For this purpose all the spinning mills allocate floor space for conditioning purpose.

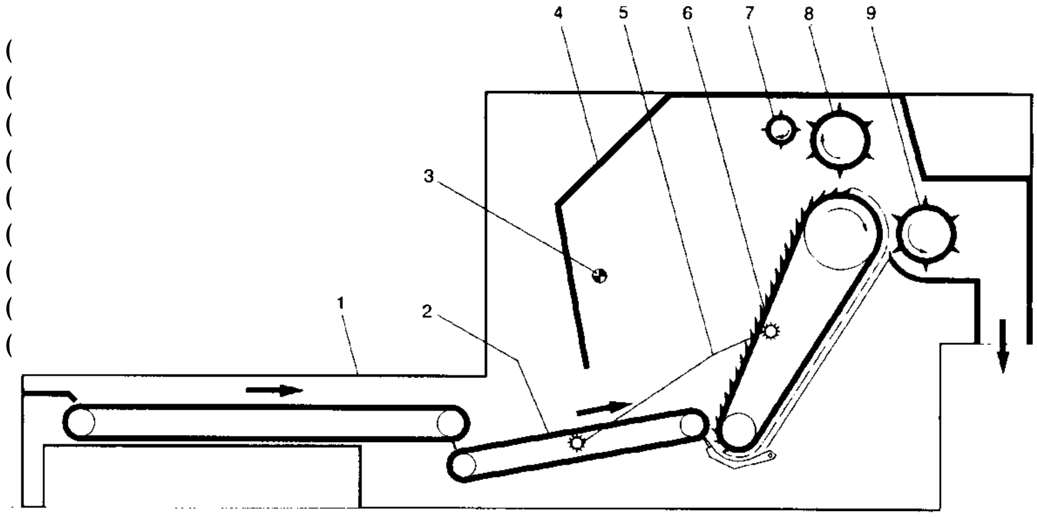
The conditioning allows the fibres to relax and maintain a temperature and moisture equilibrium with atmosphere and reduces the chance of fibre damage and inconsistency in quality.

Bale Lay Down

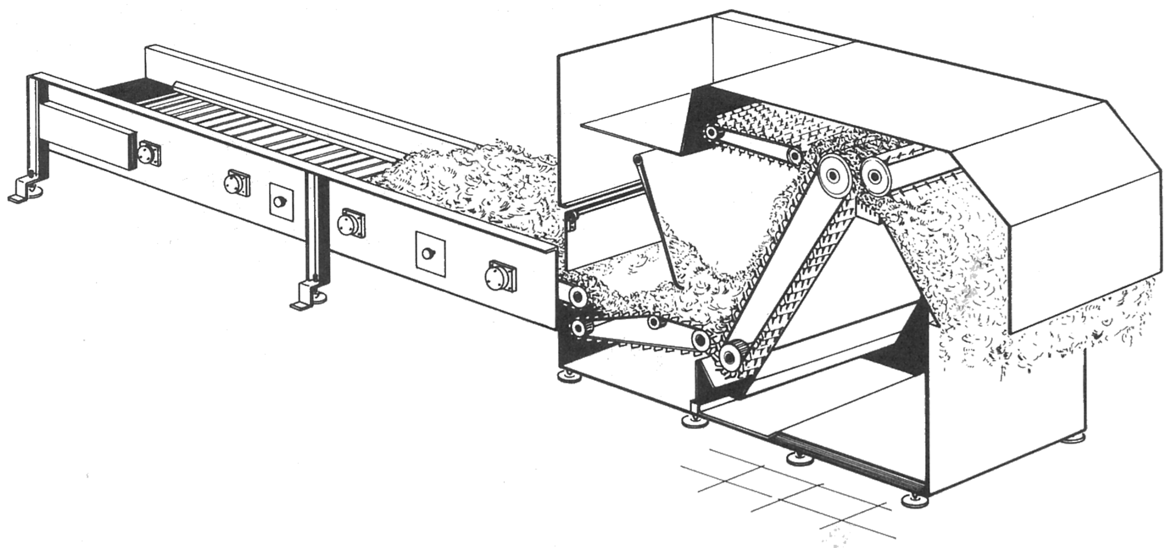
After the bales are conditioned properly they are taken to the blow room and placed in groups of special sequence for the first processing stage. This group of bales is called as bale lay down. The main aim of a proper bale lay-down is to have fibres with similar properties and spinning attributes from lay-down to lay-down so that spinning machines can be adjusted optimally and yarn of consistent quality may be produced over a longer period of time.

Zone-1 (Bale Opening Machines)

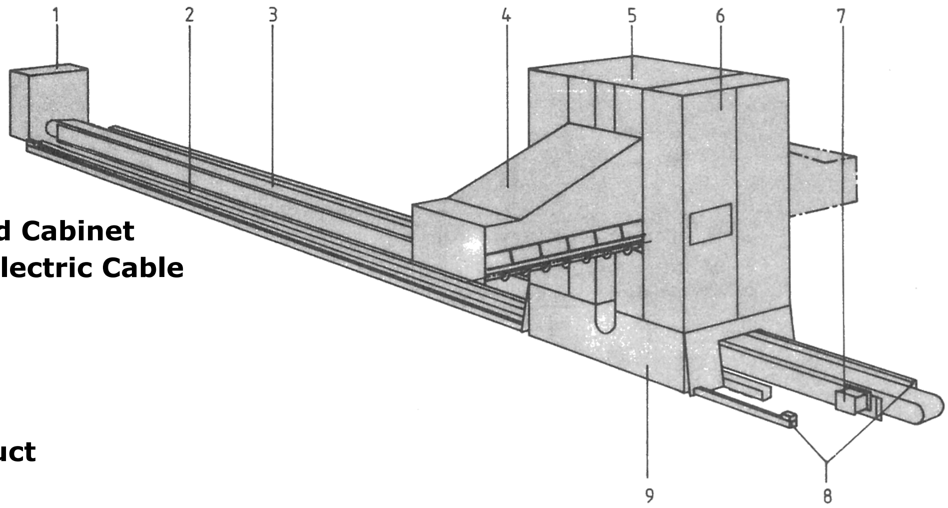
After proper bale lay-down the initial bale feeding is done either by using a parallel set of machines called as hopper feeders or by a single machine called as a top feeder. The hopper feeders have stock supply compartments which are either filled manually or by automatic machines. A cross-sectional diagram of a typical hopper feeder is shown below:



The more realistic shape of the hopper feeder can be seen in the following figure:



The hopper feeders although are still used in quite sophisticated form however they are considered to be conventional type of bale openers. They remain stationary while the raw fibres from the bales can be fed manually or by automatic machines. Nowadays the most popular and modern machine for feeding raw fibres from the bale is the top feeder. In the following Figure, the Rieter Unifloc Top Feeder is shown:

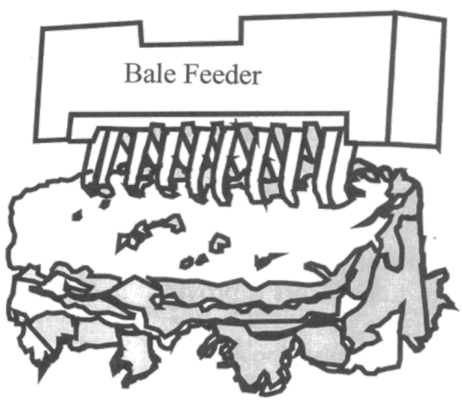


(1) **Electrical Feed Cabinet**
(2) **Channel For Electric Cable**
(3) **Covering Belt**
(4) **Take-off Unit**
(5) **SwivelTower**
(6) **Control Panel**
(7) **Evacuation Duct**
(8) **Drive Rails**
(9) **Chassis**

The top feeders are travelling machines that move over and past the bale layout and extract fibres from top to bottom. They have great advantage that more than one bale can be processed simultaneously to give a better long term blend. These machines are fitted with computerized control panels and they extract material from all the bales evenly. The production rates of such modern bale openers ranges from 750 kg/hour to 1000 kg/hour
The hopper feeders and the top feeders should perform the following functions:

(i) Extract material evenly form bales.
(ii) Open the material gently.
(iii) Open up to smallest tufts.
(iv) Form tufts of equal sizes.
(v) Process as many bales as possible in a single charge.
(vi) Easily programmable.
(vii) Blend fibres at the start of the process.

All the bale opening machines not only feed the raw fibres but also do the tuft opening. This opening actually starts from the point when these feeders start gripping the fibres for an initial feed as shown below:



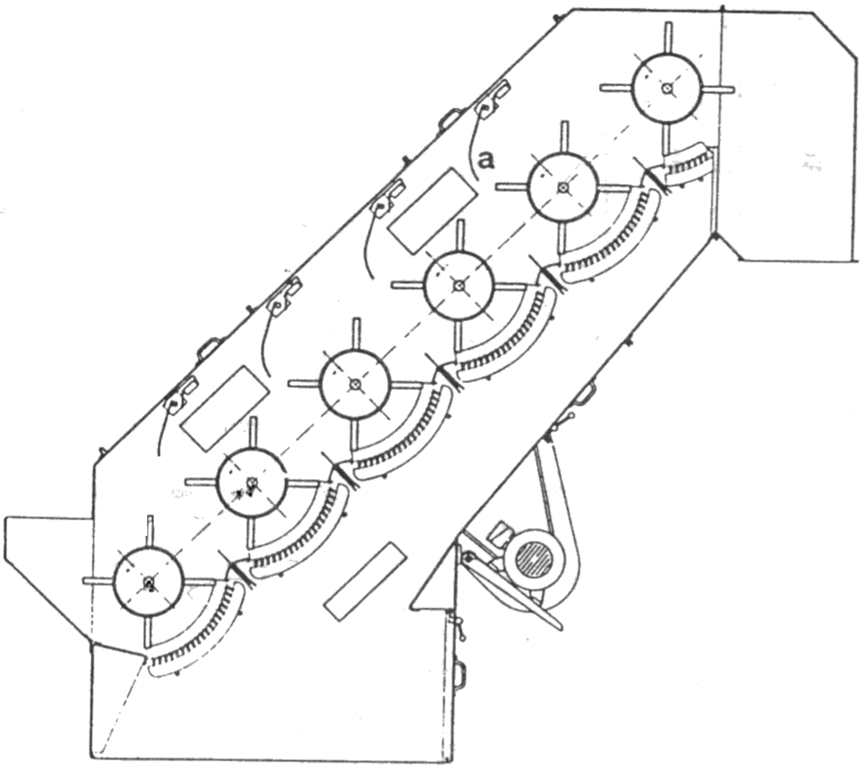
Zone-2 (Coarse Cleaning Machines)

The coarse cleaning machines directly gets it feed from the hopper feeders or from top feeders. The striking and beating elements in this zone are widely spaced and hence the opening of the fibres is also very minimal. The main purpose of these machines is to open up the mass of fibres into large tufts which are then converted into smaller tufts by using more intense opening and cleaning machines in the next zones. The machines in these zones are sometimes not even fitted with cleaning devices or even if these cleaning devices are present, they can only remove fraction of the impurities.

Different machine manufacturers have developed various types of coarse cleaning machines. The most commonly used ones are:

(i) The Step Cleaner

The step cleaner is a very standard type of a coarse cleaning machine that is produced by several manufacturers.



Truetzschler Step CLeaner

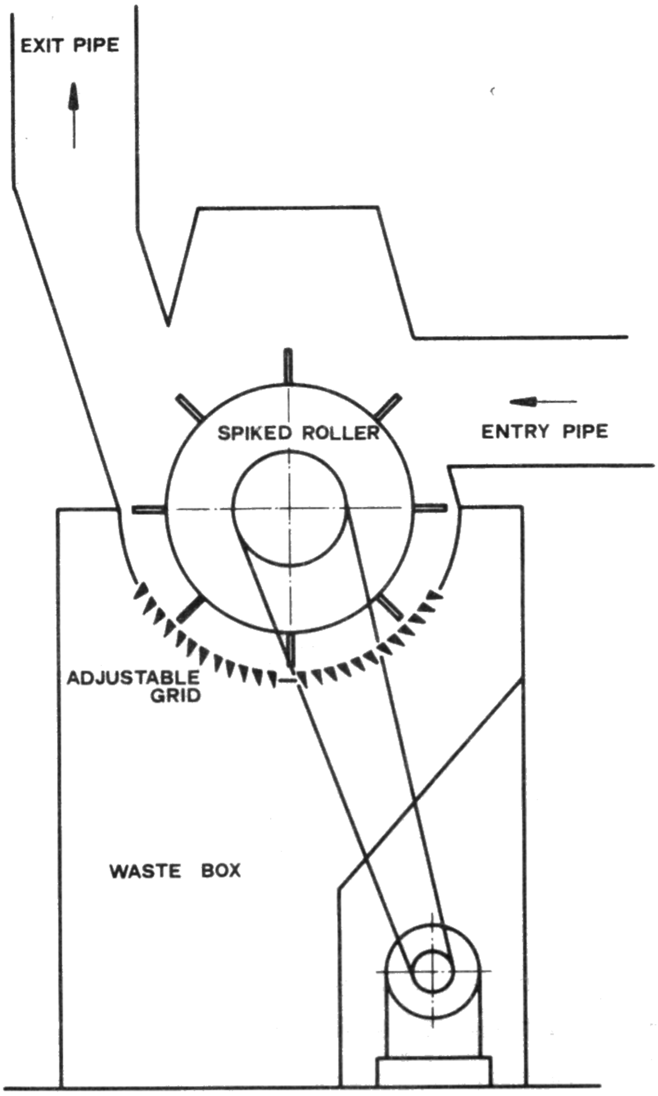
As the material falls into this machine it is subjected to first beater which not only does the initial opening but also transports the fibres upwards where sometimes 4 or 6 beaters are placed closed to one another and inclined at an angle of 45. The surface of these beater rollers are covered with blades or bars. The cleaning of the impurities takes place as the material continuously passes from one roller to the other with the help of grids placed beneath each of the roller. The speed of the beaters and the grids are both adjustable.

(ii) <u>Uni-Cleaner</u>

The uni-cleaner or the mono-cylinder cleaner relies on the use of single beater roller having its surface covered with spikes. The fibre material enters to the machine from one side due to a suction effect produced at the other side of the machine. To ensure that fibres may not pass the exit pipe untreated by the beater, following arrangement is done:

(a) The hood of the machine around the beater is designed in three portions in such a way that the fibre mass is forced to fall back into the region of the beater after being beaten by the beater. In this way the fibres are forced to circulate the beater many a times to give required opening and cleaning.

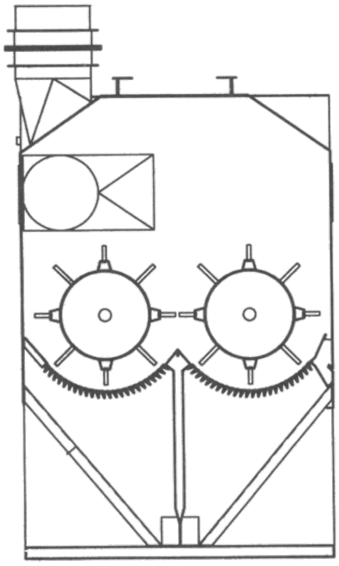
(b) The exit opening of the machine is kept higher than the in-feed opening of the machine that also ensures that only the smallest tufts can pass straight through but the bigger tufts are always subjected to the beater action of the beater.



Rieter Monocylinder Cleaner

(iii) <u>The Dual Roll Cleaner</u>

The dual roller beater is some how similar in working as that of a mon-cylinder cleaner. However in this case instead of only a single beater roller, two beater rollers of about 61 cm diameters are used. Both of the rollers rotate in the same direction and have their surfaces covered with spikes arranged in a spiral to improve passage of the material.

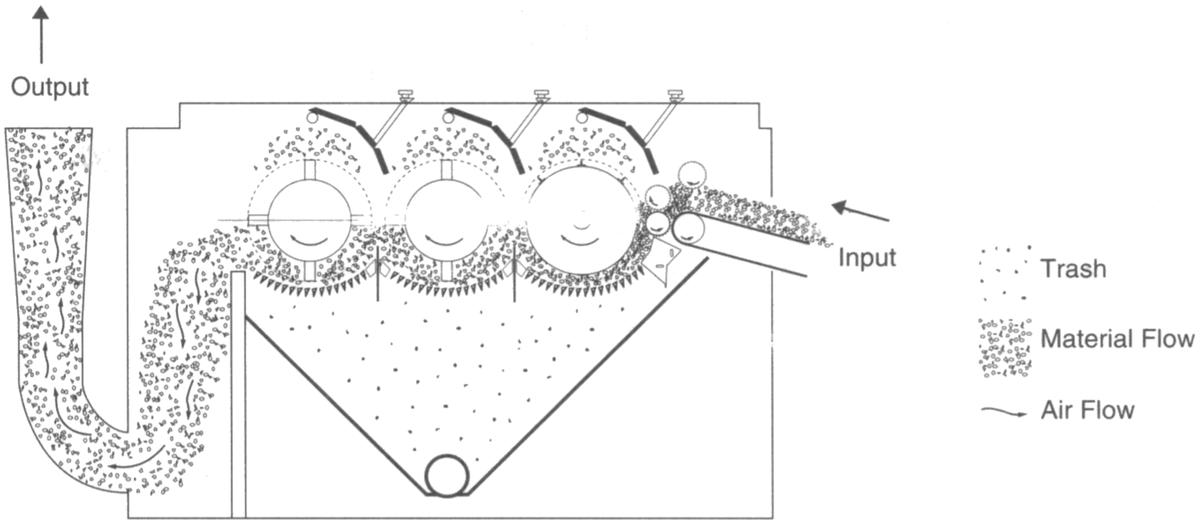


Hergeth Hollingsworth Dual Roller Cleaner

The exit opening of the machine is kept higher than the in-feed opening of the machine to ensure that only the smallest tufts can pass straight through but the bigger tufts due to weight falls down and are always subjected to the beater action of the beater.

(iv) The Three Roll Cleaner

The three roll cleaner is exactly the same in working as the dual roll cleaner. The only difference is that it has three rollers placed side by side instead of two.

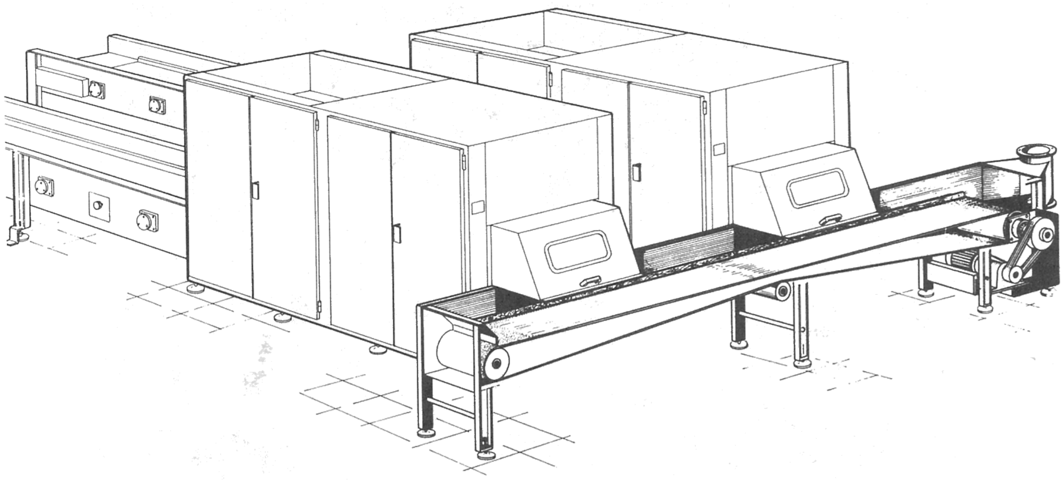


Crosrol Three Roll Cleaner

Zone-3 (Blending/Mixing Machines)

(i) The Mixing

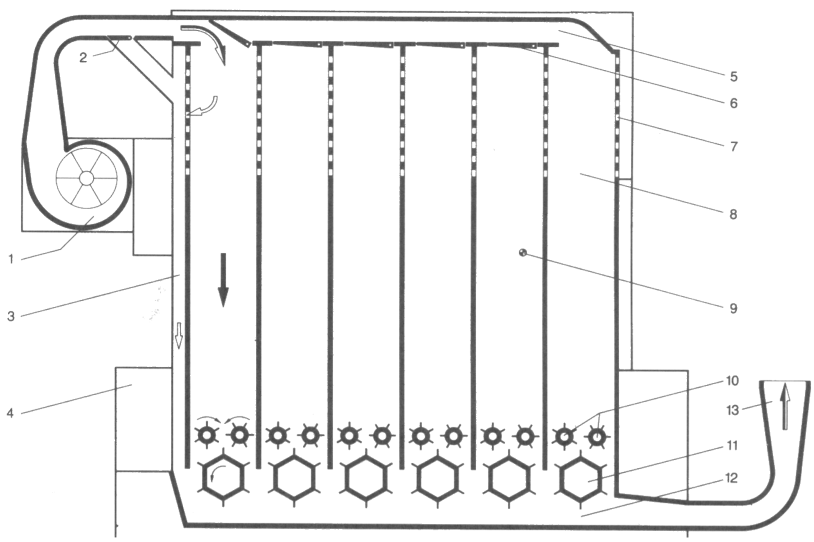
This is the most commonly used type of a mixing/blending machine that does the mixing at the start of the process. In the arrangement bale openers are operated together independently. The opened fibre material form all the bale openers are fed onto the common conveyer belt.



This gives a very good mix and blend of fibres. In the latest mixing batteries each of the bale opener is equipped with electronic weighing equipment that can easily ensure correct blends of various components of fibres at a predetermined ratios e.g. example 60% Cotton, 40% Polyester.

(ii) <u>The Multiple Mixer</u>

This is again a very simple mixer that gives very good long term blend. The machine is composed of several (6 – 8) chambers. The fibre material is pneumatically fed from the top. All the chambers are successively and simultaneously filled and the material is removed from the bottom through a single common duct.

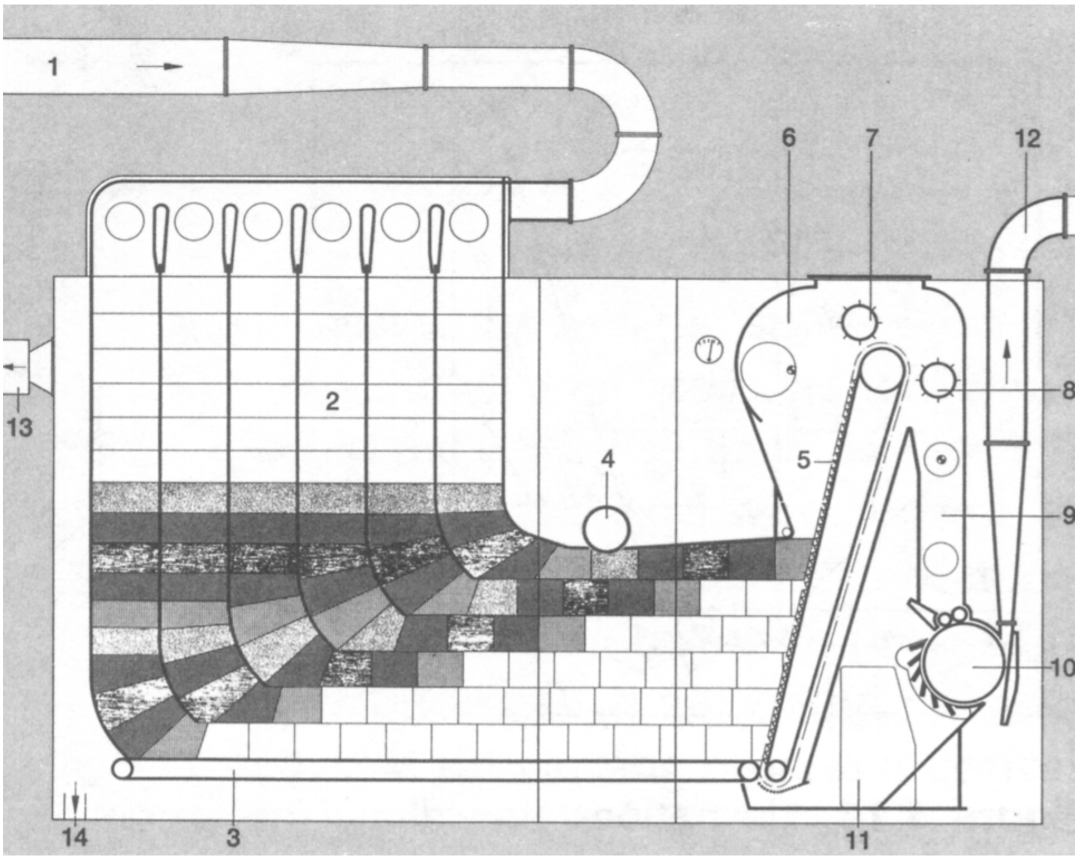


(1) **Fan**
(2) **Air Bypass**
(3) **Exhaust Air Duct**
(4) **Pressure Switch**
(5) **Feed Duct**
(6) **Closing Flap**
(7) **Perforated Plate**
(8) **Blending Chamber**
(9) **Light Barrier**
(10) **Delivery Rollers**
(11) **Opening Rollers**
(12) **Blending Channel**
(13) **Suction Tunnel**

Truetzschler Multi-Mixer

(iii) <u>The Unimix</u>

The unimix is a combination of blending and cleaning machine and both of these two operations are carried out within the single machine.



Rieter Unimix

(1) **Feed Pipe** **(2) Filling Chambers** **(3) Conveyer Belt**
(4) Conveying Roller **(5) Upright Lattice** **(6) Intermediate Chamber**
(7) Stripper Roller **(8) Take-off Roller** **(9) Filling Trunk**
(10) Cleaner Roller **(11) Waste Chamber** **(12) Fiber Delivery**
(13) Exhaust Piping **(14) Exhaust Air Outlet**

The machine is divided into three sections:

(a) Storage Section
(b) Intermediate Chamber
(c) Delivery Section

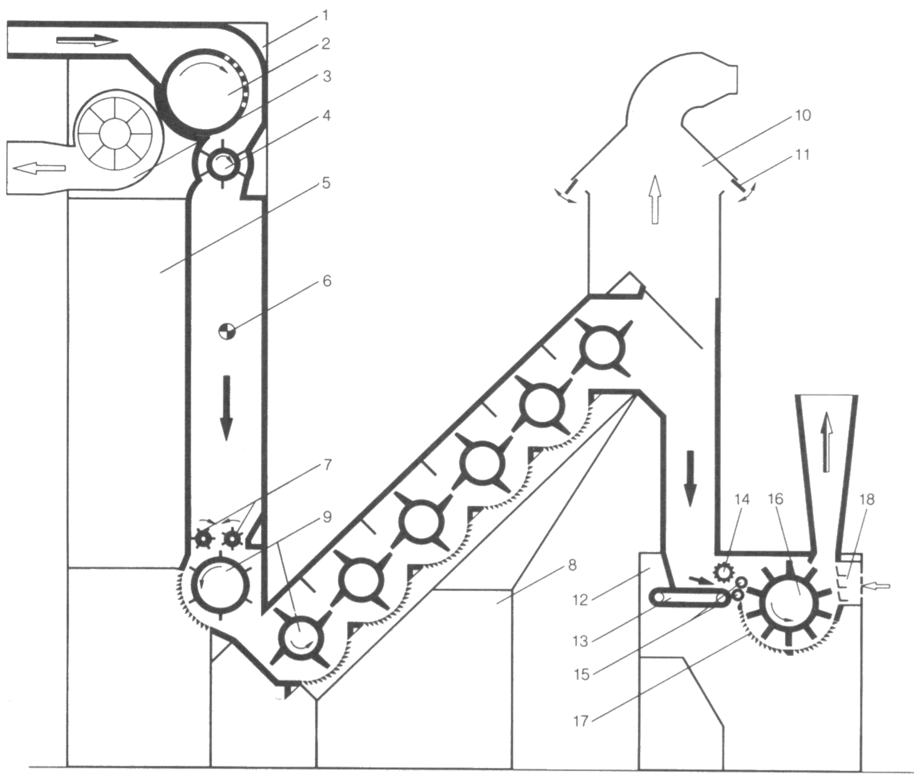
The fibres are pneumatically fed into six individual chambers of the machine. The fibres coming out of each of the six chambers are taken on a common lattice or a conveyer belt that takes the material to an intermediate chamber with the help of an inclined or upright lattice. From here the material passes through a delivery section to the next machine with the help of a pneumatic suction. In the delivery section a cleaning roller is used which does the coarse cleaning of the fibres as they are being delivered.

Zone-4 (Fine Opening & Cleaning Machines)

The Zone 4 cleaning machines although utilizes the same principles of opening and cleaning as that of the Zone 2 cleaning machines but has some differences:

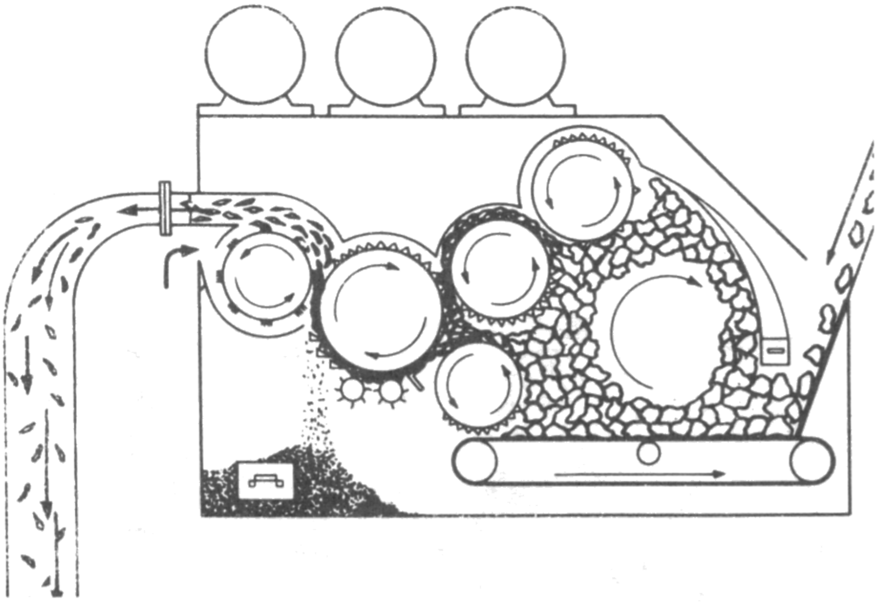
(a) The Zone 4 machines are always fed using clamp feed that is to make sure that controlled amount of fibre size and fibre quantity is fed.
(b) The spacing of the beater with the hood of the machine and with the grids is kept finer.
(c) Finer and more number of striking elements (pins, blades, spikes, etc) are used.
(d) The speed of the beaters is kept higher.

The RN Cleaner of Truetzschler as shown below is one of the most efficient and widely used fine opener and cleaner:



(1) **Condenser**	**(2) Dust Cage**	**(3) Fan**
(4) Finned Roller	**(5) Feeding Unit**	**(6) Light Barrier**
(7) Feed Rollers	**(8) Step Cleaner**	**(9) Cleaner Roller**
(10) Microdust Suction	**(11) Fresh Air Flaps**	**(12) RN Cleaner**
(13) Inner Lattice	**(14) Pressure Roller**	**(15) Feed Rollers**
(16) Porcupine Beater	**(17) Two-Part Grid**	**(18) Air Inlet**

In the above figure the feed to the RN cleaner is given directly from the step cleaner (zone 2) onto a feed lattice. The pressure roller and the pair of feed roller help to give a steady and predetermined feed of the fibres to the beater. The surface of the beater is covered with metal blades and has double hardened working edges. Beneath the beater two grid bars are placed that covers half of the circumference of the beater. These grids are fully adjustable.
Another very fine example of fine opener and cleaner is a Rando Cleaner as shown below:

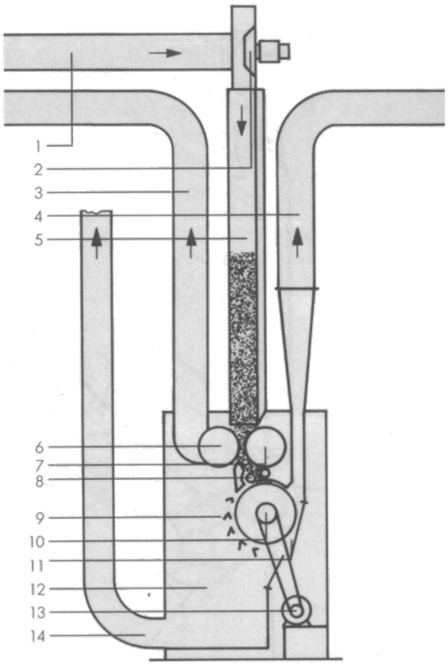


Rando Cleaner By Carolina Machine Co.

This opener and cleaner perform its working by using multiple rollers having their surfaces covered with saw teeth. All of these rollers move in opposite direction to one another and hence does the opening and cleaning by not only the beating action but also due to the opposing spikes principle.

Zone-5 (Intense Opening & Cleaning Machines)

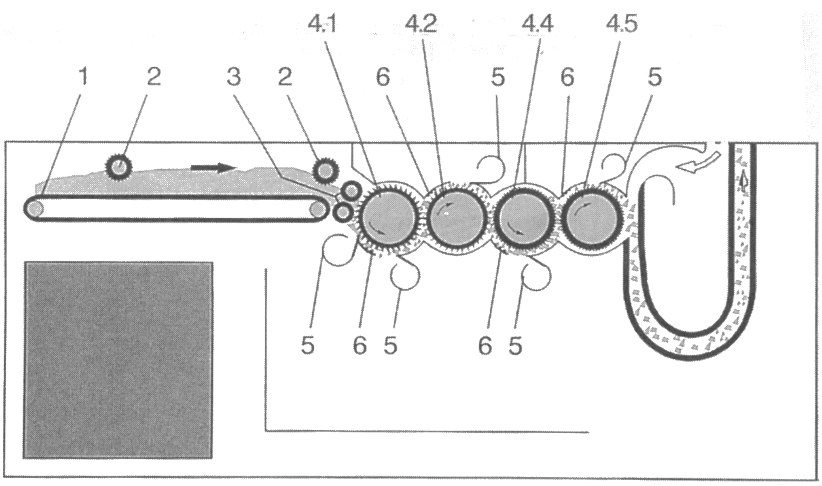
In majority of the cases the Zone 5 machines utilizes either the Kirschner beater or the carding roller (roller covered with saw teeth) as the main opening and cleaning device. However the way and the place where these opening rollers are used vary from manufacturer to manufacturer. A widely used intense opener and cleaner is the Rieter ERM cleaner as shown below:



(1)	**Material Supply**
(2)	**Feed Head with Fan**
(3)	**Exhaust Air Piping**
(4)	**Material Delivery**
(5)	**Material Chute**
(6)	**Plain Drum**
(7)	**Dust Cage**
(8)	**Feed Rollers**
(9)	**Knife Grid**
(10)	**Beater**
(11)	**Suction Duct**
(12)	**Waste Chamber**
(13)	**Driving Motor**

Here again a fan is used that sucks the fibres processed from the previous machine of the blow room line into the filling chute or filling chamber of this machine. The mass of fibres is condensed with the help of drum roller and pair of feed rollers and is subjected to a drum beater whose surface is either covered with saw teeth or bladed discs. The beaters thoroughly opens the fibre material and transports it to the next stage by suction, while the trash removed during the beating and opening action passes through the grids blades and is collected in the waste chamber.

Another type of an intense opener and cleaner is shown below:



(1)	**Feed Lattice**
(2)	**Pressure Rollers**
(3)	**Feed Rollers**
(1.1)	**Pinned Roller**
(1.2)	**Needle Roller**
(4.4)	**Saw-Tooth Roller**
(4.5)	**Fine Saw-Tooth Roller**
(5)	**Knife With Suction**
(6)	**Carding Segment**

Truetzscher Cleanomat

Zone-6 (Card Feed Preparation Machine)

Card Feed Preparation Zone

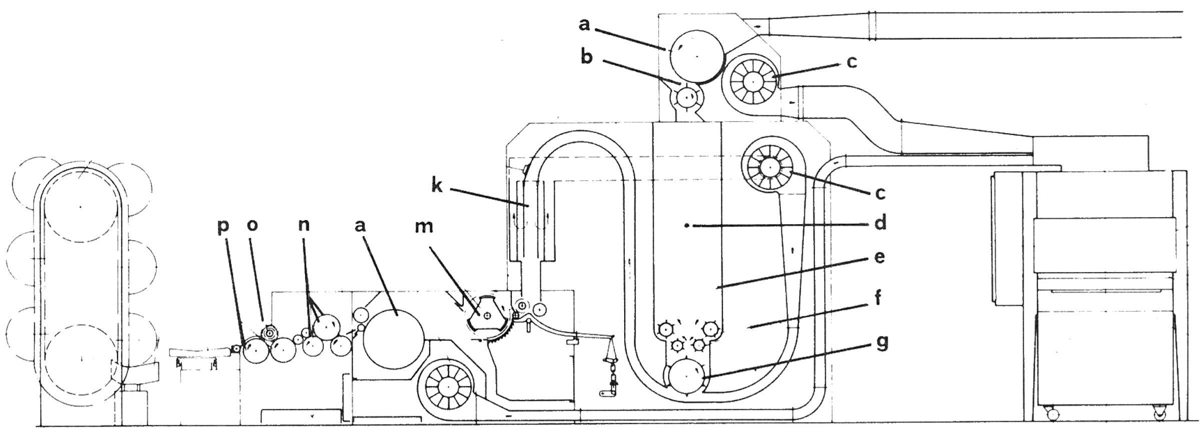
The feed to the carding machine is possible in two ways i.e. pneumatic chute feed with fibres in opened form and lap feed with fibres in form of a sheet or web. However whatever the feed method is used, it is essential that the feeding material to the card should be homogenous over a long term period. In this regard the lap feed is generally preferred because:

(1) The lap feed to the card is less problematic and it is much easy to control the homogeneity of the lap as compared to chute feed.
(2) It can be easily operated with several blends.

With these advantages the lap feed also has some serious disadvantages:

(1) Greater manual effort is required to transport the lap roller.
(2) Laps can be an additional source of faults.
(3) When the lap roller becomes full it has to be replaced by a new empty one, it also requires extra effort.
(4) Since laps are heavily compressed, it puts additional burden on the carding machine.

Because of these serious limitations all the modern cards are fed with chute feed rather than lap feed. However if lap feed is to be prepared, it is done on a machine called as a scutcher as shown below:



(a) Perforated Drum	**(b) Pocketed Roller**	**(c) Fan**
(d) Photocell	**(e) Reserve Chute**	**(f) Take-off Rollers**
(g) Opening Roller	**(k) Feed Chute**	**(m) Kirschner Beater**
(n) Calender Rollers	**(o) Lap Tube**	**(p) Winding Roller**

The main objectives or functions of a scutcher machine are:

(1) Opening
(2) Cleaning
(3) Regulating
(4) Lap Formation

Typically a scutcher machine can be divided into the following regions:

(1) Feeding Region
(2) Opening & Cleaning Region
(3) Lap Forming Region
(4) Lap Doffing Region

(1) Feeding Region

With the help of air suction produced by a suction fan (c), the fibre material form the previous machine enters the scutcher machine and is drawn against a perforated drum (a). The drum revolves rapidly and removes the air from the fibres and hence does some dust removal. A pocketed roller (b) strips off the fibres from the perforated drum and throws it to the reserve chute (e). A photocell (d) is used in to maintain the amount of fibre present in the reserve chute. At the bottom of the reserve chute with the help of the two pairs of take-off rollers (f) and an opening roller (g), the fibre mass is thrown into a narrow feed chute (k). During the transport of the fibres in the feed chute high air pressure condenses the fibre mass into a form of a strand or a web. A pressure measuring and control system ensures a steady air pressure and air flow so that even strand of fibres may be obtained.

(2) Opening & Cleaning Region

The opening and cleaning region of the scutcher line is carried out by using a Kirschner beater. The feed to the beater is given in a very controlled manner by using a feed roller and set of pedal levers. 18 set of pedal levers form a feed plate. The levers press the fibres web with the feed roller with a uniform pressure that changes the thickness of the web. Any variation in the thickness of the fibres web will cause the lever to move up and down. This up and down movement of the lever is translated to alter the speed of the feed rollers so that a constant thickness of the web may be obtained.

The grid under the Kirschner beater is made up of number of triangular bars (most commonly 10) out which the first few can be adjusted independently while the others are adjusted n groups.

(3) Lap Forming Region

The lap formation takes place with the use of a perforated drum (a) that removes the air currents by sucking them into its perforations. As the perforated drum rotates, a single layer of a compact lap is formed on the surface of the drum.

The layer of lap produced on the drum is removed with the help of special stripping rollers and is then subjected to set of three calendering roller with one large calender roller placed on top of the other two calender rollers. The calendering rollers exert a constant equally distributed pressure up to 6000 kg. Because of this high pressure the lap is uniformly condensed and its thickness is reduced. The compressed lap is then wound on a lap tube (o) with the help of two winding rollers (p). The winding rollers also exert a pressure of about 1000 kg so that a condensed lap roll may be produced having a diameter up to 55 cm and it weighs up to 40 kg.
The scutcher machines are also fitted with lap weighing devices that monitor the

weight of the lap roll. Any variation in the weight of the lap from a preset value is registered and based on the variation a signal is given to the servo motor that controls the speed of the machine. If the weight of the lap roll increases the speed of the machine is increased and vice versa.

(4) Lap Doffing Region

When a lap of required diameter and weight is formed then that completed lap roll must be replaced by a new empty one. This replacement of a full lap roll by an empty one is called as doffing. Doffing can either by carried out manually by workers or in modern machines it is done by automatic doffing units.

Dust Removal at Blow Room

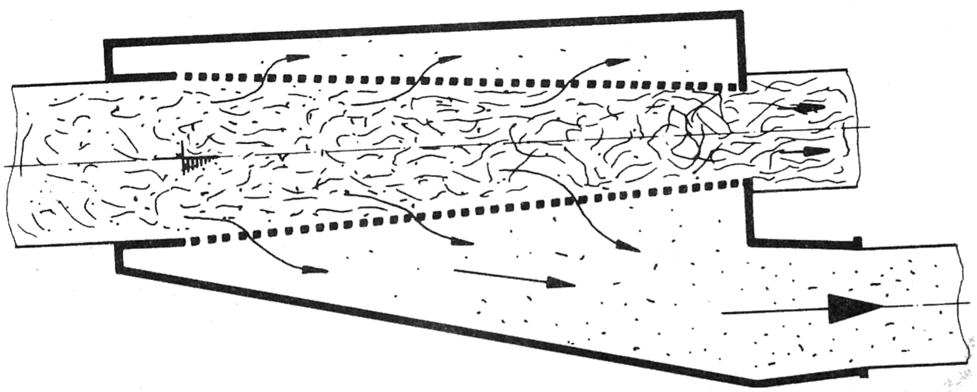
Dust and microdust are the finest particles of trash. Their removal takes place at various stages in the blow room. Two techniques are mostly used for the removal of dust:

(1) By separating the fibres and releasing dust into air, this dust is then removed by removing the dust contaminated air. The release of dust occurs whenever the fibres are rolled, beaten or opened up. In this type of arrangement its not only important to remove the dust contaminated air but also extremely important to maintain a dust free atmosphere in the blow room.

(2) By separating the dust particles directly from the fibres through suction and scarping. This arrangement is better as compared to the first one as chances of dust to fly in the atmosphere are not present. Many different techniques are used to separate the dust from the fibres, most common ones are:

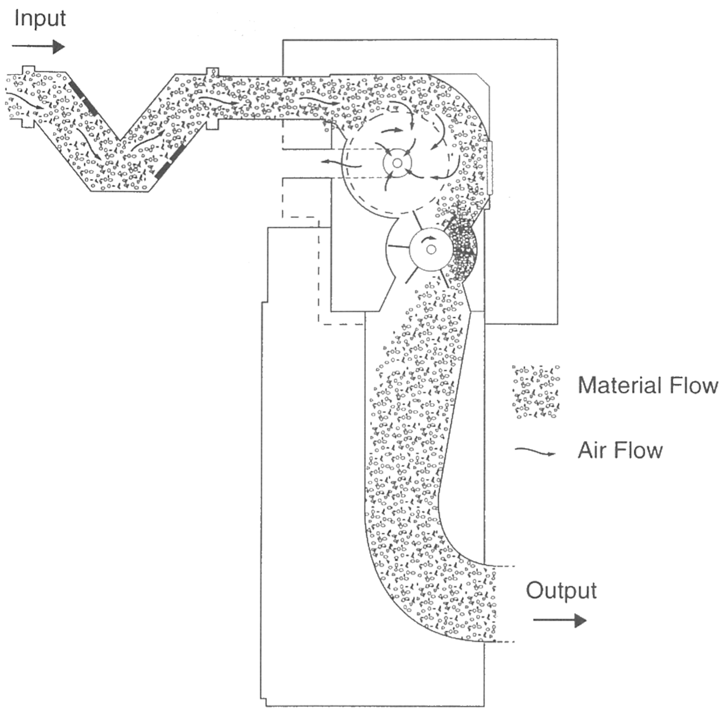
(i) Use of perforated drums.
(ii) Use of Stationary Perforated Surfaces.
(iii) Circulating perforated belts.
(iv) Stationary combs

The perforated drums and perforated surfaces are the most commonly used techniques for dust removal. For example, in the following diagram a Rieter dust extractor is shown that make use of stationary perforated surfaces.



The equipment includes a specially designed converging pneumatic duct having perforations on its either side. This duct is enclosed in a chamber. As the material passes through the duct a strong suction fan draws off the fine dust particles from the fibres.

In the following figure Truetzschler dust extractor is shown that make use of rotary perforated drum:



Here the incoming material is drawn on a perforated drum with the help of air stream. This air stream is then removed by using a high vacuum exhaust through the drum perforation using a suction fan. By doing so, fine dust also gets removed along with the air. The fibre material is stripped off the perforated drum with the help of a paddle roller. The stripped fibre material is then transported to next stage with the help of a suction provided at that end.

Cleaning Efficiency of Blow Room

The effectiveness of a machine or series of machines in a blow room to remove the trash in the fibres is expressed as its cleaning efficiency and is given by:

$$\%\text{Cleaning Efficiency} = \frac{\%\text{ trash in raw fibres} - \%\text{ trash in processed fibres}}{\%\text{ trash in raw fibres}} \times 100$$

Another very practical equation to find the cleaning efficiency is:

$$\%\text{Cleaning Efficiency} = \frac{\%\text{ Waste Removed} \times \%\text{ Trash in Waste}}{\%\text{Trash in Raw Fibres}} \times 100$$

How Much Waste To Remove

All openers & cleaners along with foreign matter also remove a certain amount of short fibres (also called as lint). The composite of trash, dust, fibre fragments and fibres removed is called as waste. Depending upon the machine design and intensity of opening and cleaning used, the removed waste has 40% to 70% of fibres by weight in it. So more fibres present in a waste makes the process more costly. To estimate the amount of waste that must be removed in the blow room in order to achieve a prescribed level of cleaning, following equation can be used:

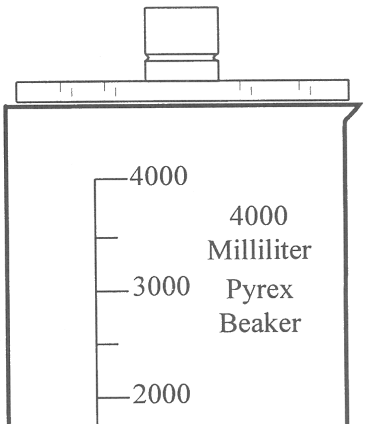
$$\% \text{ Waste Needed} = \frac{\% \text{ Trash in Bales} \times \% \text{ Trash to Remove}}{\% \text{ Trash in Waste}} \times 100$$

The amount of waste removed at each stage of cotton cleaning stage should be known for evaluation and can be found out as:

$$\% \text{ age Waste Removal} = \frac{\text{Waste Removed (Kg)}}{\text{Total Fibres Processed (Kg)}} \times 100$$

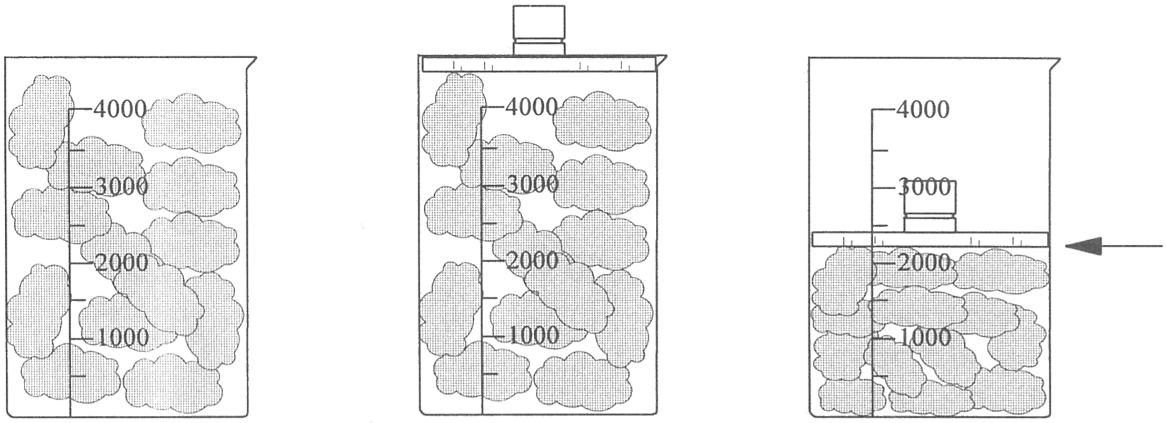
Openness Measurement

The opening effectiveness of a machine or series of machines in a blow room line can be found out by finding the openness index. The openness index can be found out by using a simple apparatus developed by the Textile Institute. The apparatus include a 4000 mm Pyrex beaker with inner diameter of 152 mm and a glass disc of 200 grams in weight. The glass disc has holes on its surface so that air can escape and its diameter is slightly less than the inner diameter of the beaker. The apparatus is shown below:



In order to find the openness index, the following procedure is followed:

(1) A random sample from processing point is taken with a care that openness of the fibre is not disturbed.
(2) The Pyrex beaker is uniformly filled with the fibre sample.
(3) The 200 grams disc is placed on top of the fibre with a care that disc should not settle at a sharp angle.
(4) The volume of the compressed sample is noted down.



(5) The disc is removed and sample weight is found out
(6) The openness index is then calculated as:

$$\text{Openness Index} = \frac{\text{Volume of Fibres (ml)}}{\text{Weight of Fibres (gms)}} \times \text{Specific Gravity of Fibre}$$

In case of blended fibres, the blended specific gravity is taken as:

Blended Specific Gravity = (Specific Gravity of Component1 x %age in Blend) + (Specific Gravity of Component2 x %age in Blend)

(7) In order to have accurate results 8 to 10 readings are taken.

The following table shows the change in openness index of fibres after being processed by various machines and components in the blow room line.

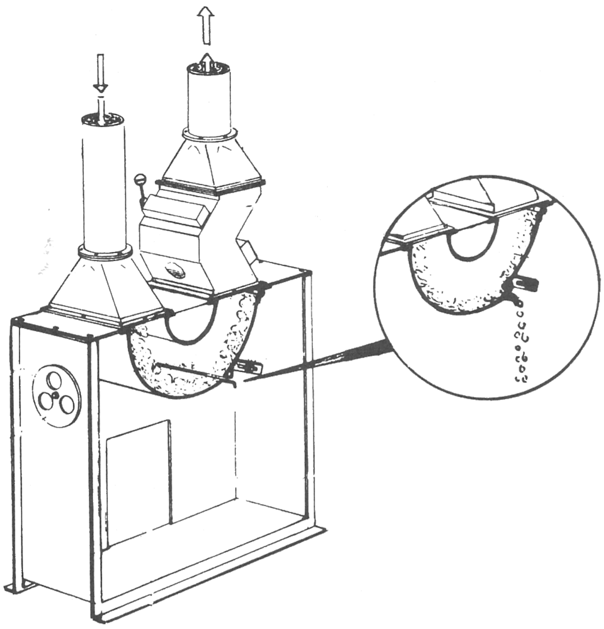
Machine	Change in Openness Index
Hopper Feeder	40 to 50
Top Feeder	80 to 85
Coarse Opener & Cleaner	5 to 10
Fine Opener & Cleaner	15 to 25
Intense Opener & Cleaner	20 to 30
Mixer & Blender	0
Transport Fan	0

Blow Room Accessories

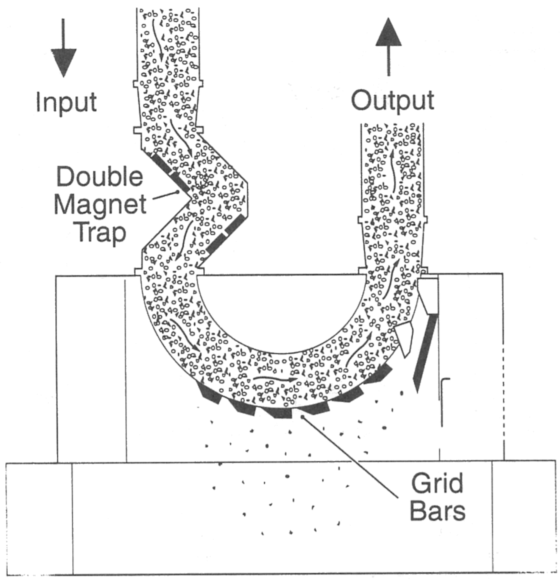
In addition to the main machinery of the blow room many useful accessories are also used such as:

(1) Heavy Particle Separator (HPS)
(2) Magnetic Metal Traps.
(3) Fire Eliminator
(4) Waste Disposal

The heavy particle separator (HPS) removes heavy particle like metal, plastic, wood, etc. These units take advantage of greater inertia of heavier particles in order to remove them. For example in the following figure a heavy particle separator is shown:



Similarly magnetic traps are also but will naturally remove only metallic particles. These magnetic traps can either be used individually or in combination with the heavy particle separator (HPS). One such example is shown below:



If these heavy particles are not removed before processing of fibres then at high speed beaters, they may generate spark resulting in fire. Since the fibres are flammable they can cause lot of damage to the machinery and raw fibre and sometimes can also become life threatening.

So in order to have extra protection in the blow room machinery, it is sometimes also equipped with fire eliminators. The fire eliminator on detecting a spark or a burning material immediately transports the fibre material to stand in open air. Simultaneously an alarm is given and the blow room line is switched off.

THE CARDING PROCESS

The carding is a one of the most important process of the short staple spinning system. Carding is an operation where the tufty condition of the fibres is converted into an individual fibre form. The separation of fibres in individual form is one fundamental operation of carding while the other fundamental operation is the formation of the card sliver. The carding is a very important process because unless the fibres are separated into individuals, they can not be spun into smooth and uniform yarns neither can they be blended properly with other fibres.

Functions of Carding

(1) **Opening**: As the blow room only opens the fibre mass from larger tufts to small ones, the main objective of the carding machine is to further open up the smallest tufts into an individual fibre form.

(2) **Cleaning:** The removal of impurities is also an important objective carried out by the card. Since not all the impurities are removed by the blow room, it is essential at the carding to remove the remaining impurities. Modern carding machines can remove about 85 to 95% of the foreign matter present in the fed fibres. The overall degree of cleaning achieved by both blow room and carding room can be as high as 95 to 99%.

(3) **Mixing & Blending:** As the fibres are processed in the carding machine, they are not only opened up to the extent of the individual fibre form but also are thoroughly mixed together.

Sometimes blending of two or more different types of fibres can take place at the carding machine. The card can be a very good point of blending as with the carding action an intimate fibre to fibre blending is achieved.

(4) **Disentanglement of Neps**: Because of the repetitive beating and opening of the fibres, the number of neps increases from machine to machine in the blow room line. The carding machine due to its special action on the fibres opens the majority of the neps and hence their number is reduced considerably.

(5) **Removal of short fibres:** The carding machine also removes a very small quantity of short fibres. The amount of short fibres removed at the carding process is not more than 1%.

(6) **Sliver Formation:** The end product of the carding machine is produced in a form of a cylindrical mass of fibres called as silver. The sliver is the very first intermediate product of spinning that start to resemble somehow like a yarn.

(7) **Fibre Orientation:** Although not majority of the fibres in the card sliver are parallel and aligned however with formation of the card sliver, the fibres for the very first time becomes slightly parallel and assumes some longitudinal orientation. So the carding process also helps to create partial

longitudinal orientation of the fibres.

Types of Carding Machines

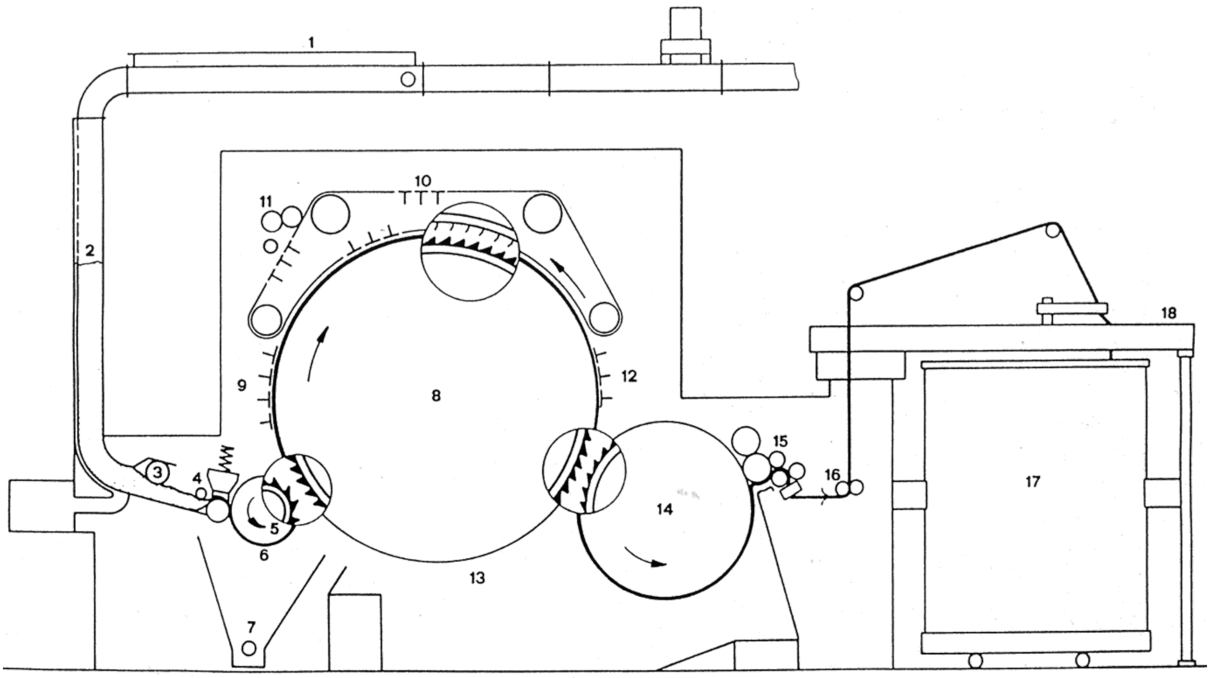
Depending upon the staple length of the fibres to be processed, two types of carding machines are available:

(1) Revolving Flat Card
(2) Roller and Clearer Card

Revolving flat card is meant for short staple fibres with staple length up to 2 inches. The name 'Revolving Flat' card is given because these cards make use of flats that revolve on an endless path. The cotton fibres are carded using the revolving flat card.

The roller and clearer card instead of having revolving flats have number of pairs of working and clearing rollers based on which its name is given. The roller and clearer card is mainly used for woollen fibres and is also sometimes called as woollen card.

Flat Revolving Card and its Components



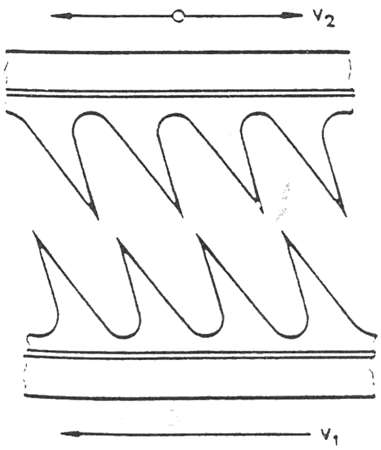
Description of Parts

(1) Conveying Duct	**(2) Feed Chute**	**(3) Feed Roller**
(4) Card Feed	**(5) Taker-in**	**(6) Knife Grid**
(7) Suction Duct	**(8) Cylinder**	**(9) Front Carding Segment**
(10) Flats	**(11) Cleaning unit**	**(12) Post Carding Segment**
(13) Cylinder Grid	**(14) Doffer**	**(15) Stripping Device**
(16) Calender Rollers	**(17) Can**	**(18) Coiler**

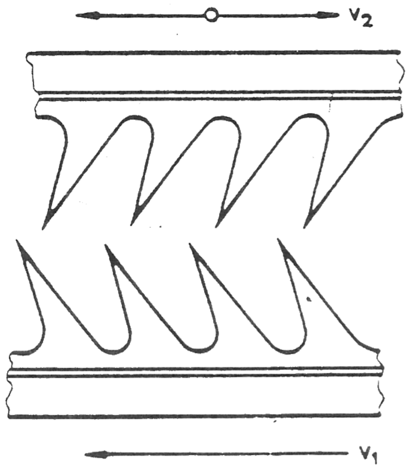
Principles of Working

The carding action refers to passing of fibre material in between two moving wire surfaces. This typical action is repeatedly carried out in the carding machine to individualize the fibres. At various stages of the carding machine the fibres are forced to pass through closely spaced surfaces covered with sharp metal teeth. The use of these sharp pointed surfaces give rise to two types of actions:

(1) Point to point action or Carding Action
(2) Point to back action or Stripping Action



Carding Action



Stripping Action

(1) <u>Carding Action</u>

The carding action is used to separate and individualize fibres. This action takes place between:

(i) Feed roller and taker-in
(ii) Cylinder and flats

<u>Requirements of Carding Action</u>

(a) There should be two moving wiry surfaces between which fibres are subjected.
(b) The action between these two wiry surfaces should be point to point.
(c) There should be a difference in the surface speed of these two surfaces. Greater the speed difference more carding power is achieved

Carding Power = Surface Speed of Cylinder / Surface Speed of Flats

To achieve best carding power, the speed of the flats should be kept as low as possible. The optimum running speed of flats is about 4 to 6 inches per minute. To vary the carding power the surface speed of the flats is altered depending upon the opening and cleaning required at carding.

(d) The distance between the two wiry surfaces should be constant. For cotton fibres a gauge of 8/1000 to 10/1000 of an inch is used.

(2) <u>Stripping Action</u>

The stripping action is used to transfer the material from one place to the other. As the material is transferred by this action, opening and cleaning also takes place. Stripping action takes place between:

(i) Taker-in and cylinder
(ii) Cylinder and doffer
(iii) Doffer and stripping roller

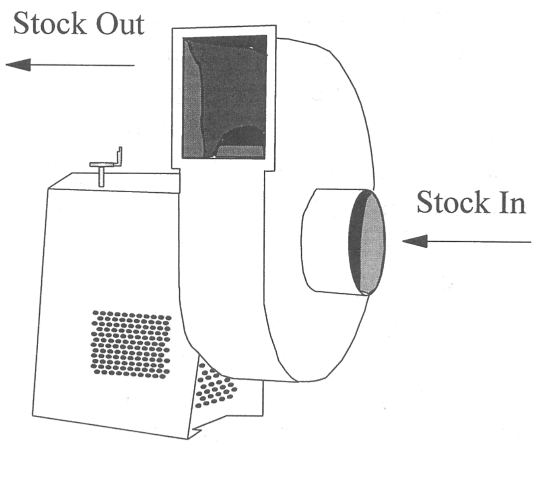
Requirements of Stripping Action

(a) There should be two moving wiry surfaces.
(b) The action between these two wiry surfaces must be point to back.
(c) There should be a difference in the surface speed of two surfaces. However the difference in the surface speeds should not be as high as that in carding action. The recommended difference ratio is 1:2 i.e. the surface to which the material is to be transferred should have twice the surface speed.
(d) The distance between the two wiry surfaces should be constant. For cotton fibres a gauge of 3/1000 to 7/1000 of an inch is used.

Material Feed To The Card

The fibre feed to the card coming from the blow room can either be in the form of a lap or in chute feed form. Although the lap may have some advantages but because of the serious limitations associated with the lap feed, it is no longer used in the modern short staple spinning, instead the chute feed is preferred.

The final machine in the modern blow room line also acts as a card feeder. Depending upon the amount of trash present in the raw fibres and the degree of opening and cleaning, the card feeder can either be a fine opener & cleaner or an intense opener and cleaner. Whatever the case may be, after the fibres are processed by the final machine, the fibres are transported with the help of a stock transport fan to the ducts and chutes that lead to the carding machine. A typical stock transport fan is shown below:



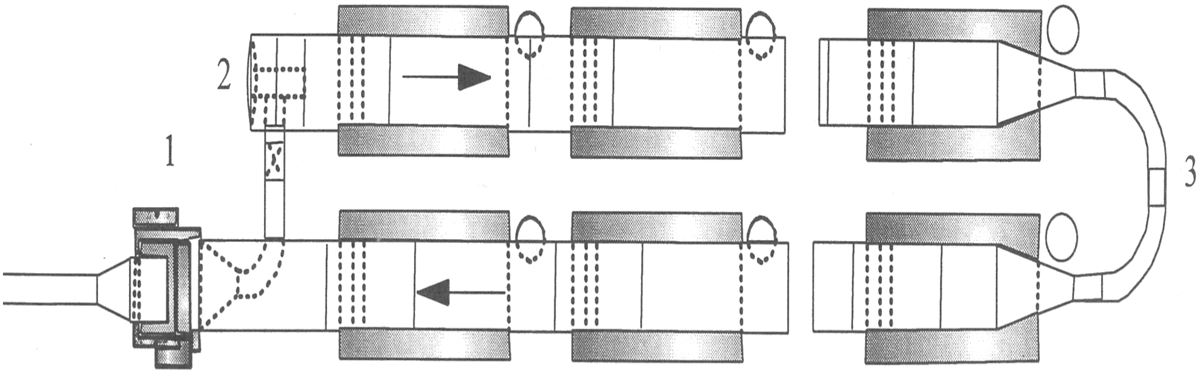
Generally one fine or intense opener and cleaner with a transport fan can give feed to line of cards.

Transport Duct Systems

Two basic transport duct systems are used commercially:

(1) Re-Circulation System
(2) Dead End System

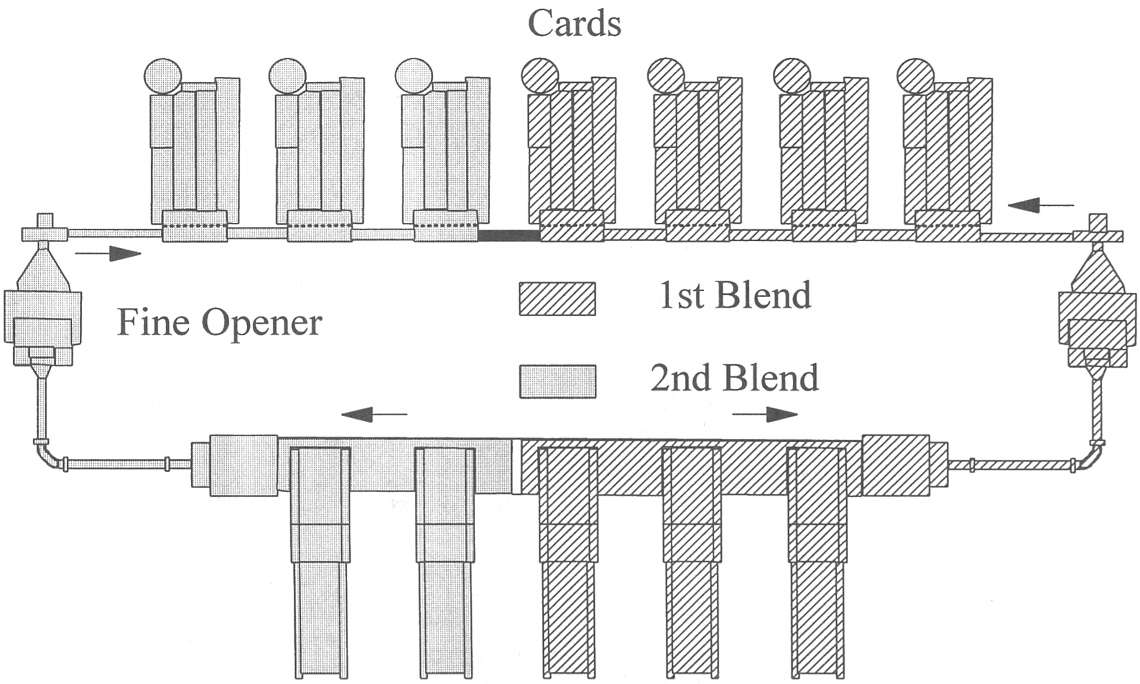
(1) Re-Circulation System



As shown above, in this system a fine or intense opener (1) with the help of a stock transport fan (2) supplies the opened fibres in the direction of arrows to a circular pneumatic duct. A number of carding machines are connected to this circular pneumatic duct with the help of vertical chutes. In this system an excess of fibre is supplied to the duct and the stock of fibres that do not fall in the vertical card chutes is returned back to the opener to be re-circulated.

(2) Dead-End System

A typical dead-end transport duct system is shown below:



As shown above, the system makes use of two separate fine openers each with a separate stock transport fan. Both of these openers feed the chute distribution duct from opposite sides. Since there is no re-circulation of fibres, the distribution duct can be blocked between any two particular cards thus allowing two groups of cards to process simultaneously two different fibre stocks independently. Blockage of the duct is achieved by used a simple slide plate having pressure sensitive sensors. These sensors control the speed of the feed roller of the opener.

The dead-end system is widely used in modern installments because of the following reasons:

(iii) Fewer neps are generated.
(iv) Fibre breakage is less.
(v) The dead-end system has greater flexibility.
(vi) Machinery instalment is easier.
(vii) Feeding is easy and reliable.

Operation of Revolving Card

The operation of the card can be divided into three main areas:

(1) Feeding
(2) Carding
(3) Doffing

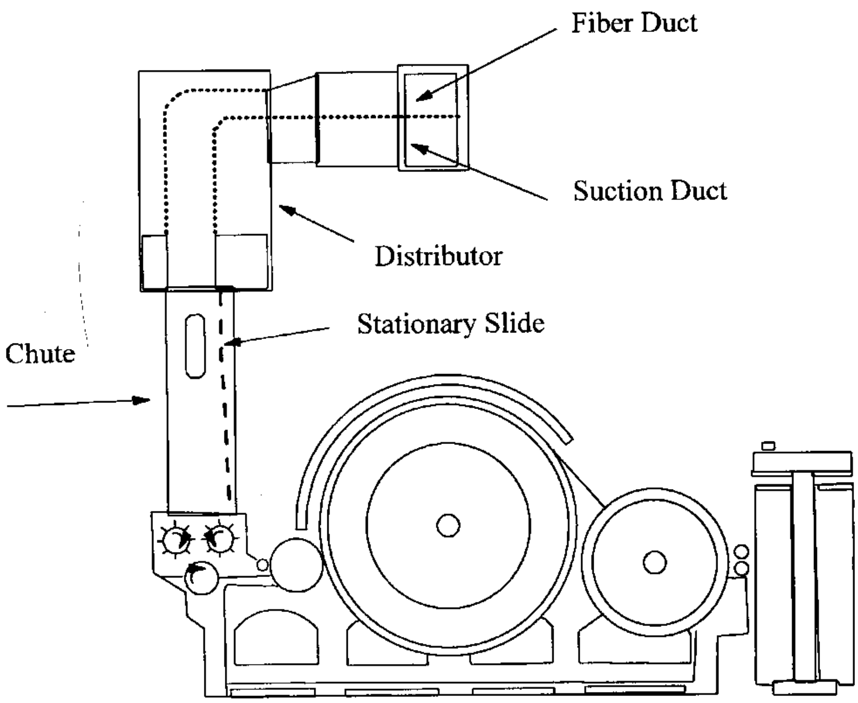
(1) Feeding Region

Functions of the Feeding Region

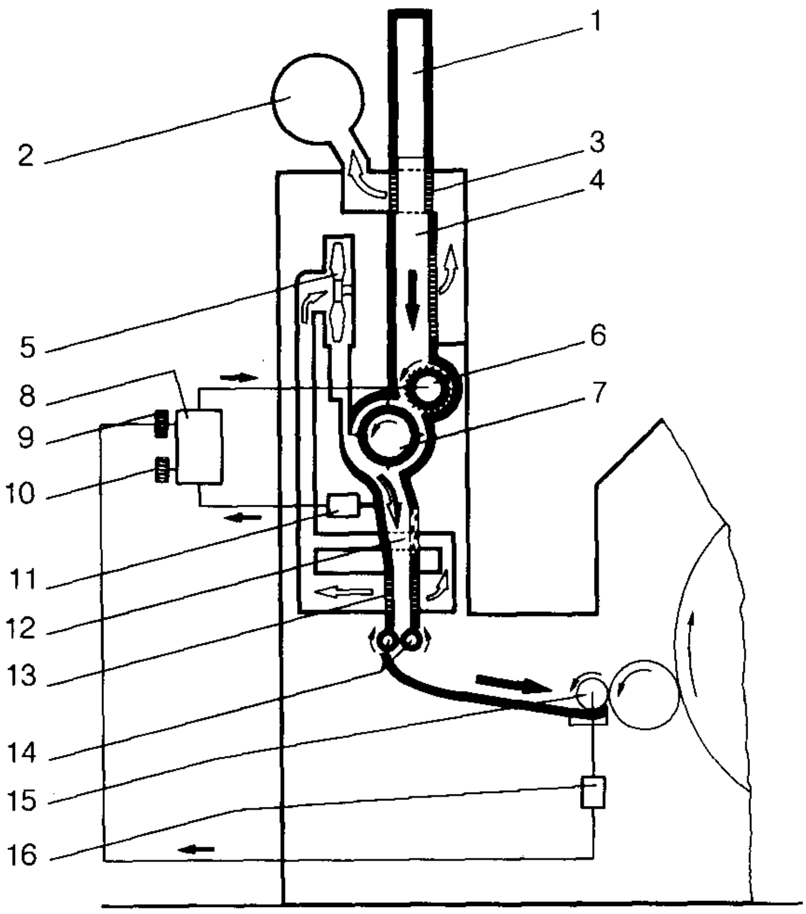
(i) Feeding of fibres to the carding machine at a controlled and pre-determined rate according to the speed and productivity of the card.
(ii) Thorough opening of the fibres.
(iii) Removal of impurities (cleaning).
(iv) Transferring the fibres from the taker-in to the main cylinder.

The Chute Feed System

The output of the carding machine i.e. card sliver should be regular and free from faults so that the resultant yarn made out of it can also be regular and consistent in quality. This is only possible if feed given to card is even and uniform. If the card uses lap feed then even feeding may not be a problem since the lap is already checked for its count accuracy at the scutcher. However the chute feed is more sensitive and inconsistent. To obtain even chute feeding, the fibres in the chute should be equally thick, evenly distributed over the whole width of the card and should have same density all over. In its simplest form the chute feed to the card is shown below:



This simple arrangement is called as a single chute system. Here the fibres are fed from the top. The fibres fall down due to gravity. A pair of delivery roller at the bottom discharge the fibre stock on to the card feed table. This is a conventional system used in old machinery and has poor consistency. A better and modern version of chute feeding system is the double chute system as shown below:

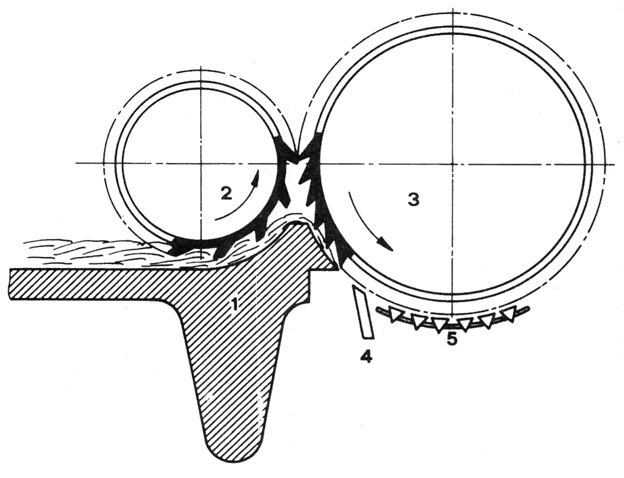


(1)	**Distribution Duct**	**(2)**	**Dust Extraction**	**(3)**	**Air Outlet**
(4)	**Reserve Trunk**	**(5)**	**Fan**	**(6)**	**Feed Roller**
(7)	**Opening Roller**	**(8)**	**Control Unit**	**(9)**	**Pressure Adjustment**
(10)	**Speed Adjustment**	**(11)**	**Pressure Sensor**	**(12)**	**Feed Trunk**
(13)	**Air Outlet**	**(14)**	**Take-off Rollers**	**(15)**	**Card Feed Roller**
(16)	**Speedometer**				

This is a more sophisticated designed feeding system that makes use of a fan to keep consistent air pressure on the fibre stock. A sensor is used that register pressure variation on the fibres. If the pressure on the fibre mass increases, the speed of the feed roller is also increased and vice versa. This helps to keep a constant pressure on the fibres and hence a consistent fibrous stock is maintained in the lower compartment and a controlled feed is given to the carding machine.

Card Feeding Device

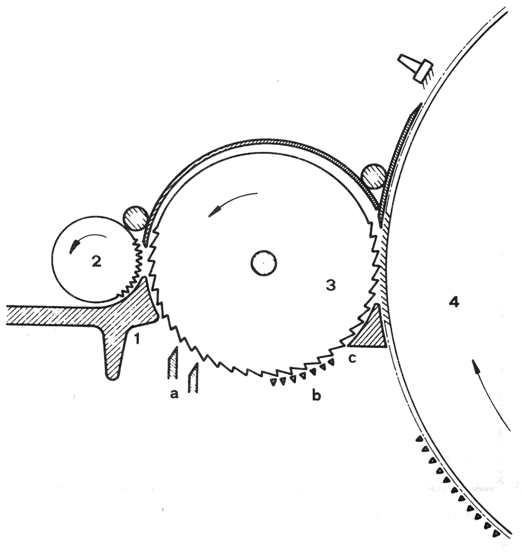
The fibre stock at a consistent rate is fed to the feed assembly of the card. In its simplest form, feed assembly is shown below:



This feed assembly comprises of a stationary feed table with a feed plate (1). A feed roller (2) with a diameter of 80 to 100 mm is used that presses the fibres against the feed plate. The surface of the feed roller is covered with saw tooth wire. The special design of the feed plate forces the fibre mass towards the taker-in and the carding begins.

Taker-in and its Operation

The taker-in roller has a diameter of about 250 mm having its surface covered with saw tooth. The speed of taker-in roller ranges between 800 to 1500 rpm. Beneath the taker-in an enclosure of grid elements for cleaning purpose are used.



Working at 1000 rpm the taker-in provides 600,000 beating points per second with a circumferential speed of about 50 km per hour and a draft of about 1000 is given. This severe point to point or carding action of the taker-in does majority of the fibre opening and about 50% opening of the entire carding machine is achieved here.

Cleaning

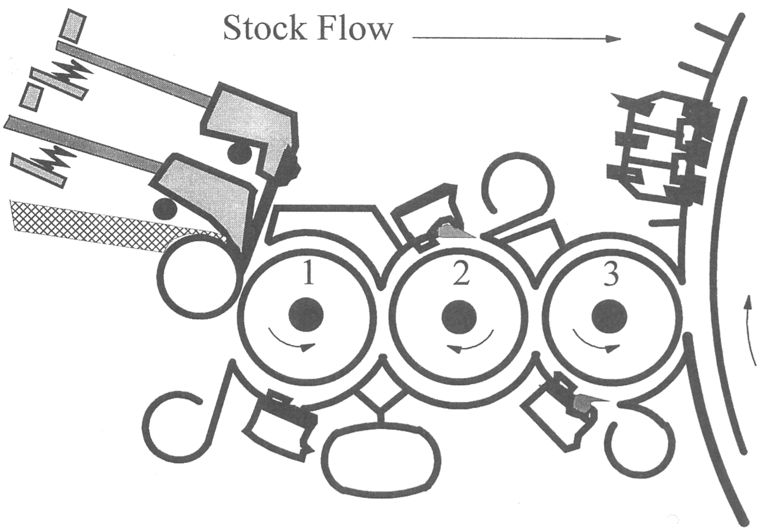
The extensive opening of fibres at the taker-in allows the removal of impurities with the help of cleaning aids placed beneath the taker-in. The cleaning aid in the conventional card includes 1-2 mote knives and a grid whose half of the surface is perforated sheet and the other half is slotted sheet. The impurities are removed as the fibre mass at high speed strikes the knives and the grid. In modern cards to achieve high speeds instead of using grids triangular carding segments are used.

Transfer of Fibres to Main Cylinder

Between the surfaces of the taker-in and the main cylinder the condition of point to back action or stripping action arises. Due to the stripping action, the fibre material is transferred to the main cylinder. As the fibres are transferred to the main cylinder, longitudinal orientation of the fibres takes place here. This orientation depends upon the ratio of the surface speed taker-in to cylinder, ideally this ratio should be 1:2. i.e. a draft of slightly above 2 is given at this point.

Use of Multiple Taker-in Rollers

The standard carding machine has only one taker-in roller. At higher production rates to achieve good opening without fibre damage some manufacturers have come up with a technique of using two or sometimes three taker-in rollers. For example Truetszchler DK-803 card as shown below utilizes three taker-in rollers:



Three taker-in rollers are used so that at very high speeds, the opening of fibres may be done gradually. This is done by:

(v) Rotating all three taker-in rollers in opposition directions to each other.
(vi) Keeping the speed of the each succeeding taker-in roller higher than the previous one (each roller runs 25% faster than the last one).
(vii) Using finer tooth covering on each of three succeeding taker-in rollers to ensure steady flow and opening of material at high speed.

(2) Carding Region

Functions of the Carding Region

(1) Intensive opening of the fibres into individual fibre form.
(2) Removal of the remaining trash and impurities.
(3) Removal of short fibres

Carding Action

The major carding action takes place in the area between the main cylinder of the card and revolving flats. As the material is stripped off the taker-in towards the main cylinder, the fibre mass is subjected to severe carding action due to a significant difference in the surface speed of the cylinder and flats.

The flats move at a speed of about 4 to 6 inches per minute whereas the cylinder having a diameter of about 50 inches rotates at a speed of 150 to 600 rpm. The cylinder of this diameter and speed produces a surface speed which is about 10,000 times more than that of the flats. To alter the carding power, only the speed of flats is changed while the speed of the main cylinder remains the same. The direction of movement of flats in old cards is kept towards the front of the machine while in modern cards it is kept towards the back. The direction of motion of flats has no effect on the carding power of the machine.

For proper carding action, the space distance between the flats and main cylinder is very important. It should not neither be very great where carding action is compromised nor very less where fibre breakage may take place. For cotton fibres usually spacing of 10/1000" and for polyester 17/1000" is used.

Removal of Trash & Short Fibres

During the carding action between the flats and the main cylinder the waste gets embedded into the interspacing between the adjacent wires of the flats. The waste includes mainly the short fibres, neps, trash particles and dust. It is therefore very essential to clean off the surface of the flats so that the carding action between the main cylinder and the flats may not be affected. In old carding machines manual cleaning was carried out by stopping the machine after a specific period of time (4 to 6 hours). However in modern cards the waste removal off the flats is carried out continuously with the normal operation.

Carding Power

The degree of carding or carding power achieved on a carding machine can be expressed as:

Carding Power = Rotary Speed of Cylinder / Surface Speed of Flats

Since the carding power does not only depend upon this ratio, so instead the carding power of a card machine is more effectively expressed in terms number of beating points presented per fibre. This can easily be found out by averaging total number of fibres being fed in specific time divided by the total beating points presented in that same time.

Carding Power = Beating Points per unit time / Fibres Fed in unit time

For example in modern cards at the taker-in region there are about 0.3 beating points per fibre in other words approximately every three fibres will have one beating point. At the main carding region (between cylinder and flats) there are about 10-15 beating points available for each fibre. So by comparing the number of points available per fibre, true carding power is determined.

The production rate of the modern carding machine has increased considerably. This means that more number of fibres will pass through the machine in any given time. In order to keep the same carding power, the number of beating points must also increase proportionately. This is possible by:

(i) Having more points per unit area (finer clothing) on the carding surface.
(ii) Increasing the speed of the carding rollers
(iii) Using additional carding segments.

The clothing of the carding elements can not be changed to a great extent because a suitable distance must be given in between the two adjacent wires or points. For coarse fibres coarse clothing and for fine fibres fine clothing is used.

Similarly speeds of the carding rollers can not be increased infinitely. For example the production of the card has increased from 25 kg/hour to about 75 kg/hour. In order to achieve same carding power, old 300 rpm speed of the cylinder must be raised to 900 rpm. However this is not possible from both design and technological aspects and there would be lot of fibre damage at this speed.

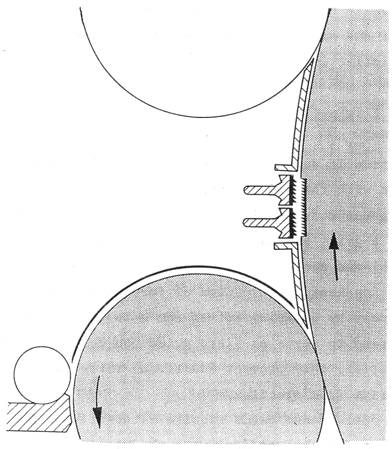
So the only approach that is applicable for increasing the carding power is the use of additional carding surfaces or carding positions. Two possibilities are present in this regard:

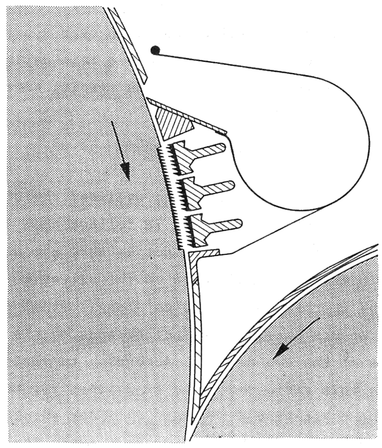
(i) Increase in number of rollers used in carding machine.
(ii) Use of additional carding segments.

Use of Additional Carding Segments

Additional carding segments can be used in two positions in the carding machine:

(1) Under the taker-in roller.
(2) Between the taker-in and flats (pre-carding segment).
(3) Between the flats and doffer (post-carding segment).





Pre-Carding Segment **Post-Carding Segment**

- The carding segment used under the taker-in region is to facilitate better removal of impurities.
- The pre-carding segment helps in an efficient transfer of the fibres from the taker-in to the main cylinder. It also ensures that fibres are transferred evenly and no lumps of fibres are allowed to pass to the main cylinder.
- The post-carding segment is mostly used in conjunction with the mote knife. The short fibres, impurities and the dust passes through the small gap provided between the machine cover and the mote knife and are sucked off using a suction fan. This helps in removing further impurities during the operation in the card.

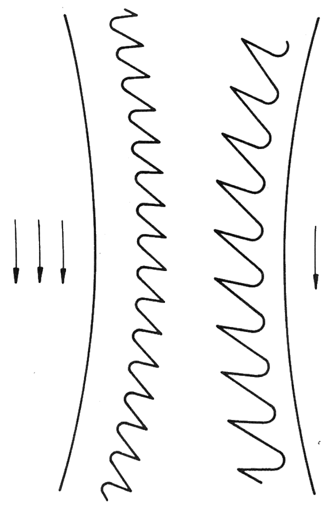
(3) Doffing Region

Functions of the Doffing Region

(1) Transferring of fibres from the main cylinder on to the doffer.
(2) Stripping the fibre web from the doffer.
(3) Gathering the fibre web into a twistless strand (sliver).
(4) Condensing or calendering the sliver.
(5) Depositing the sliver into the sliver can.

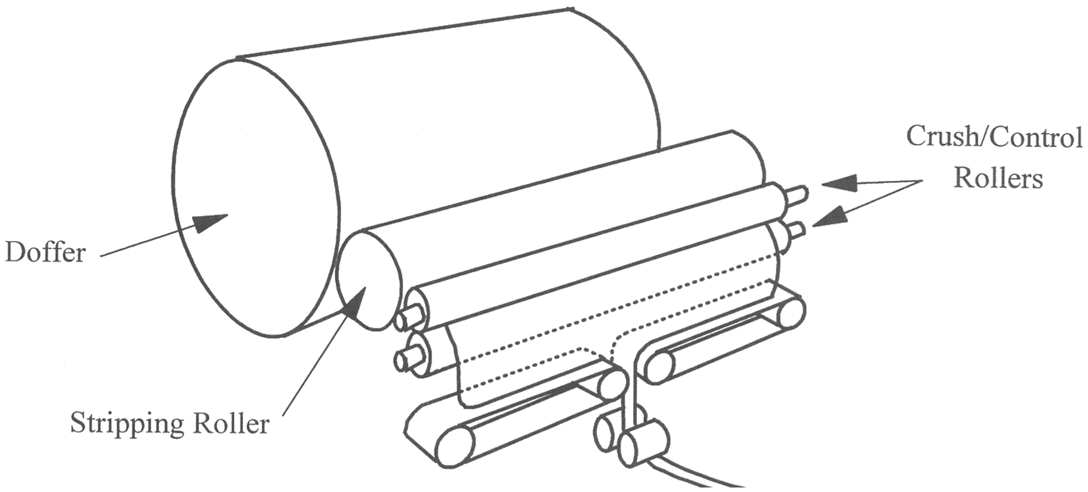
The Doffing Operation

The cylinder is followed by a roller called as doffer. The main purpose of the doffer is to take the individual fibres coming from the cylinder and to condense them to a web form. The diameter of the doffer is 24 to 27" and it rotates at a speed of 20 to 60 rpm. The surface speed of the cylinder is about 20 to 25 times more than the surface of the doffer. This helps to create a thick layer of fibres on the surface of the doffer. The action between the cylinder and doffer surfaces is shown below:



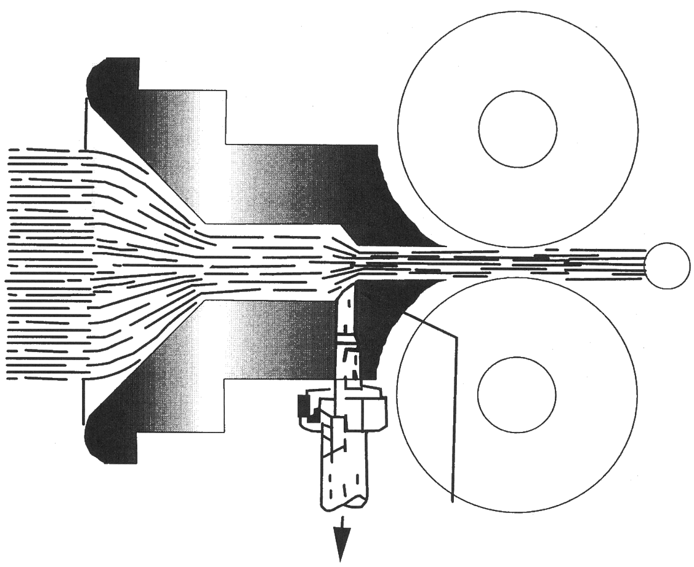
Owing to a very low surface speed of the doffer, the rate of transfer of the fibres is only about 0.2 to 0.3 i.e. on average a fibre rotates 3 to 5 times around the cylinder before it is transferred to the doffer. In order to improve the transfer rate, the spacing between the cylinder and doffer clothing is reduced to only 3/1000" as compared to a standard stripping gauge of 7/1000".

The Detaching Apparatus



In old conventional card the detaching of the web from the doffer is done by using an oscillating comb or doffer comb that moves up and down at a rate of 2500 strokes per minute. However in the modern high performance cards, the web of fibres from the doffer is detached by using a special detaching or stripping roller as shown in the figure above because the reciprocating motion of the doffer can not be used at higher speeds.

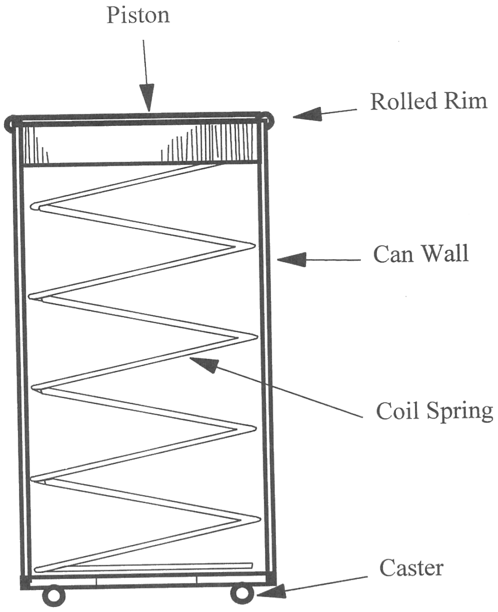
The detached web is then passed between a pair of calendar rollers or crush rollers placed on one another. The surface of these rollers is smooth and a pressure is applied in between these rollers. These rollers provide an additional point of cleaning because any foreign matter present in the fibres can be squashed and dropped off at this stage. The crushed fibre web is finally subjected to transverse belt sliver condenser. The opposite motions of these transverse belts convert the fibre web into a condensed strand of fibres commonly known as sliver. Another way of converting the fibre web into a sliver is by using a specially designed trumpet guide as shown below:



The special funnel shape of the trumpet guide forces the web stripped off the detaching roller to be condensed into a sliver form.

Depositing Sliver into Cans

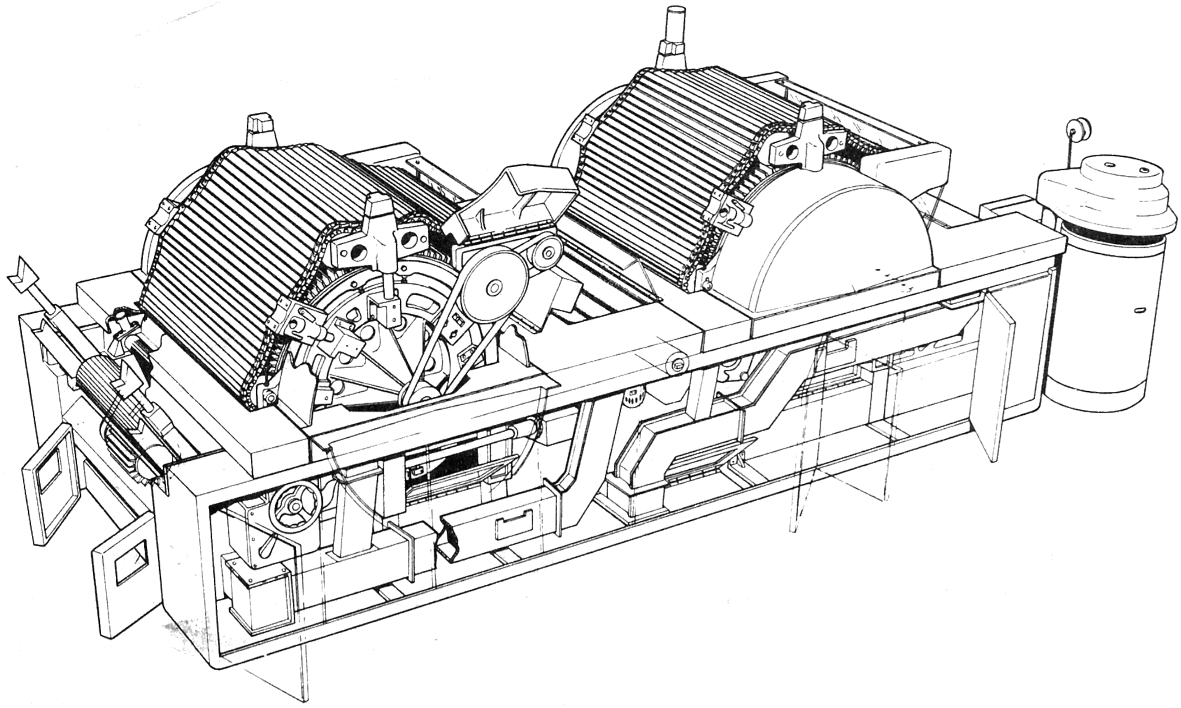
The sliver produced by the card must be properly stored in packages called as cans. Normally can used for sliver storage are 48 inches with a diameter of 30, 36 or 40 inches. The sliver coming from the transverse belt is passed through a special spiral motion of the coiler calendar rollers which helps to deposit the sliver in a spiral form.



Cross-sectional View of an empty Sliver Can

Duo or Tandem Carding

As the name implies the duo or tandem cards consist of two individual cards joined together as a single unit as shown below:



The doffer of the first card gives feed to the taker-in of the second card. The dual carding action on the fibres has a positive effect on the quality and blending of the fibres. Research has shown that tandem cards result in lower nep count, improved yarn appearance and also reduces yarn breakage during spinning. However the main disadvantages of the tandem carding are its very high initial cost, high power consumption and higher maintenance cost. Also since high performance cards can give almost the same quality of carding as that of tandem carding, the higher cost of tandem carding is not justified for its common use. Due to this reason tandem carding has not become very popular.

Draft

The degree of reduction in the linear density of the fibre material is called as the draft. Draft can be expressed in two forms:

(1) Actual or Technical Draft

Actual Draft = Linear Density of Input / Linear Density of output

(2) Mechanical Draft

Mechanical Draft = Linear Speed of Output / Linear Speed of Input

If the percentage waste removal during the carding machine is (W) then the actual and mechanical draft are related to each other as:

Mechanical Draft = Actual Draft (1 – W/100)

THE COMBING PROCESS

Combing is an optional process in the processing of short staple fibres necessary for the preparation of high quality combed yarn. The process of combing is carried out after carding and the combed sliver after passing through the draw frame follows the regular path of yarn formation.

The carded sliver still has some trash particles, neps and short fibres in it. In addition to it, the individual fibres in the card sliver are not well aligned longitudinally and majority of them have hooked surfaces. The basic purpose of combing is to remove short fibres and remaining impurities and to make the fibres well aligned and straight so that only long high quality long fibres are used for yarn making a yarn. The carding process brings out following positive influence on the yarn character:

(i) More uniform yarns and stronger yarns can be made as compared to carded yarns.
(ii) Owing to greater cleanliness and alignment of the fibres, the combed yarns are much smoother and have better lustre as compared to carded yarns.
(iii) Combed yarns are less hairy and compact as compared to carded yarns.
(iv) Combed yarns can be spun into much finer counts as compared to the carded yarns. Counts finer than 40 Nc are usually spun with combing where uniformity and quality is required. However to make stronger yarns, even coarse yarns are spun by combing.
(v) The combed yarn requires less twist as compared to carded yarns. So high quality knitted fabrics are also made from combed cotton to have better appearance and handle.

The combing process therefore results in an improvement in the quality of the yarn and also enables the spinner to spin finer yarn counts. However the above mentioned quality improvements in the yarn are obtained at a cost of additional machinery, additional process, extra labour and extra floor space. This increases the cost of yarn production considerably.

Functions of Combing

(1) To separate the long fibres from the short ones. The longer fibres are processed into a combed sliver whereas the shorter fibres are removed as a waste. Depending upon the quality of the yarn required predetermined quantity of short fibres are removed during the combing process.

(2) To eliminate the remaining impurities and trash left by the carding process. The waste combination of trash, short fibres and neps is collectively also called a noil. The amount of noil removed during combing ranges from 5% to 25% depending upon the quality of the yarn.

(3) Elimination of majority of the neps in the fibre material

(4) To straighten and align the separated long fibres.

(5) To create a combed sliver with maximum possible evenness.

Degree of Combing

The quality of the combed yarn and degree of yarn fineness achievable depends upon the type and quality of the raw material and degree of combing carried out during the combing process. Based upon the degree of combing, following different combing processes can be employed in the production of a combed yarn:

(1) **Scratch Combing** is carried out to produce lower quality of coarser combed yarns. In scratch combing only as little as 5% noil is removed. This slightly improves the quality of the yarn as compared to carded yarns. Scratched combed yarns are produced by using medium quality and medium lengths of fibres.

(2) **Half Combing** removes noil in the range of 7 to 10%. Such degree of combing is again used for medium lengths of fibres.

(3) **Normal Combing** is carried out in majority of the cases where fine quality of long fibres is combed with noil removal in the range of 10% to 15%.

(4) **Super Combing or Fine Combing** is used for making best possible fine yarns. Here up to 25% noil is removed by using best quality Egyptian cotton.

(5) **Double Combing** was once used with the finest Egyptian cotton to produce extremely fine counts of yarns. In this double stage of combing, noil up to 25% is removed. However this method is rarely used nowadays.

Comber Lap Preparation

Since the main function of combing is to remove short fibres, if the carded slivers are directly fed to the combing machine, the waste extraction would be very high and also lot of fibre breakage will take place. This is due to the fact that fibre orientation in the card sliver is very poor and also the card sliver has majority of hooked surfaces. So it is desirable for the card sliver to be prepared into such a form which is suitable for the combing operation. For this reason a suitable lap with straight and parallel fibres is formed which is presented as a feeding material to the comber.

The majority fibres in the card sliver have trailing hooks (about 50%). It has been established with experience and experiments that better combing results are obtained when majority of fibres presented to the comber has leading rather than trailing hooks. This is because the leading hooked fibres can be straightened out better and they pass into the combed sliver whereas the trailing hooked fibres have less chances of straightening and more chances of being removed as a noil. In order to straighten and align the fibres and also to convert the trailing hooks into leading position, even number of machines must be used in the preparation of a comber lap and most commonly two machine processes are used. Straightening and orientation of fibres is achieved by using roller drafting method in both of the preparatory operations. The total draft of both the machines ranges from 8 to 12. Since the drafting tend to cause imperfections and unevenness in the material, operation of doubling is also carried out. The doubling not only helps to improve the evenness of the material but also is necessary to form a sheet of material which is converted into a lap.

Methods of Comber Lap Preparation

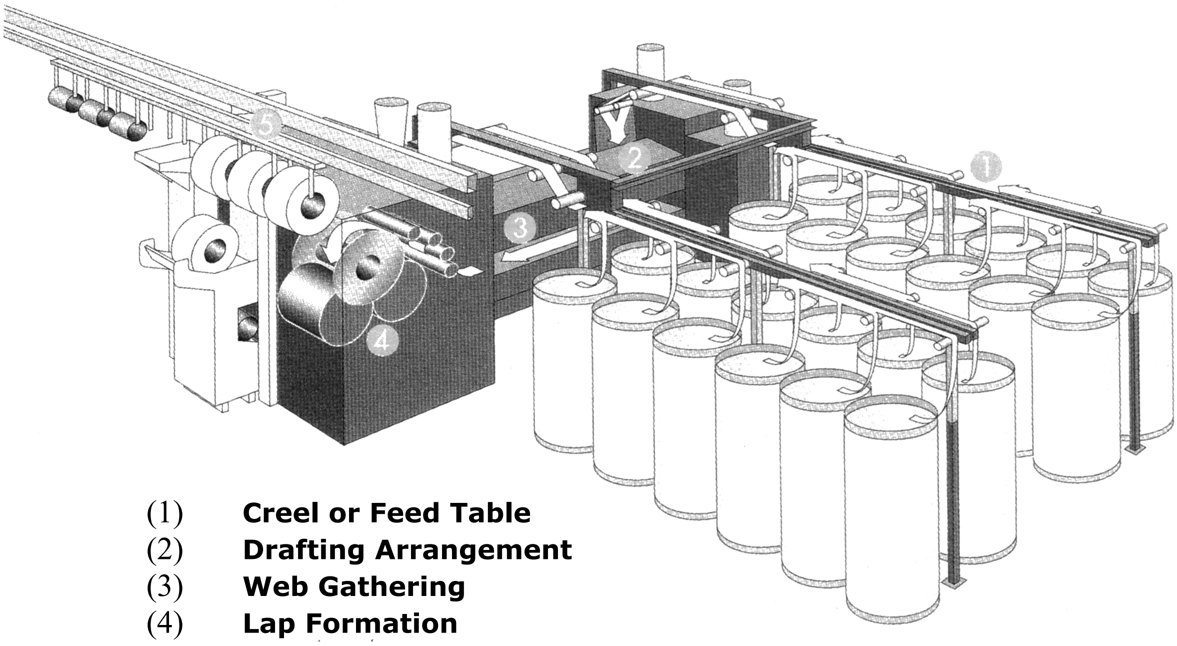
Commercially two systems of preparing the comber lap are used:

(1) Lap Doubling System
(2) Sliver Doubling System

(1) **Lap Doubling System**

In the lap doubling comber preparation system the carded sliver is passed through a sliver lap machine followed by a ribbon lap machine.

The Sliver Lap Machine



(1) **Creel or Feed Table**
(2) **Drafting Arrangement**
(3) **Web Gathering**
(4) **Lap Formation**
(5) **Automatic Lap Transport**

The sliver lap machine is divided into the following regions:

(1) Creel Region
(2) Drafting Region
(3) Winding Region

(1) **Creel Region**

The creel of the machine consists of two feed arrangements; each usually holds 12 card sliver cans. All together it gives a doubling of 24. All card slivers after passing through series of guide rollers enter the drafting arrangement.

(2) **Drafting Arrangement**

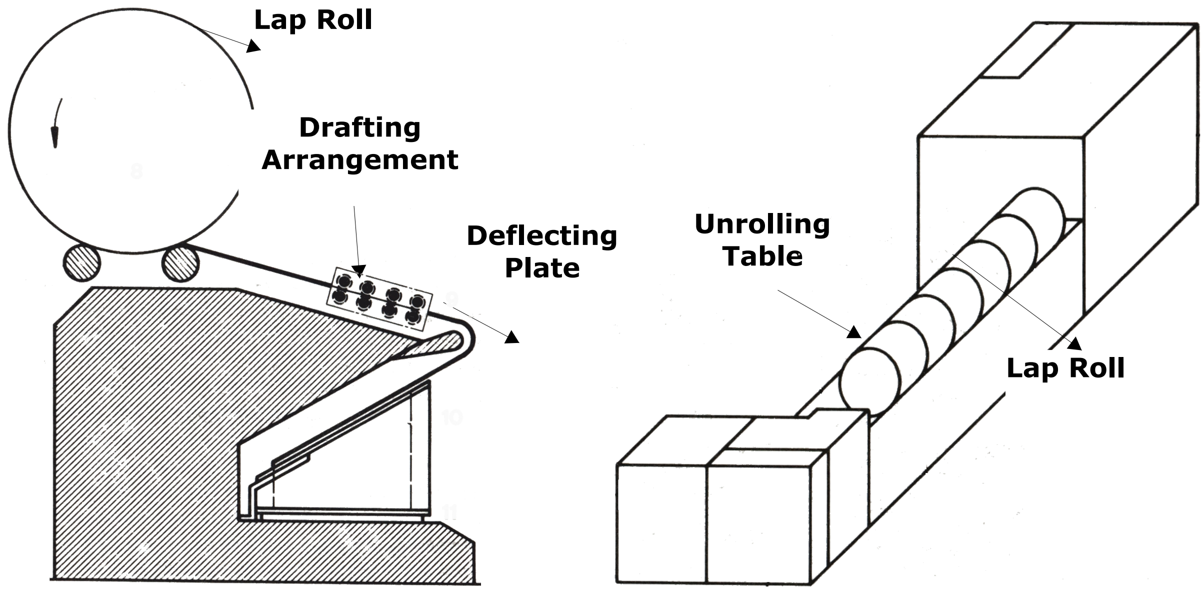
The sliver lap machine commonly uses a 4 over 4 roller drafting system with top roller pneumatically weighted. The pneumatic pressure can be adjusted up to 1600 Netwons. A total draft of 1.3 to 3 is given at this arrangement.

(3) **Winding Region**

The sheet or web of fibres after being drafted out is passed over a guide plate or deflecting plate which changes its direction towards four calender rollers. The high compression (up to 16000 Newtons) created by the calneder rollers transforms the fibre web into a lap. The lap then passes through two winding rollers that press against the lap tube with a pressure of 10000 Newtons and assists in winding of the lap on to the lap tube. The lap tube is placed on lap weighing devices which on the modern machines automatically removes the lap roll when its required weight has been reached and is ejected on an automatic transport system that will take the lap roll directly to the next machine i.e. ribbon lap machine.

The Ribbon Lap Machine

The basic concept of ribbon lap machine is same as that of the of the sliver lap machine as shown below:



Here instead of a feed table a lap unrolling table is provided for 6 lap rolls. The sheet unrolled from the lap passes through a standard 4 over 4 roller drafting system where a draft of 3 to 6 can be given. The drafted material after passing through calender rollers is wound by the winding assembly on a lap tube. The ribbon lap machines have an advantage that it gives a doubling of 6 in web form and thus high degree of evenness in transverse direction is achieved.

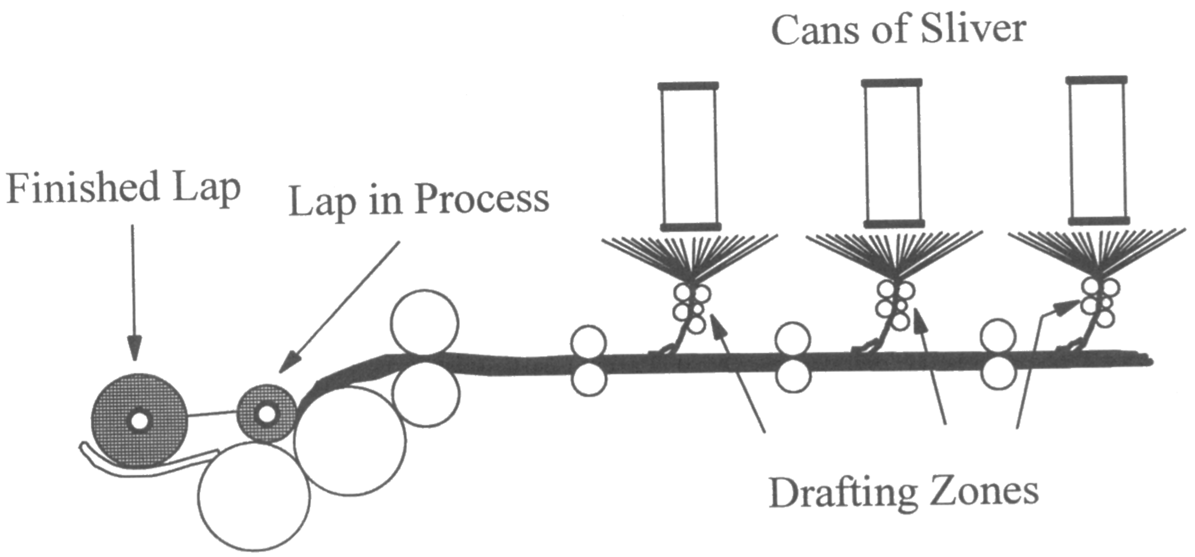
The lap doubling system is considered to be old conventional system of preparing comber lap. But with the introduction of high performance modern machinery the trend is tilting towards using a sliver doubling system rather than lap doubling.

(2) **Sliver Doubling System**

In the sliver doubling process the carded sliver is given first passage through a normal draw frame and then series of drawn slivers are given second passage through a sliver doubling machine.

Sliver Doubling Machine

The working principle of a modern sliver doubling machine also known as the super lap machine is shown below:



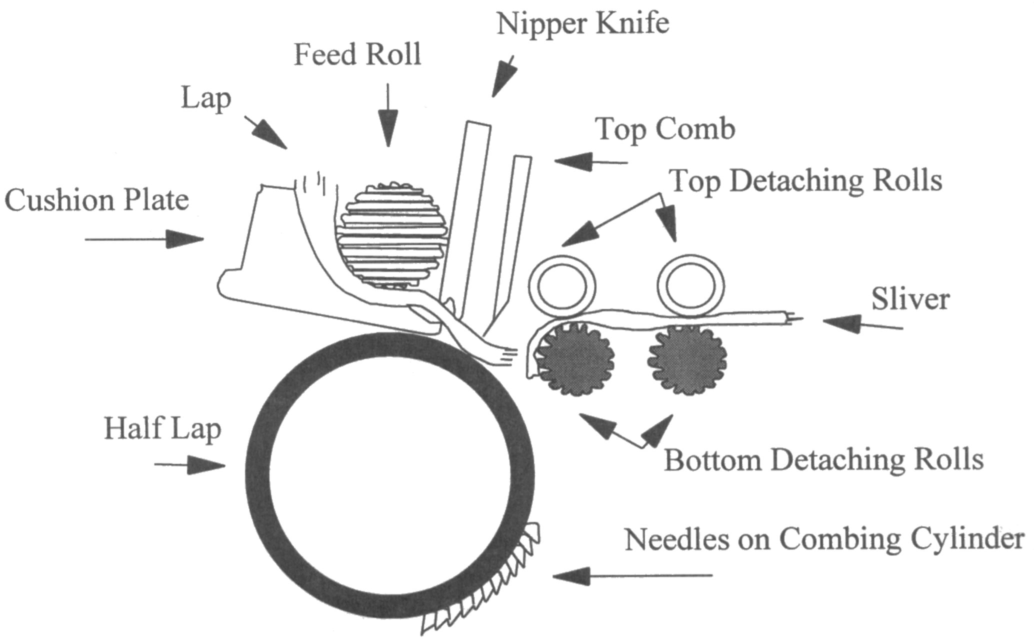
The super lap machine has three feeding heads in the creel portion with each head holding 16 to 20 draw sliver cans. All the slivers coming from each feeding head is passed through a vertically held 2 over 3 roller drafting system. The lap sheet formed by the combination of these drafted slivers are passed through a pair of calender rollers and is ultimately wound on the lap tube with the help of two working winding rollers.

THE COMBING MACHINE

Many different types of combers are used for different fibre materials, combers can be classified into following types:

(1) Rectilinear Combers (used for cotton)
(2) Circular Combers (used for worsted)
(3) Rotary Combers (used for spun silk)
(4) Hackling Machines (used for bast fibres)

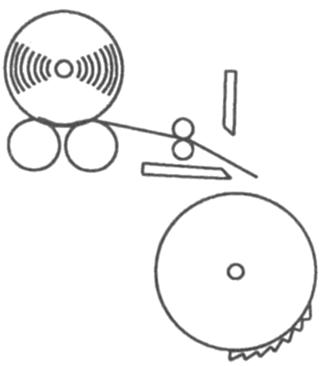
The rectilinear or cotton combers operate intermittently because the short length of the fibres does not allow continuous method of combing. One end of cotton fibre bundle is combed with cylinder comb or half lap having half of its circumference covered with teeth while the other end is combed with single row of needles called as the top comb. After both ends of the cotton fringe has been combed separately, the separated fringes are reunited by a piecing unit. The standard parts of the comber are shown in the figure below:



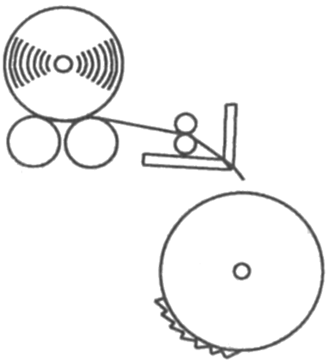
The combing of the cotton fibres is carried out in an intermittent cycle of operation called as the combing cycle. In one combing cycle, the short fibres are removed and the long fibres are passed forward into a sliver. One combing cycle can be divided into many phases

(1) **Feeding**

The combing cycle begins with the feed of the lap. The lap sheet is fed to the comber between the feed roller and smooth cushion plate also called as the bottom nipper. The top nipper or the nipper knife moves down to fix on the bottom nipper (cushion plate). Hence the lap sheet is gripped between the top and the bottom nippers.



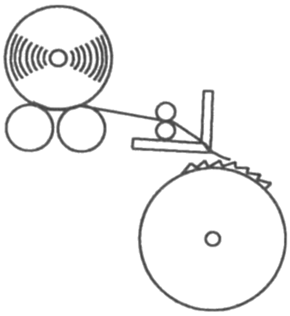
Lap unrolls for feeding



Top nipper moves down

(2) Cylinder or Half Lap Combing

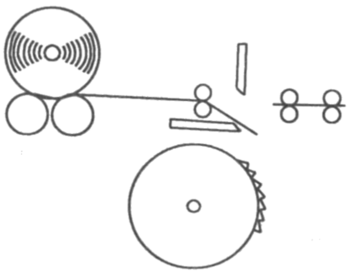
As the lap is held by both the nippers, the half lap or the cylinder comb rotates and the protruding fringe of the fibres is combed with the help of needles mounted on the cylinder comb. Any fibres not held by the needles will be treated as short fibres and will be removed as a waste during the rotation of the circular comb. The waste (noil) is removed from the surface of the needle with the help of a revolving brush mounted just below the cylinder. The waste removed is then collected by suction at the back of the comber.



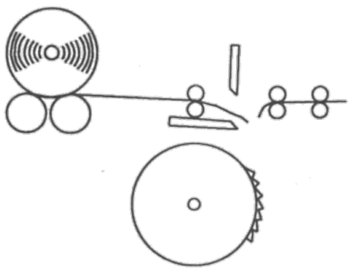
Half Lap Combing or Cylinder Combing

(3) **Piecing**

As the half lap or circular comb has finished combing and has cleared the fibre fringe, the detaching roller remains stationary and does not rotate however only the back top detaching roller rocks backward. At the same time the top nipper is raised while the cushion plate or bottom nipper rocks forward. Also the feed roller rotates by a small and amount feeds a predetermined length of lap. This increases the length of the lap fringe and as the bottom nipper moves forward, the leading edge of the lap fringe is entered into the nip of the detaching rollers and initiates piecing. During piecing the top comb also starts descending.



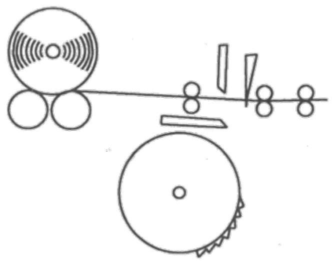
Retracting of Top Nipper

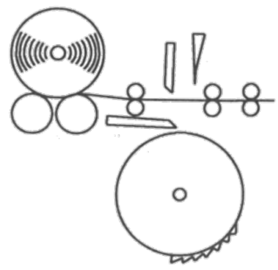


Detaching roller rocks backward

(4) **Top Combing**

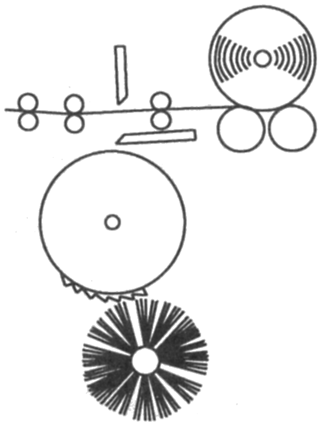
Just as the piecing has started, a top comb with one row of needles is descended into the fibre fringe from the above. As the combed web of fibres is pieced or connected to the surface of the detaching rollers, the detaching rollers now start rotating forward and the combed web of fibres is pulled through the top comb. As the fibres web is pulled through the top comb, short fibres, neps and entanglements not removed by the circular comb is removed here by the top comb. As the bottom nipper reaches its maximum forward position, the detaching is completed because the detaching rollers continue to move forward while the bottom nipper begins to rock backwards. As detaching finishes the top comb is withdrawn upwards





Top combing & Detaching **Retracting of Top Comb**

The feed roller again rotates and advances a new short section of the lap to be combed by the bottom circular comb and the same combing cycle continues.

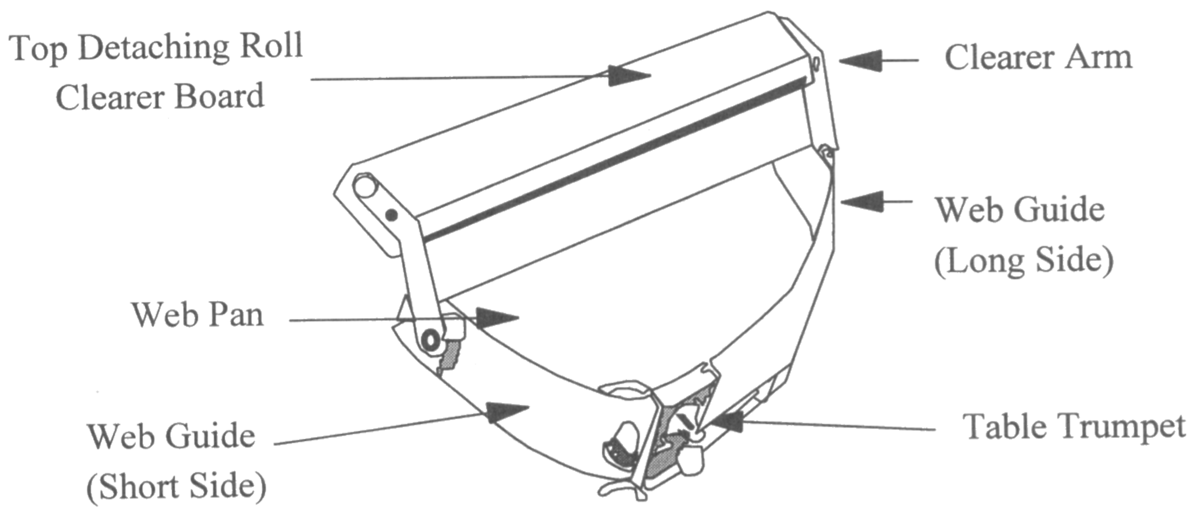


New Feeding

On a modern comber the cycle of combing takes place 3 to 5 times in a second.

(5) **<u>Sliver Condensing & Drafting</u>**

The combed web taken by the detaching rollers is delivered to the web pan having a trumpet guide on its one side as shown below:



The combed web is pulled through the trumpet guide with the help of a pair of calender rollers that converts the web into a combed sliver. The combed slivers coming from all the heads of the comber are laid side by side and are passed through a draw box where a draft of 5 to 12 is given. Most commonly a 3 over 5 roller drafting is used where the rollers are inclined at an angle of 60. The drafted slivers are coiled into sliver cans. On modern combing machines, the sliver cans are automatically doffed on completion.

THE DRAWING PROCESS

The carding process is one of the most important process in short staple spinning as it separates fibres into individual form and also removes the remaining portion of impurities left by the blow room. Despite of many advantages of the carding process it has a big draw back of producing variation and misalignment of the fibres with in the card sliver. The alignment and the slight parallelization achieved at the carding region between the main cylinder and flat largely disappears again because of the doffing action at the doffer. During the transfer of the fibres from the cylinder to the doffer hooked surfaces in the fibres arise. About 50% of the fibres in the card sliver has trailing hooks, 15% fibres have leading hooks and 15% of the fibres have double hooks and only a small portion (20%) of the fibres remain straight.

In order to produce a strong and uniform yarn it is necessary to straighten and align the fibres and to improve the evenness of the sliver. All of these objectives are achieved by the drawing process carried out by a machine called as the draw frame. At the draw frame a number of card slivers are drawn or stretched between several pairs of rollers. As the fibres are attenuated or drafted, the fibres are straightened and aligned to the axis of the sliver in the direction in which they are drawn.

Functions of the Draw Frame

(1) To straighten the fibres and to make them parallel to the central axis of the sliver. This is done by subjecting the sliver in between several pairs of rollers with each subsequent pair of rollers moving faster than the previous one. The drafting tends to reduce the linear density of the sliver.

(2) To improve the evenness of the sliver. This is achieved by feeding more than one sliver at the draw frame and drawing it together. The feed of multiple slivers is called as doubling. Most commonly 6 to 8 sliver are fed to the draw frame and hence a doubling of 6 to 8 is achieved. The doubling reduces the mass variation of the sliver by averaging out the heavy and light sections of the sliver. The decrease in the linear density of the sliver caused by drafting is balanced out proportionately by combining a number of card slivers.

(3) The doubling process at the draw frame in addition to improve the evenness of the silver can also be used to blend different origin of fibres. For example to obtain a 50:50 blend of cotton and polyester fibres equal number of both cotton and polyester card slivers must be doubled together provided that the count of all card slivers is same.

(4) To produce a proper weight of sliver required for the following process. Doubling and drafting are the two main processes employed at the draw frame. Drafting tends to decrease the linear density of the sliver whereas doubling tends to cancel out the effect of drafting. If drafting and double are of same proportion then the drawn silver will have same linear density as that of the card sliver. But if the drafting employed is more than the doubling than the resultant drawn sliver will be finer than the fed card sliver and vice versa. Therefore the degree of drafting and doubling actually depends upon the required final count of the yarn.

Main Parts of the Draw Frame

The draw frames are built with one or two deliveries. The single delivery draw frame is more efficient and flexible but the double delivery draw frames have the advantage of having twice the production covering nearly the same floor area as that of the single delivery draw frame. The double delivery draw frames also have a less initial cost. A standard draw frame is divided into following sections:

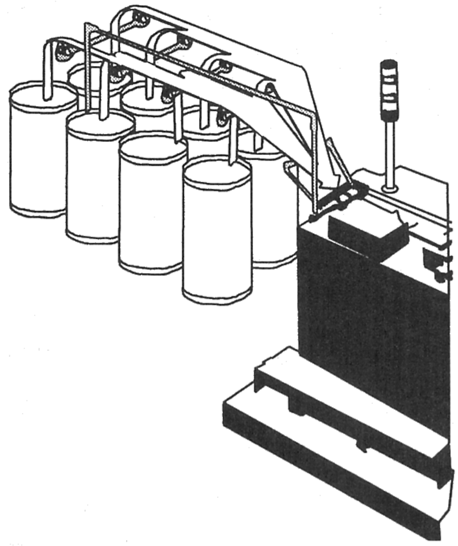
(1) Creel Section
(2) Drafting Section
(3) Sliver Condensing Section
(4) Coiler Section
(5) Suction Section

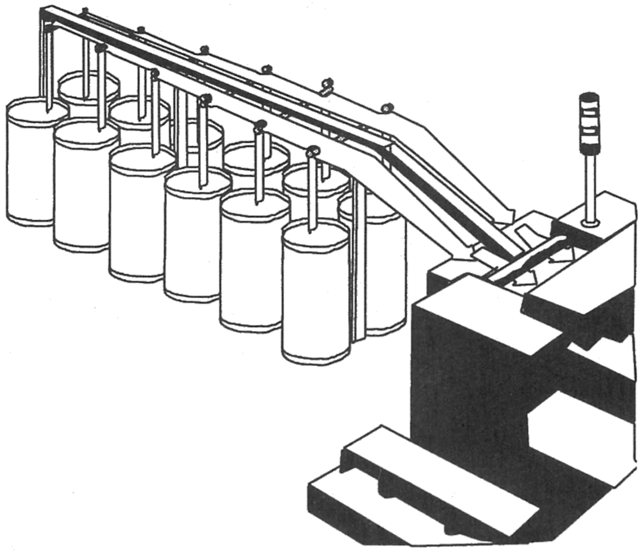
(1) Creel Section

Creel is the portion of the draw frame where the card sliver cans are placed. The cans behind the draw frame are placed in two most common arrangements:

(i) The nested creel arrangement
(ii) In-Line creel arrangement

In nested creel arrangement, the cans are placed in a rectangular group. Such an arrangement is exclusively used for single delivery draw frames. On the other hand the in-line creel arrangement has all the cans placed in a straight line and is mostly used for double delivery draw frames. Both the arrangements are shown below:





Nested Arrangement In-Line Arrangement

The sliver coming out of each can is passed over a guide plate and is fed to the main drafting rollers. The sliver is either directly pulled by the drafting rollers or in order to avoid unnecessary stretch it is pulled by power driven rollers placed just above the cans. The creel also sometimes has an automatic stop motion to detect sliver breaks and on breaking of any sliver, the machine will be stopped.

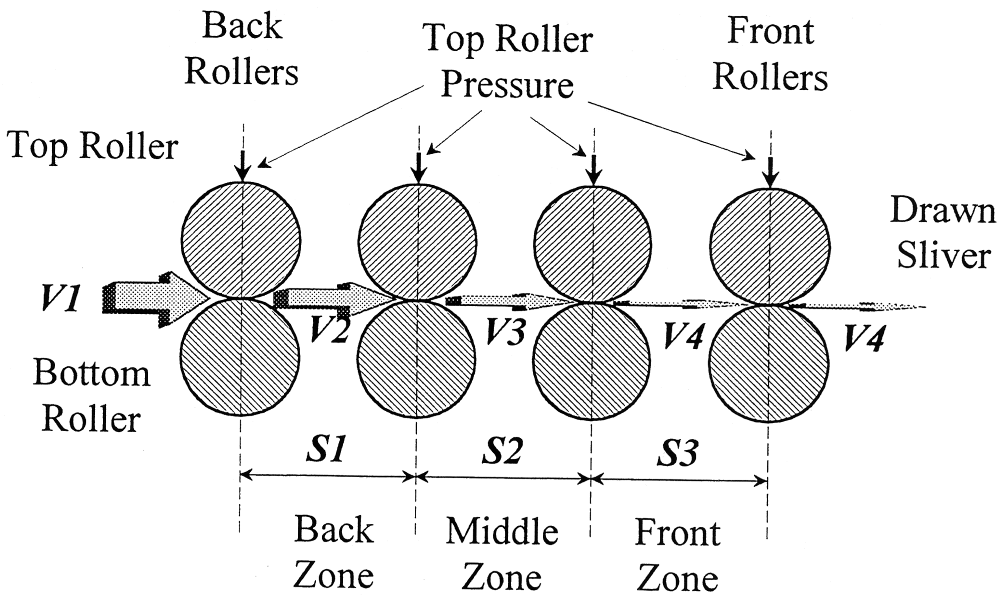
(2) Drafting Section

The drafting of the sliver at the draw frame is carried out by roller drafting method in which the card sliver is passed through two or more pairs of rollers. In modern draw frames the top roller used are rubber coated and are called as cots while the bottom rollers are steel rollers having fine flutes on their surfaces. The cots exert pressure on the bottom rollers and their surface is treated with anti-static material. The back cots exert less pressure as compared to the next succeeding cot in the drafting system.

The surface speed of each succeeding pair of roller is kept more than the previous one. The slower pair of roller grips the fibres whereas the next faster pair of rollers draws the fibres forward. This increases the length of the sliver and reduces its linear density by a factor equal to the ratio of the surface speed of the fast moving roller to the surface speed of the slow moving roller. This ratio is called as mechanical draft.

The distance between the two pair of rollers is called as drafting zone. The distance between the nip lines of the two adjacent pair of rollers is called the roller setting. The first pair of rollers (at the feed end) is called as the back rollers and the last pair of rollers (at the delivery end) is called as the front rollers.

The roller drafting systems used on various draw frames are of many types. However every roller drafting system is named according to the number of top and bottom rollers it has. Draw frames are available with 4 over 4, 3 over 3, 4 over 3, 5 over 3 and 3 over 4 roller arrangements. All of these arrangements give good results when set appropriately. A 4 over 4 roller drafting system is shown below:



The over 4 over 4 drafting system has four pair of rollers and hence has three drafting zones namely the back zone, middle zone and the front zone. The draft given in the back zone is called as the break draft, the draft in the middle zone is called as the middle draft and the draft given at the front zone is called as the main draft. The break draft is always smaller than middle draft and the main draft is always kept the greatest.

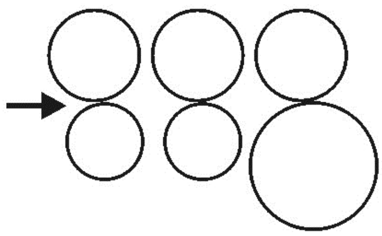
Break Draft = V_2 / V_1 Middle Draft = V3 / V2 Draft = V4/V3

The total draft is the product of the individual drafts given in all drafting zones.

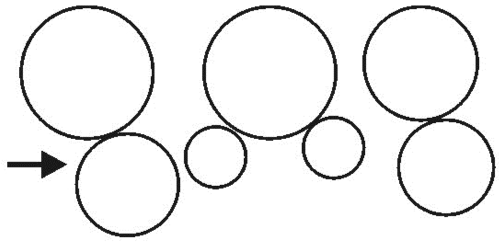
Total Draft = Break Draft x Middle Draft x Main Draft

Total Draft = $V_2/V_1 \times V_3/V_2 \times V_4/V_3 = V_4/V_1$

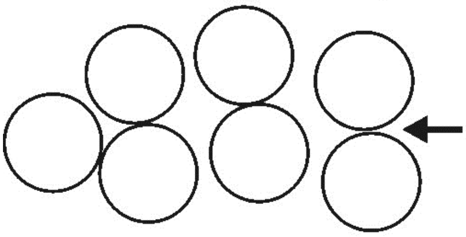
In addition to 4 over 4 drafting system various other drafting systems are shown below:



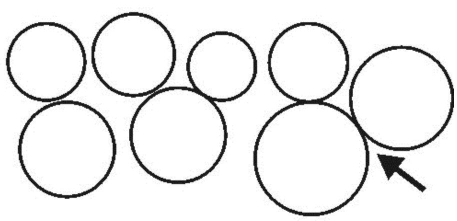
3 Over 3 Roller Drafting



3 Over 4 Roller Drafting



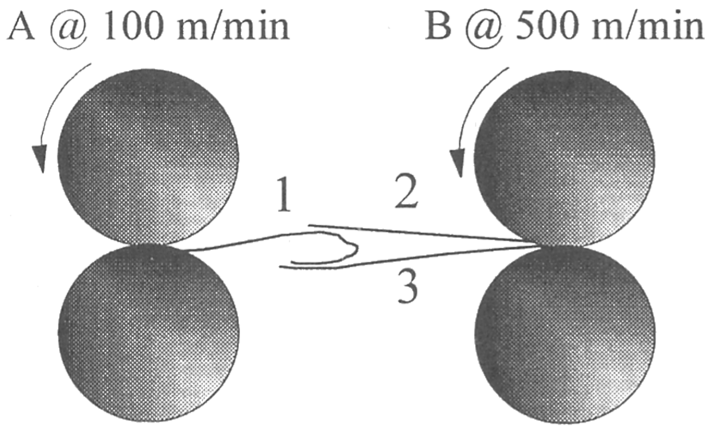
4 Over 3 Roller Drafting



5 Over 3 Roller Drafting

Fibre Straightening During Drafting

As the fibres are drafted out at the draw frame, the hooked fibres are also straightened out. This is illustrated in below:



In this example for simplicity three fibres are shown to be caught between two pair of rollers. The roller pair (A) is moving at a linear speed of 100 m/min whereas the roller pair (B) is moving 5 times faster at 500 m/min. When the slower hooked fibre (1) held by the nip of roller pair (A) comes in contact with the faster moving fibres (1 & 2) held by the nip of roller pair (B), the faster fibres (1 & 2) will tend to pull the slower fibre (1) and the hooked end will be aligned with other fibres moving in the same direction.

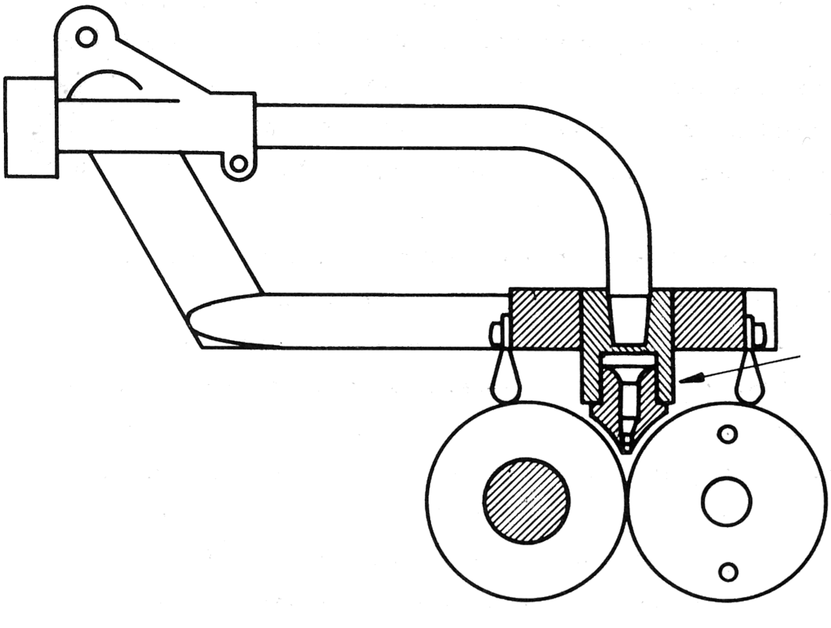
Roller Settings

The roller setting which is the distance between the nip lines of the two adjacent pair of rollers is mainly governed by the fibre length. The roller setting is kept widest apart in the back zone while it is narrowest in the front zone. This is due to the fact that fibres in the back zone will have more hooks and a wider spacing must be given in this zone to allow the fibres to attenuate and grow. Since fibres reaching the front zone will have many of their hooks removed by the previous zone so less wide roller spacing is required here.

When adjusting roller settings, the distance between the nips of the two adjacent rollers should be just wide enough to let the longest fibre grow. If the spacing is too narrow, the longer fibres will break. If the spacing is too wide then too many fibres will float in between the two draft zones. The floating fibres are the ones which are not held by any pair of drafting rollers. Floating fibres can bulge at a point to create thick and thin places. The succession of thick and thin places along the sliver is called as the drafting wave. Drafting wave may also be caused by worn off cots and other machine imperfections.

(3) Sliver Condensing Section

The flat fibre web (consisting of several card slivers) exiting the drafting section must be converted back into a web. The fibre web leaving the front pair of drafting rollers is passed through a converging tube and is guided to a specially designed condensing funnel called as the trumpet guide as shown below:

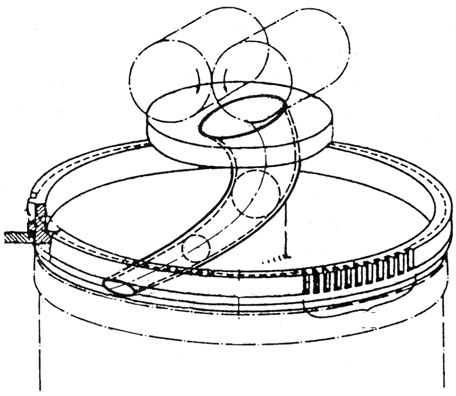


The degree of condensing at the trumpet guide is essential for providing a good fibre to fibre cohesion to hold them better in a sliver. However if too much condensing is done then the drawn sliver develops thick places.

After condensing of fibres at the trumpet guide back into a sliver form, the sliver is passed through a pair of calender rollers which does a further compressing of the fibre mass and ultimately deposits the drawn sliver into a sliver can.

(4) Coiler Section

The drawn sliver coming out of the calender rollers is passed through a coiler tube fixed on a coiler plate. The coiler gears fixed on the coiler plate help to rotate the coiler tube so that sliver can be laid in the can in form of special coils.

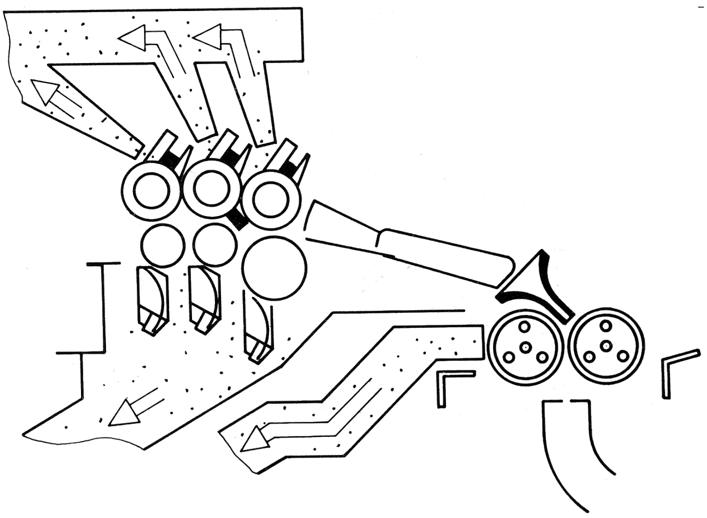


The can rests on the rotating plate, with the rotation of the plate the can also rotates. The rate of rotation of the can is kept slower than the rate of rotation of the coiler tube. This helps in proper deposition of drawn sliver in a spiral arrangement.

It is necessary to keep the sliver deposition rate slightly higher than the sliver delivery so that blockage of the sliver in the tube may be avoided. However this difference should not be too large where false draft may arise in the sliver.

(5) **Suction Section**

As the fibres move swiftly over the surface of the drafting rollers, dust and lint may be dislodged into the air. The purpose of the suction system on the draw frame is to remove these particles so that they might not get deposited on the surface of the drafting rollers and also to maintain a dust and lint free working environment. The accumulation of the fibrous mass on the surface of the rollers causes unevenness in drafting and sometimes also causes sliver breakages causing the machine to stop. A typical air suction system used on the draw frame is shown below:



THE ROVING PROCESS

The drawn sliver is composed of clean and straightened fibres lying parallel to one another and to the axis of the sliver. These characteristics of a drawn sliver are ideal for creation of a yarn. However this is not possible because if the drawn sliver is to be directly converted into a yarn it would require a mechanical draft of a range of 300 to 600. But even on the most modern machines technologically it is not possible construct a ring frame that could give such high drafts in a single process. So an intermediate stage of drafting is carried out using the roving frame. The draft given at the roving frame reduces the linear density of the drawn sliver into a less thick strand of fibres suitable as an input to the ring frame. This roving which is fed to the ring frame can then be easily converted into a yarn by giving a draft of 15 to 40.

Another advantage of making roving is to have a better package as an input to the ring frame. The roving frame produces roving on compact small packages called as bobbins. The bobbins are much more convenient to transport and have less chances to get damaged as compared to the can sliver mode of package.

In earlier times because of lack of technological advancements in drafting systems, to produce a roving three separate machines were used one after another. The first machine was called as the 'Slubber', the second machine as 'Intermediate" and the third machine as the 'Jack Frame'. As improvements were made in the roving frame to give higher drafts, the process of roving formation can now be accomplished by using only one machine called as the Roving Frame or the Simplex Frame.

of research is being carried out on the prospects of creating a yarn directly from the drawn sliver eliminating roving frame. Some modified 'sliver to yarn' ring spinning frames equipped to give mechanical draft of 600 have already been manufactured and are used for research purposes. In near future the roving frame in addition to the draw frame is one more candidate that is facing elimination from the scene of the short staple spinning.

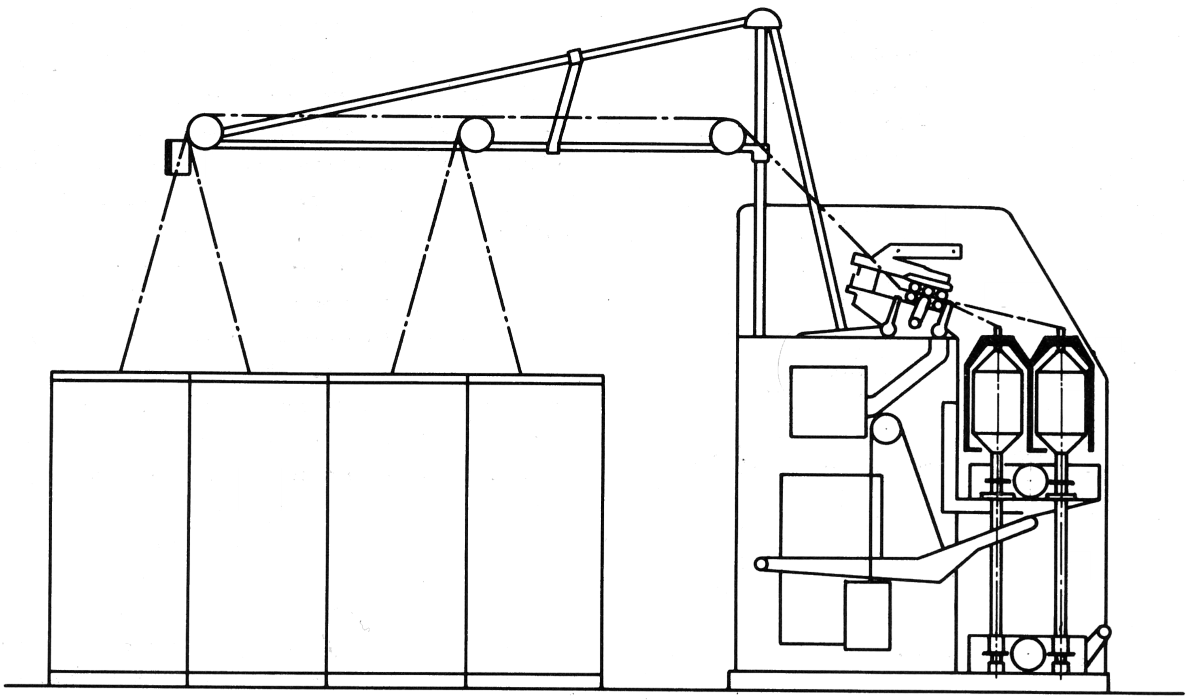
Functions of The Roving Frame

(1) The basic function of the roving frame is attenuation or drafting so that the mass per unit length of the sliver may be reduced down to the extent which is suitable to be fed to the ring frame. The range of draft given at the roving frame is 5 to 20.

(2) After drafting the fine strand of fibres (roving) has very little coherence and becomes unsuitable for further attenuation at the ring frame. So a protective twist must be imparted to give coherence to the fibres and to give strength to the roving. The amount of twist given at the roving frame is low and ranges from 0.7 to 2 TPI.

(3) The drafted and twisted roving has to be properly wound on a package called as bobbin. This is done by the winding operation at the roving frame. The winding operation is a complex mechanical process which not only winds the roving on the bobbin but also maintains a special built of the package.

Main Parts of the Roving Frame



A standard type of a roving frame has following sections:

(1) Creel Section
(2) Drafting Section

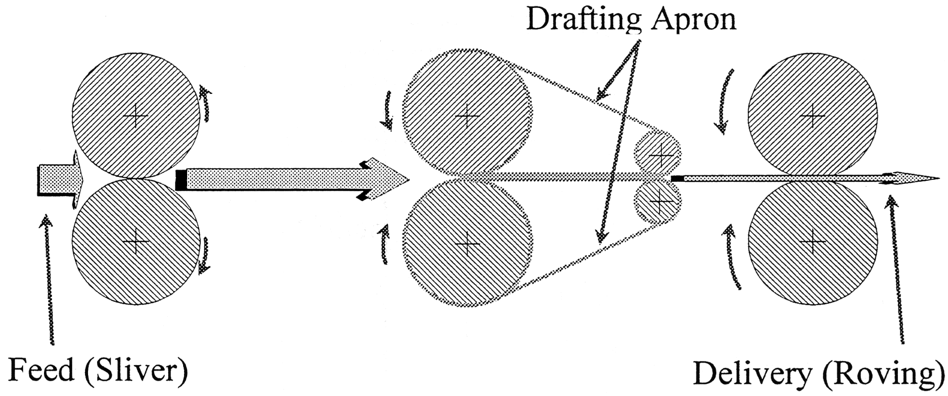
(3) Winding Section

(1) Creel Section

The creel is the area designated for the drawn sliver cans which are positioned at the back of the machine. Just above the cans number of independently driven guide rollers are provided that helps the sliver to move toward the drafting section. Since the fibres in the drawn sliver have less coherence so it is necessary to keep the surface speed of the guide rollers equal to the surface speed of the back drafting rollers so that any false drafting may be avoided that can damage the sliver. Just before the drafting section a photo-electric stop motion is used which detects the presence of the sliver and as the sliver breaks it automatically stops the machine.

(2) Drafting Section

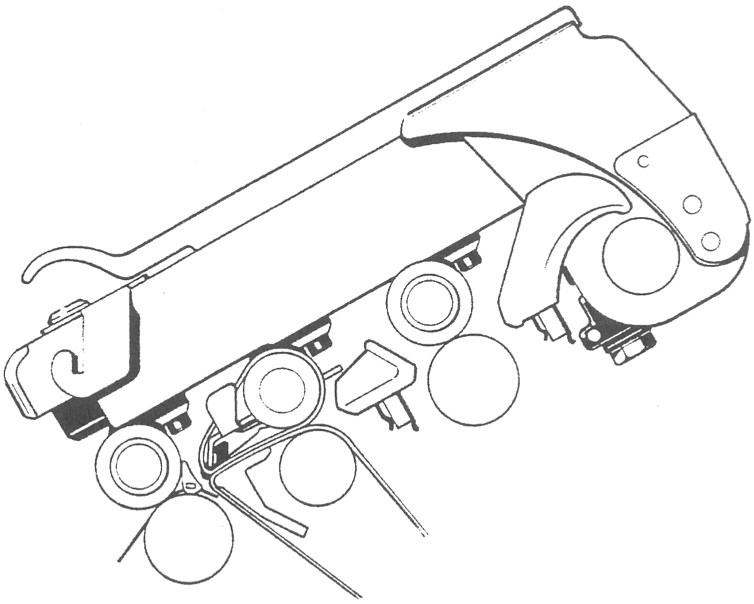
A typical drafting section of the roving frame is composed of 3 over 3 roller arrangement. However some of the machines also make use of 3 over 4 roller drafting arrangement. Regardless of the type of roller arrangement the bottom roller used is always a steel fluted roller while the top roller is covered with some synthetic rubber covering. The top rollers are pressed down with sufficient force on to the bottom rollers to ensure proper grip of the fibres. A pressure of 100 to 250 N per roller is provided on the top rollers by using mostly the spring pressure. However in addition to spring pressure, pneumatic and magnetic weighting is also used by some manufacturers. A simple 3 over 3 roller drafting arrangement is shown below:



In the modern roving frames a double apron system is provided at the middle pair of drafting rollers. The top apron is short while the bottom apron is longer. Both of these aprons are made of either soft leather or synthetic rubber. Both these aprons in cooperation with each other guide and transport the fibres during drafting. The aprons help to support the floating fibres and drastically reduce the drafting wave. It is important that the aprons should extend as close as possible to the nip line of the front rollers. The length of the aprons also called as the cradle length is kept approximately equal to the staple length of the fibres.

Use of Condensers in the Drafting Section

Three specially designed trumpet guides or condensers are used in the drafting section of the machine. First trumpet guide also known as in-feed condenser is used just before the back pair of drafting rollers and its purpose is to lead the sliver properly into the drafting arrangement. The second trumpet guide is used near the nip of the middle pair of rollers and the third one is used just before the front pair of rollers. The main function of the last two guides is to bring back the fibre mass into a strand that tends to tear apart because of the drafting action.



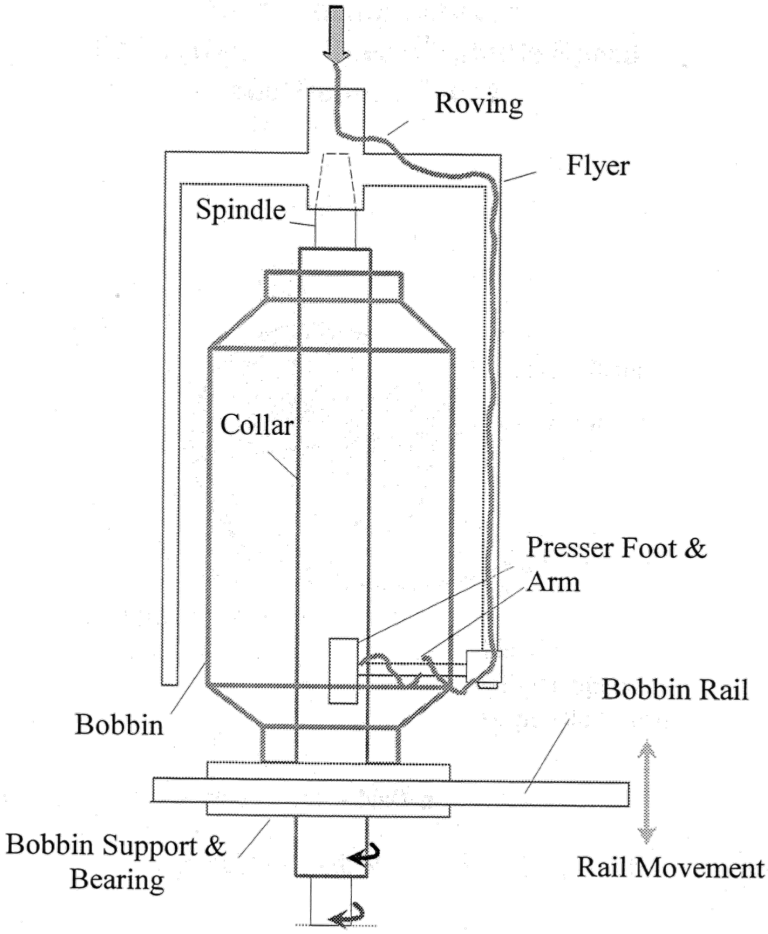
The trumpet guides are usually mounted on a reciprocating bar giving the sliver a traversing motion so that the wear of the rollers may spread out gradually over the entire width of the roller.

Draft Distribution

An important consideration of the drafting zone is the draft distribution i.e. how much draft should be given in the back and front zones. The draft at the back zone is called as break draft and it should be as low as feasible while majority of the draft is given at the front zone where there is an apron control over the fibres and is called as the main draft. The total draft is the product of break and main draft. Generally the break draft for cotton lies in the range of 1.05 to 1.15 and all the remaining draft is given at the main drafting zone. The break draft is just meant to straighten the fibres and to prepare them for a major draft at the front drafting zone. If the break draft is increased beyond an optimum value then the evenness of the spun yarn drastically reduces due to the formation of thick and thin places.

(3) Winding Section

The winding section comprises of a spindle and a flyer. A spindle is a long steel shaft that acts as a support and a driving element for the flyer. The flyer is a special component of the roving frame that helps to insert twist in the roving. The spindle is mounted at its lower end in a bearing which gets its drive from the train of gears and transmits it to the flyer. Just around the flyer a shaft is fixed around the spindle with a collar that gets its drive independently from a separate set of gears. An empty hollow package made of wood or plastic is mounted on this shaft. The arrangement of a spindle and a flyer is shown below:



The winding portion of the machine with the help of the spindle and the flyer meets the following two main objectives of the roving frame:

(1) Twisting
(2) Package Winding

(1) Twisting

The sliver after being drafting out to form a roving coming from the front delivery rollers have little fibre cohesion among themselves and is weak to be wound on packages and also may not sustain further drafting at the next stage of processing i.e. the ring frame. So in order to give cohesion and strength to the roving strand a small amount of protective twist is given. The twist is imparted by using a flyer method of twist insertion.

The roving coming out of the front delivery roller is threaded through the top of the flyer, passes through its hollow leg around the presser arm on to the bobbin. The presser arm maintains certain tension on the roving which is necessary for proper compact winding.

The flyer rotates with the spindle at a constant speed with each revolution of the flyer inserting one twist in the roving strand. The relation is given by:

Twist Per Inch = Flyer Rotary speed (rpm)/ Delivery Speed (inches/min)

Since the rotary speed of the flyer is constant so the amount of twist inserted per unit length depends upon the delivery rate of the front delivery rollers. High values of twist cause production loss along with difficulty in drafting at the ring frame. On the other hand very low twist makes the roving weak and it can break during the package winding. The level of twist inserted for cotton at the roving frame is about 0.7 to 2 TPI.

(2) <u>Package Winding</u>

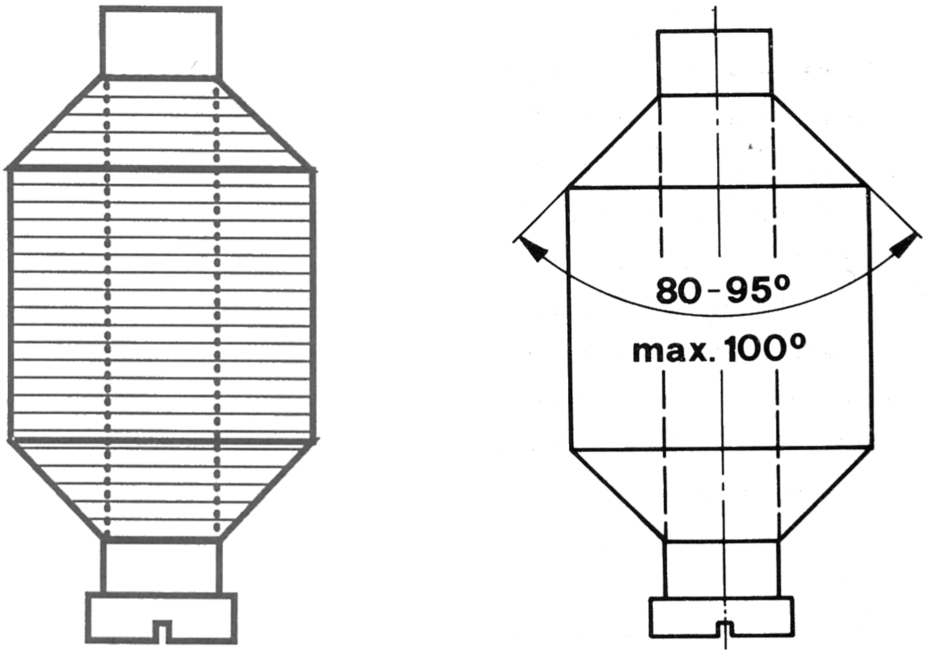
In order for the winding to take place on the surface of the bobbin, the surface speed of the roving coming from the flyer should be different from the surface speed of the bobbin. The bobbin therefore is driven independently of the flyer and it rotates with the collar around the spindle. Winding at the roving frame is possible by one of the following two methods:

(1) Bobbin Lead Method
(2) Flyer Lead Method.

In the bobbin lead method to facilitate winding, the surface speed of the bobbin is kept greater than the surface speed of the flyer. On the other hand in flyer lead method, the surface speed of flyer is kept more than that of the bobbin. In cotton roving frame, the bobbin lead method is used.

<u>The Package Built</u>

The roving coming out of the hollow leg of the flyer is made to wind on a cylindrical package called as the bobbin. The bobbin is either made of wood or plastic. The roving is wound on the bobbin in such a way so that tapered ends on both sides of the package are formed. The angle of taper of the ends lies between 80° to 95° depending upon the adherence of the material. By increasing the angle of taper, larger packages are possible to make however the adherence between the layers decreases. On the other hand low angle of taper gives better adherence to the material but only smaller packages are possible to make with it.



Bobbin is an ideal form of a supply package to be fed to the ring spinning frame because when full it can hold large length of roving owing to its compactness and when empty it is light and occupies small volume and is easy to handle and transport.

The Builder Motion

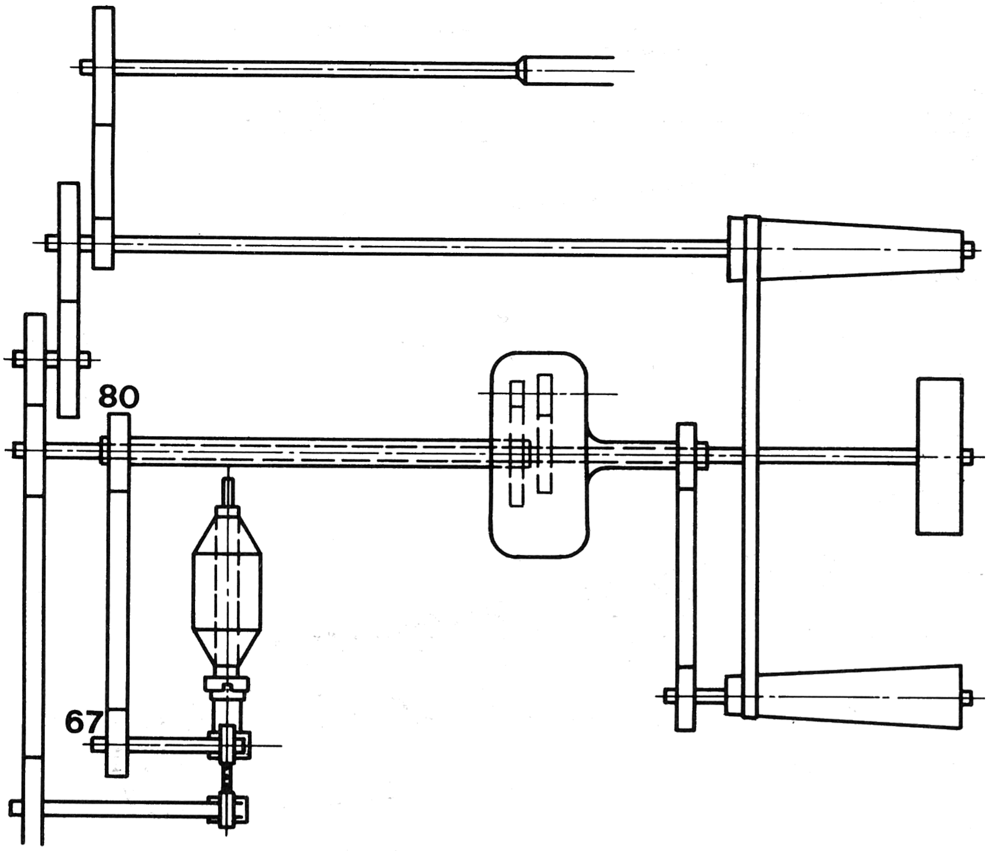
The above mentioned required package built is not easy to construct. There are lots of complex mechanical arrangements provided at the roving frame to achieve this. Due to these special winding needs at the roving frame it makes it a very complicated machine. The builder motion is a device or series of mechanical arrangements necessary to obtain a proper built of the roving bobbin. The builder motion performs the following important tasks related to the package built:

(1) Controlling Bobbin Drive
(2) Controlling Lifter Motion of Bobbin Rail
(3) Formation of tapered ends

(1) Controlling Bobbin Drive

During package winding with each new layer of roving wound on the bobbin, the diameter of the bobbin increases which causes the surface speed of the bobbin to increase as well. However for a uniform package winding, it is absolutely essential to keep the difference in the surface speed of the flyer and bobbin constant. Since the rotary speed of flyer in a roving frame is kept constant so to keep this difference of the surface speed constant, the rotary speed of the bobbin is reduced proportionately with the increase in its diameter.

The reduction in the rotary speed of the bobbin originates from a cone drum drive. With each new layer of roving wound on the bobbin, the builder motion shifts the cone belt enough to reduce the rotary speed of the bobbin so that its surface speed may remain constant A simple arrangement of a cone drum drive is shown in the figure below:

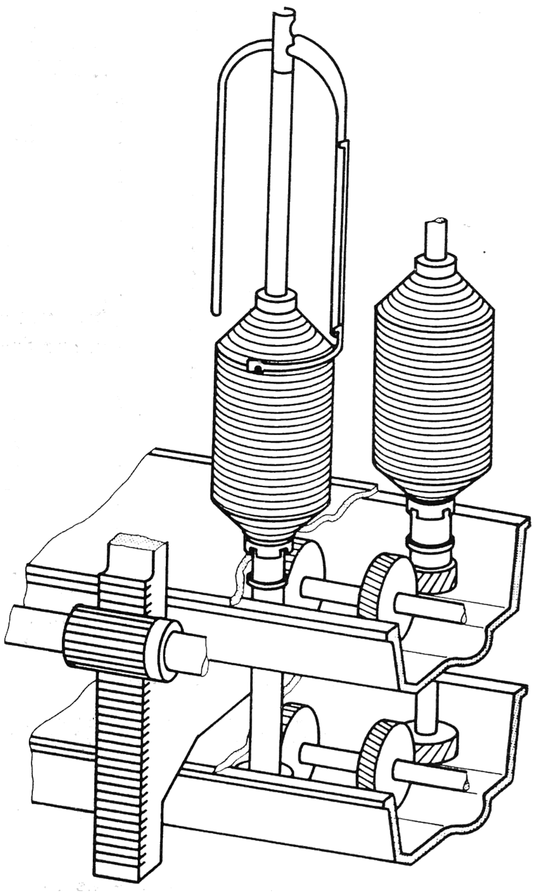


(2) <u>Controlling Lifter Motion of Bobbin Rail</u>

The roving package is created by placing layer upon layer of parallel coils of roving on the surface of the bobbin. The built of the package is carried out in a precision manner where each successive layer or coil of roving is laid in a precise spacing to the previous coil. This can be achieved by

(i) Raising and lowering of the flyer.
(ii) Raising and lowering of the bobbin

The flyer is never moved because by doing so the unsupported length of the roving coming from the front delivery roller to the top of the flyer will vary. Also the angle of the roving from the front delivery roller to the flyer top will also change. This can cause uneven winding tension and is not suitable. So the only way to achieve a proper built of the package is to move the bobbin up and down. For this purpose the bobbins are supported by a movable rail that lifts and lowers the bobbins as per requirement.



Since the package diameter is steadily increasing, the lift speed must also be reduced by a small amount after the completion of every layer. This is necessary because with a bigger diameter of the package more length of roving will be accommodated and the lifting and lowering of the bobbin should be slowed down. To obtain this, the drive to the lifter mechanism is also obtained from the same cone drum drive used for the bobbin.

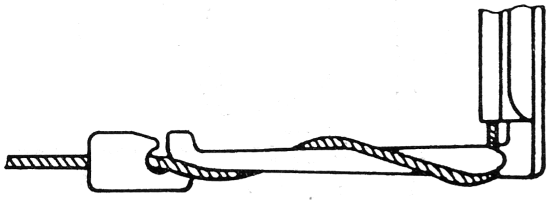
The lifter mechanism is also fitted with a reversing mechanism so that the bobbin rail is alternately raised and lowered so that the roving could be wound on the entire length of the bobbin.

(3) <u>Formation of Tapered Ends</u>

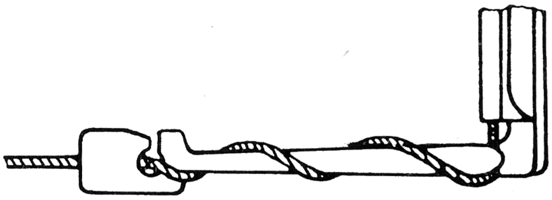
In order to form a special taper ends on the bobbin the height of the lift through which the lifter motion is going to raise and lower the bobbin is gradually reduced after each layer of roving has been completed. For this the builder motion of the roving frame is fitted wit special micro switches that perform this action.

<u>Controlling the Roving Tension</u>

The roving coming out of the lower end of the hollow leg of the flyer passes over a presser arm. The presser arm has to guide the roving from the lower exit of the flyer leg on to the package. Before the roving could be wound on the package it is wrapped two or three times on the presser arm.



Two Turns on the Arm



Three Turns on the Arm

The number of turns determines the roving tension. More turns would mean greater roving tension and would result in a harder and more compact roving package. However the tension should not be kept so high where false drafts or roving breakages may occur.

THE RING SPINNING PROCESS

The ring spinning is the final operation in the formation of the ring spun yarn. The basic purpose of the ring spinning frame is to attenuate the roving until the required fineness of the yarn is achieved. The ring spinning machine was first invented in 1828 in America. Since then a lot of modern modifications have been carried out but the basic principle of operation and the basic machine design remains the same. Even with the introduction to new sophisticated spinning systems, the ring spinning system is widely used and is the most popular form of spinning system. The reason behind is the ability of this system to produce very fine yarns which is not possible to obtain at the moment with any other form of spinning systems. Only the rotor spinning system provides good competition to the ring spinning system which again can not produce fine yarns of the order produced by the ring spinning frame.

The initial and maintenance cost of the ring spinning is quite high. The ring frame contributes about 60% towards the final cost of production of the yarn. So every effort is being put in to make modify the ring spinning machine to give more productivity at a less cost.

Functions of The Ring Spinning Frame

(1) The basic function of the ring spinning frame is drafting. Drafting is carried out to such an extent so as to achieve desired fineness of the yarn. The drafting is carried out by using a 3 over 3 roller drafting arrangement with double apron support. At the ring spinning frame a draft of 15 to 40 is given (sometimes also up to 50).

(2) The attenuated yarn formed by drafting is weak and lack cohesion. In order to give strength to the final yarn, twist is inserted. Twist is inserted at the ring spinning frame by using the popular traveller method. The amount of twist inserted in the yarn varies with the count of the yarn. To make finer yarns, greater TPI is given and vice versa. The value of Twist Multiplier (TM) at the ring spinning frame generally ranges from 3 to 5.

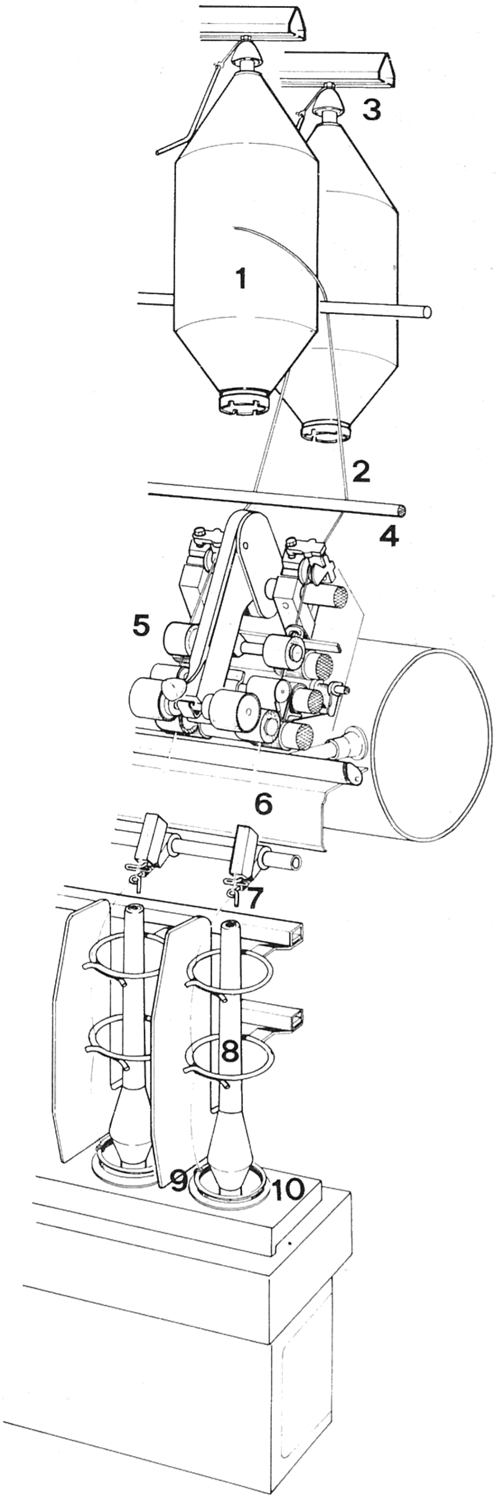
(3) The final yarn produced after drafting and twisting is wound on special ring bobbins also called as cops. The built of the package kept is such which is suitable for storage, transportation and further processing.

Main Parts of The Ring Spinning Frame

The ring spinning frames are double sided or double delivery machines having up to 500 delivery points or spindles on each side. Hence a single machine can have a capacity of up to 1000 spindles.

A typical ring spinning frame is divided into four zones:

(1) Creel Zone
(2) Drafting Zone
(3) Twisting Zone
(4) Package Winding Zone



(1) **Roving Bobbin**

(2) **Roving**

(3) **Bobbin Holder**

(4) **Guide Rail**

(5) **Drafting Arrangement**

(6) **Yarn**

(7) **Yarn Guide**

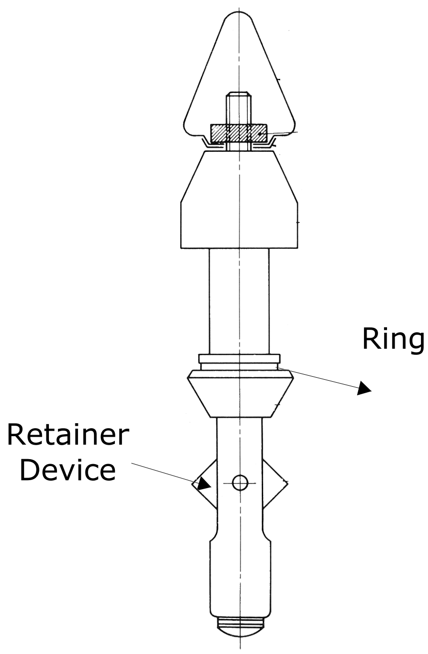
(8) **Spindle**

(9) **Traveller**

(10) **Ring**

(1) <u>Creel Zone</u>

The creel of the ring spinning frame is a simple device that holds the roving. It is very important that the roving should unwind properly and evenly to avoid any false drafts or roving breakages. To facilitate proper unwinding the roving bobbins are held vertically by inserting the roving bobbin on the bobbin holder placed at the upper portion of the frame. A typical bobbin holder is shown in the figure below:

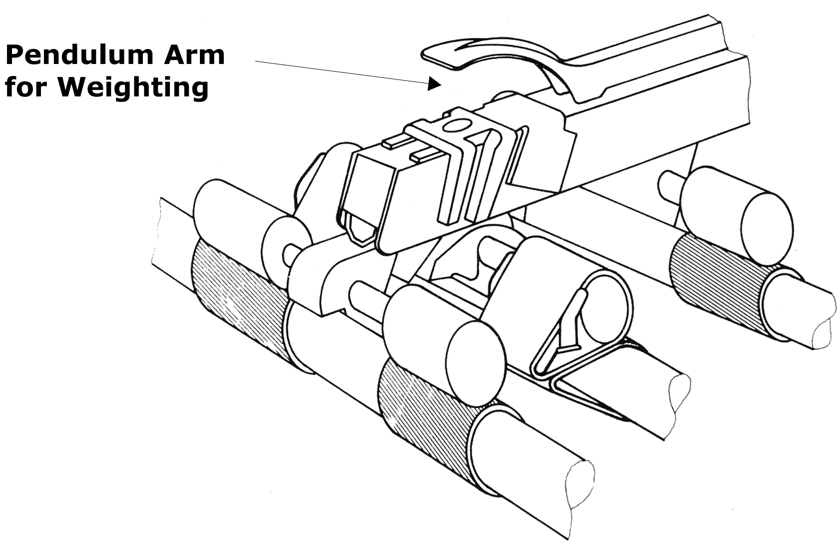


The upper end of the bobbin holder is suspended by a bearing. The roving bobbin is pushed upward on to the bobbin holder. Since the ring of the bobbin holder is attached to the retainer device so as the bobbin is pushed upward, the ring will also move upward causing the retainer device to grab the inner portion of the roving bobbin tube.

As the roving is pulled forward by the drafting rollers, the roving bobbin rotates and unwinding takes place. To avoid excessive rotation to the bobbin, a brake arm is used to lightly press the roving bobbin to restrict its motion. Alternately this can also be achieved by using internal brakes in the ball bearings.

(2) <u>Drafting Zone</u>

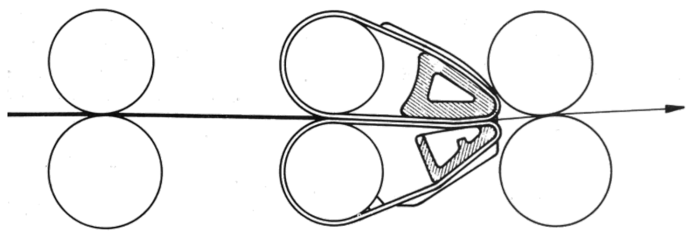
Since the at the ring spinning frame greatest value of draft is given, the drafting zone of the ring frame is the most important part of the machine that directly influences the evenness and strength of the yarn. So it is important to have a precision control on the fibres in the strand which is being drafted out to suppress the drafting waves.



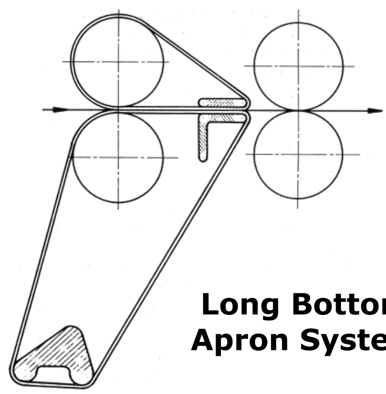
All the modern ring spinning frame makes use of a 3 over 3 roller drafting with both the top and bottom middle rollers covered with aprons. The bottom rollers are steel fluted and are driven positively. The top rollers are covered with synthetic rubber coating and are driven by the frictional contact with the bottom rollers and are hence pressed down on the bottom rollers with a considerable force. For this purpose the top rollers are weighted by using spring, pneumatic or magnetic weighting with the help of a pendulum arm.

A total draft of 15 to 40 and in some cases even up to 50 can be given at the ring spinning frame. The distribution of draft in the back and front drafting zone is very important as a proper draft distribution helps to reduce the drafting wave problem. Practically the break drafts should be given in the range of 1.1 to 1.5 and the remaining draft is given in the main drafting zone. High degree of drafting in the front zone will tend to create drafting waves. To avoid this middle pair of drafting rollers is covered with aprons. Aprons give support to the fibres through out the roller spacing between middle to front rollers not letting even the shortest fibre to float. Apron systems are not perfect but they help to drastically reduce drafting waves. Based upon the type of the bottom apron used, two types of apron systems are used commercially on the ring spinning frame:

(i) Short Bottom Apron System
(ii) Long Bottom Apron System



Short Bottom Apron System



Long Bottom Apron System

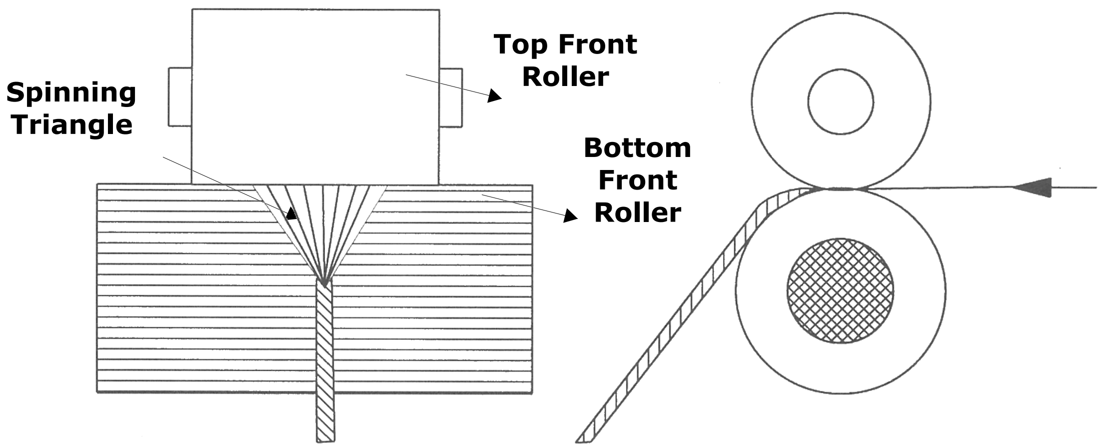
The short bottom apron system was used in old machinery. Although the short aprons require a simpler design of the ring frame and also have the advantage that they can be brought more close to the nip of the front rollers, however they are difficult to replace when damaged and can also cause choking of fibre mass. To avoid these limitations the modern spinning machines make use of long bottom aprons.

<u>Using Trumpet Guides</u>

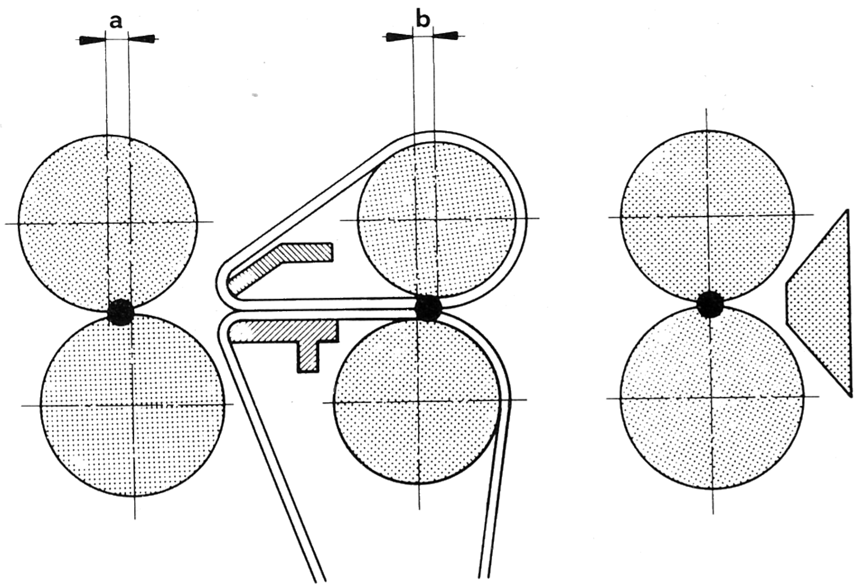
The strand of roving has few numbers of fibres in a cross-section and upon drafting even fewer number of fibres will remain in a yarn. These fibres have hardly any cohesion between themselves. Special fibre guiding elements are therefore essential to carry out drafting without breaking the strand. For this purpose specially designed trumpet guides are used in the drafting zone to help keep the fibre mass together and to avoid tearing apart of the strand. Three trumpet guides or condensers are used one just before the back pair of rollers, second in between the back and middle rollers and the last just before the front pair of rollers. These guides are mounted on reciprocating bar that oscillates slowly so that the wear of the rollers may spread out gradually through out the entire roller width.

Overhang of Front and Middle Top Roller

As the twist is given to the yarn with the help of a traveller, the twist must run back as close as possible to the nip line of the front rollers. But it never penetrates completely to the nip because at the nip the fibres are diverted inwards and are made to wrap around the surface of the roller. So at the exit point of the front pair of rollers there is always a small triangular mass of fibres which remain without twist, this is called as the spinning triangle. This triangle bundle of fibres will remain without twist during twisting and create a weak point in the yarn and hence breakage rate of the yarn during spinning increases. The effect of spinning triangle is enhanced at the ring spinning frame where greatest draft along with greatest twist is applied.



So in the ring spinning drafting arrangement the front top roller is deliberately kept 2-4 mm forward relative to the bottom front roller while the middle top roller is kept 2-4 mm backward relative to the middle bottom roller. This type of arrangement gives smooth running of the top roller and helps to reduce spinning triangle and ultimately the breakage rate during the spinning process is reduced.



To further enhance the flow of the fibre strand through the drafting arrangement, the drafting roller instead of being placed in a straight horizontal line as depicted from the above figure, they are arranged at certain inclination.

(3) Twisting Zone

The yarn leaving the front pair of drafting rollers is threaded through a guide also called as the lappet guide that is placed directly over the spindle axis. The yarn then passes through a traveller on to the yarn package (cop). The traveller is mounted on the ring encircling the spindle. The cop is mounted on the spindle and rotates with the spindle. When the cop rotates the tension on the yarn pulls the traveller to rotate around the ring. Due to the friction created between the traveller and the ring and also due to the air drag created by the balloon formation at the winding section, the rotary and surface speed of the traveller is slightly less than that of the spindle and is given by:

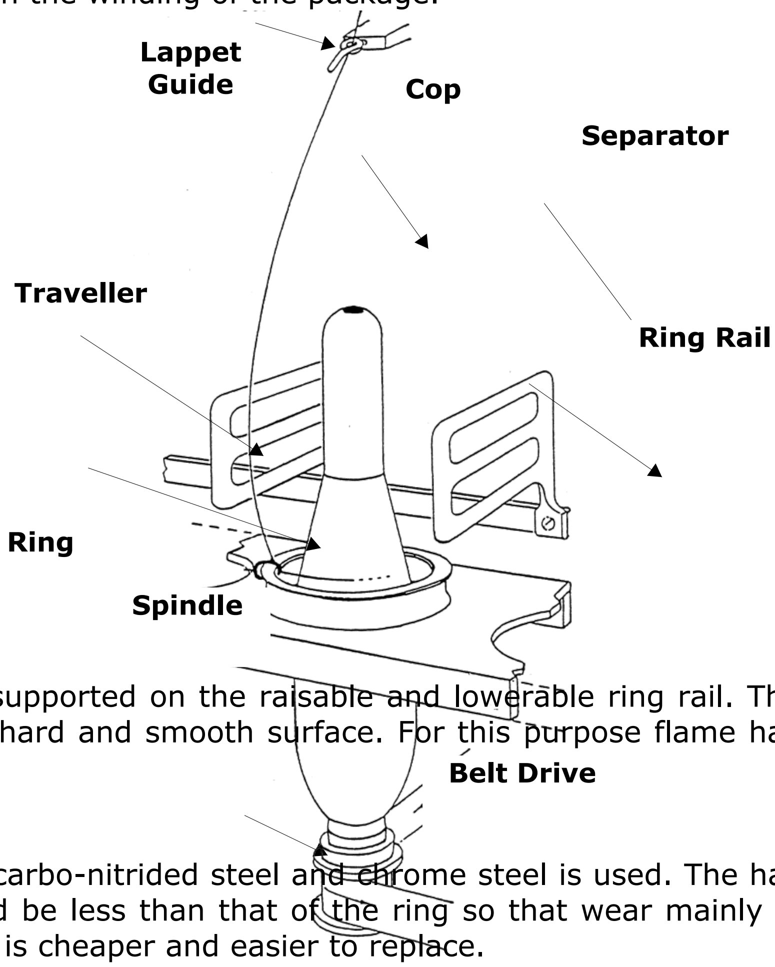
RPM of Traveller =RPM of Spindle – Delivery Speed / □ x Package Dia

So in one rotation of the traveller one twist is inserted in the yarn. Since the difference between traveller and spindle rotary speed is very small so this difference is ignored. Thus for calculating twist rotary speed of the spindle is considered, mathematically:

T.P.I = Rotary Speed of Spindle (rpm) / Delivery Speed (inches/min)

The ring/traveller arrangement and the spindle are also very important elements of the ring spinning frame because it not only helps to insert twist in the yarn but also helps in the winding of the package.

The Ring



The rings are supported on the raisable and lowerable ring rail. The ring should have a tough, hard and smooth surface. For this purpose flame hardened steel, nitrided steel, carbo-nitrided steel and chrome steel is used. The hardness of the traveller should be less than that of the ring so that wear mainly occurs on the traveller which is cheaper and easier to replace.

The rings can either be classified as:

(i) Lubricated Rings
(ii) Un-lubricated Rings

Lubricated ring is used for woollen and worsted spinning where external lubrication on its surface is applied. For cotton and other short staple spinning only un-lubricated rings are used. This is due to the fact that that all natural short staple fibres are made up of cellulose and has small quantity of natural waxes in it. As the yarn moves swiftly with the traveller, a lubricated layer of waxes and cellulose is generated due to the abrasion of the fibres. This lubrication is beneficial for decreasing the friction between the traveller and the ring and ensures a smooth continuous running. The amount of lubrication generated depends mainly upon the count of the yarn spun and quality of raw material being used. Coarser yarns generally produce more lubrication.

On the basis of working sides of the ring, rings can also be classified as:

(i) Single Sided Rings
(ii) Double Sided Rings.

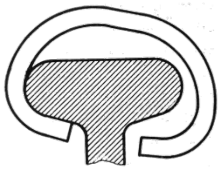
Double sided rings have the advantage of having two working sides. When one side gets abraded the ring can be turned over so that the other side can be used. Whereas when single sided rings get damaged, they have to be replaced by new ones. However double sided rings are not used anymore because when it is time for the ring to be turned over, the other side of the ring will become unstable due to corrosion and rusting and can not be used.

The Traveller

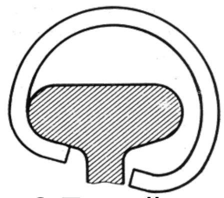
The traveller is an important element of the ring frame as it imparts twist on the yarn and also helps in winding the yarn on the cop. The traveller does not have a drive of its own but is dragged along with the yarn as it gets wound on the cop due to the rotating spindle. As the traveller moves at a high speed on the ring it creates lot of friction that generates significant amount of heat. So in order to cope up with such frictional forces the material used for traveller should exhibit the following properties:

(i) Generate as little heat as possible.
(ii) Should dissipate heat quickly to the ring and the air.
(iii) Should be elastic so that it might not break.
(iv) Should have high wear resistance.
(v) Should have less hardness than the ring.

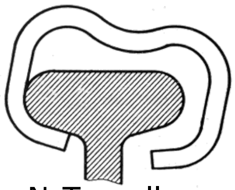
To meet these requirements, the traveller is made exclusively of steel having its surface either electroplated with nickel and silver or treated with chemicals to increase wear and reduce friction.
Different types and varieties of yarns can not be spun using a single type of traveller. Therefore travellers come in many different varieties. The differences among travellers are found in shape, mass, wire profile and yarn clearance (bow height).



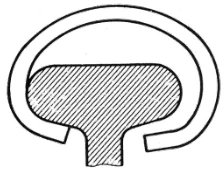
Flat Traveller



C-Traveller



N-Traveller



Elliptical Traveller

The traveller is shaped according to the ring so that single point of contact with greatest possible surface area with the ring can be achieved. The height or bow of the traveller should be as low as possible to keep the centre of gravity low and to ensure smooth running. However the bow should be not so small where the yarn starts getting abraded which can damage the yarn hairiness.

Another important parameter of the traveller is its mass. The mass of the traveller directly influences the frictional forces between itself and the ring. The mass of the traveller is selected according to the yarn count being spun. If the traveller is too light for a specific yarn count then tension created on the yarn will be low resulting in a loose softly wound cop and also the size of the balloon increases. On the other hand, if the traveller is too heavy then it causes excessive tension on the yarn and cause frequent yarn breakages. For convenience instead of the traveller weight they are standardized by its number. The following table shows various traveller numbers suitable for different yarn counts:

Yarn Count	Traveller Number For Cotton	Traveller Number For Synthetics and Blends
85	16	22.4
75	20	28
65	23.6	31.5
60	26	35.5
50	31.5	40
42	35.5	45
35	45	56
30	56	71
24	71	90
20	90	100
16	100	112

Limitations of Traveller/Ring Arrangement

The greatest limitation faced by ring spinning frame is its incapability to further increase its productivity and speed. This is mainly due to the use of traveller ring arrangement. At high speeds the traveller generates significant amount of heat due to friction with the ring. If the speed of the ring frame is to further increase, owing to a very small mass and size of the traveller, dissipation of heat generated by the traveller is not possible. Thus the operating speed of the traveller and the ultimately the entire machine is limited. Currently the spindle of the ring frame is capable of running up to 30,000 rpm but the use of traveller permits the speed only to be raised up to around 22,000 rpm.

Another way of increasing the speed of the ring frame is by using ring with smaller diameter so that spindle speed can be further increased without increasing the frictional forces on the traveller/ring. However by doing so smaller packages will be formed and they will have to be doffed more frequently. This can decrease the productivity of the machine. However this problem can be rectified by using automatic doffing devices.

To put into a nutshell, there is a very small room as far the speed advancement in the ring spinning frame is concerned. However measures like automatic doffing, use of precision instruments and precision components (specially ring and traveller), increase in the number of spindles per machine to reduce cost per spindle and automatic linkage of ring frame with the winding machines will help the ring spinning frame to be economically viable to use for years to come.

(4) <u>Package Winding Zone</u>

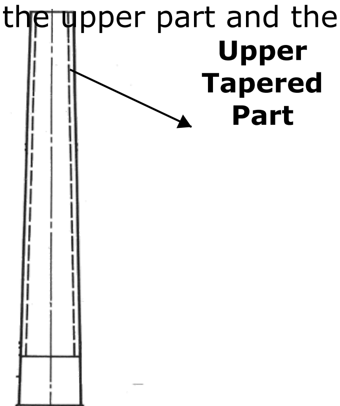
The yarn after being twisted by the traveller has to be properly wound on the entire length of the package called as the cop. In order for the winding to take place there should be a difference in the surface speed between the spindle and the traveller. The traveller has no drive of its own instead it is carried along with the yarn which is being wound on the cop after passing through the traveller. The frictional forces between the spindle and the traveller and also the air drag because of the balloon formation between the lappet guide and the spindle makes the surface speed of the traveller less than that of the spindle. This automatically fulfils the requirement of winding. The traveller and the spindle cooperate with each other to perform winding.

In order for the yarn to be properly wound on the entire length of the cylindrical ring bobbin (cop), the ring is raised and lowered which is mounted on a longitudinal ring rail.

<u>The Spindle</u>

Spindle is a very important component of the ring frame, it not only supports the cop and helps in winding of the yarn on it but also gives motion to the traveller. The spindle and the traveller therefore work in close cooperation with each other to perform both twisting and winding.

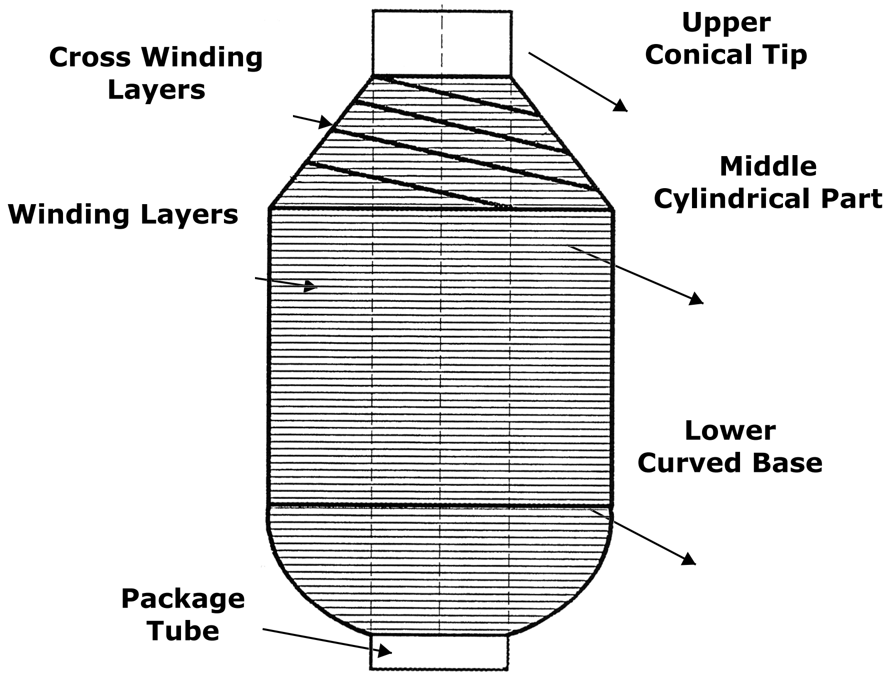
A spindle is a metallic shaft that holds the yarn package or cop. The spindle is divided into two main parts namely the upper part and the bolster.



The upper part is made of aluminium alloy and is slightly tapered to firmly hold the package. The bolster or the lower part is secured in a bearing to rotate freely and is also connected to the ring rail by means of a nut. The drive to the spindle can either be given with the help of tapes or belts in group form or in individual form where one motor is supplied per spindle.

Package Built of Ring Spinning Frame

A typical form of a package produced by a ring spinning frame is called as the cop. The package is produced on a tube of paper, card board or plastic material. About 10 mm of the tube is left free of the yarn on both upper and lower ends. The tube has a slight taper corresponding to the taper of the spindle so that the package can be firmly secured on the spindle.



The structure of the cop is divided into three distinct parts:

(1) The Upper Conical Tip.
(2) The Middle Cylindrical Part.
(3) The Lower Curved Base.

The cop has two distinct layers of the yarn wound on its surface i.e. the main winding layers and the cross winding layers. The main winding layers are close to each other and are densely wound whereas the cross winding layers are openly laid and are loosely wound. The cross winding layers separates the main winding layers so that the high tension of the yarn may not cause the successive layers to be pressed causing problems in unwinding. The package built of the cop as compared to that of the roving bobbin is much more complex which also requires complex mechanical arrangements; however it is optimal for unwinding at a very high speed on the winding machines.

The Builder Motion

To obtain the above mentioned built of the cop, complex mechanical arrangements called as the builder motion is provided at the ring frame. The builder motion achieves the structure of the cop by performing the following tasks:

(1) The ring rail on which the ring is mounted is moved up and down by the builder motion in a special manner. The ring rail while moving up is moved slowly but with an increasing speed and is moved down quite faster but with a decreasing speed. During the slow upward movement of the ring rail, a dense main winding layer is laid and during the fast downward movement, a loose cross winding layer is laid. This gives the ratio between the length of the yarn in the main and cross windings to be 2:1. This difference in yarn length in the upper and middle part creates a taper or conical shape of the upper part. The stroke or the distance by which the ring rail moves up and down is less than the total winding height (lift) of the tube.

(2) The stroke of the ring rail is deliberately kept less than package tube height so that the ring rail can be moved upward by a small distance from the previous point of lay of the yarn after one complete layer of the yarn has been laid. This helps in creating the lower curved base of the package.

In older machinery, instead of moving the point of lay of the ring rail upwards after every layer has been laid, the spindle is made to move downward. This is carried out by mounting the spindle on the spindle rail. However in modern machinery this arrangement is no longer used and only the ring rail is made to move up and down and also its point of lay is continuously lifted upwards by a small amount. This somehow reduces the complexity of the builder motion.

The tasks of the builder motion to move the ring rail up and down is carried out by using special heart shaped eccentrics or cams in its drive given to the ring rail. These eccentrics in its rotary motion give an up and down motion to the ring rail. The rise in the point of lay of the ring originates by using a ratchet wheel that after every layer of the yarn makes the pint of the lay of the ring rail to shift upwards.

Use of Balloon Control Rings (BCR)

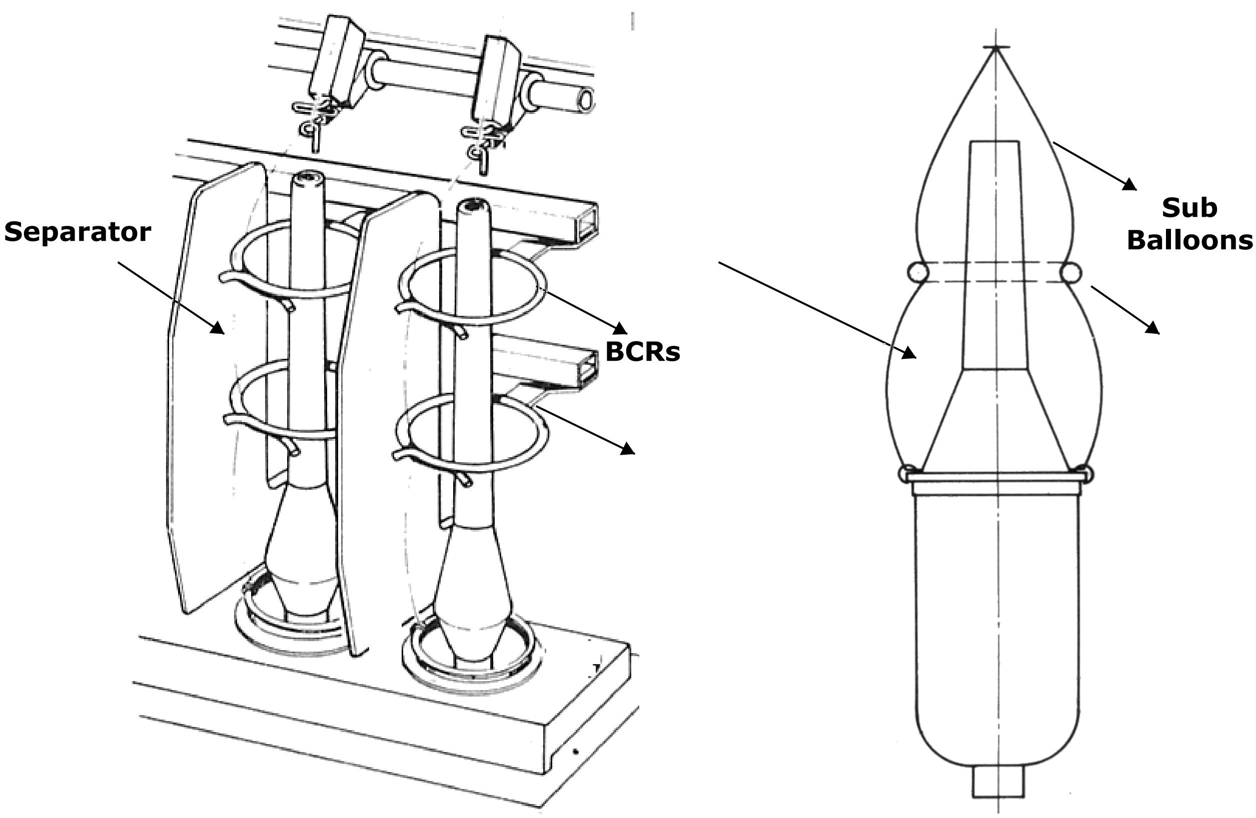
To achieve greater production speeds with minimum friction produced by the traveller, the spindle and the rings used on modern ring frames are comparatively small. This small ring size only permits a very limited length of yarn to be wound on the bobbin and the doffing would have to be performed more frequently and hence the productivity would suffer. On modern machines this problem has been over come by using longer length of spindles and bobbins so that even with less package diameter more yarn length can be wound. This reduces the amount of doffing and productivity can be increased in this way.

The use of long spindles will mean that the distance between the lappet guide and the ring would be quite high resulting in a formation of a bigger balloon. The greater balloon size has following disadvantages:

(i) To facilitate a larger balloon during winding, more spacing will be required between the adjacent spindles and hence the size of the machine has to be increased.

(ii) The large balloon causes the air drag on the yarn to increase and due to which the yarn can be broken due to balloon collapse.

In order to avoid these disadvantageous effects, balloon control rings are used. Each balloon control ring divides the balloon into two smaller sub balloons which are more stable and create less air drag on the yarn. The use of balloon control rings is illustrated below:



The balloon control rings enable the spinning operation with long spindles at high speeds. However the use of such rings cause the surface of the yarn to become rough and abraded as the yarn is rubbed against the surface of these rings. This can also creates more fly in the spinning department.

Use of Separators

Most of the end breakages during spinning occur because of the weak spots created by the spinning triangle. When the thread breaks the free broken end of the thread lashes around the spindle. If a protective plates called as separators are not provided to separate the adjacent spindles, the broken end of the thread can get entangled into the neighbouring spindles causing more threads to break. So a single end breakage can cause a chain reaction of yarn breakages in all the spindles placed in one line. To prevent this separator plates made up of aluminium or plastic is placed in between every adjacent spindle.

THE WINDING & CLEARING PROCESS

The quantity of yarn on the ring spinning bobbins or cops is very small as compared to the size of the package required for efficient processing at the knitting and weaving process. In addition to the small package size, the ring bobbins are also full of spinning defects i.e. thick and thin places.

So the process of winding involves unwinding of the yarn from the spinning packages i.e. ring bobbins and winding it on to a new bigger package. During the formation of the new package, spinning faults i.e. thick and thin places are also removed. Two types of packages can be produced by winding machine i.e. cheeses or spools (rectangular or parallel side packages) and cones (tapered side packages). But the type of package build within these two types of packages can vary depending upon the end use of the package.

It appears that winding process is just a simple process where the yarn is unwound from the ring bobbins and again wound on the new package and it seems that winding has no great significance but this is in fact not true. Suppose if we use ring bobbins directly in the process of weaving or knitting, then following problems may arise :-

(1) The ring bobbins will keep on exhausting very quickly and lot of time will be wasted in replacing the empty bobbins with new ones.
(2) The ultimate fabric produced by using ring bobbins will have defects and a lot of time and resources will go wasted.
(3) Because of the thin places in the yarn, threads will break more frequently during the fabric formation and thus efficiency and production will suffer.

All these points make the winding process very important. Even though it is an extra and expensive process for the preparation of a suitable package for fabric formation but still it proves its worth.

Objectives of Winding Process

(1) To prepare a bigger package having a sufficient length of yarn on it.
(2) To remove spinning faults e.g. tick and thin places.
(3) To improve the quality of yarn.
(4) In some cases, the yarn is also treated with certain chemicals or dyes during the winding process. Waxes are also applied to the yarn to reduce the abrasion and friction during the winding process.
(5) To produce a package of required density and shape suitable for the next stage of processing.

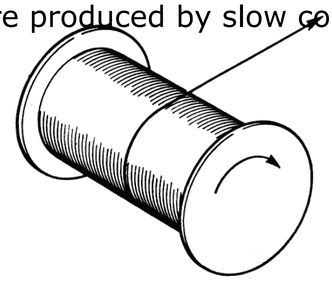
Types of Winding Packages

Two types of packages can be produced by winding machines:-

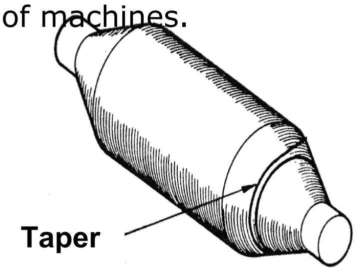
(1) Rectangular or Parallel Side Package.
(2) Tapered Side Package.

(1) Rectangular or Parallel Side Package

Rectangular or Parallel side packages are called as cheeses or spools. Cheeses or spools are produced by slow conventional type of machines.



Spool With Flanges

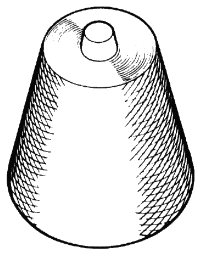


Cheese Without Flanges

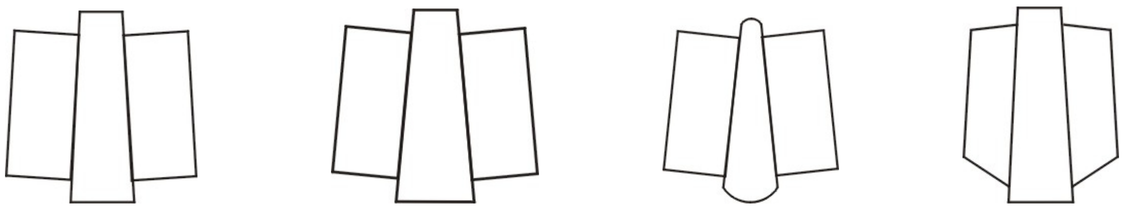
Parallel side packages are also suitable for staple fibres and for those yarns where the desirable length on the package is not very long. This type of package is also suitable when the package has to be dyed. The Parallel or rectangular side packages may or may not have flanges.

(2) Tapered Side Package

The tapered side packages are called as cones. Cones are produced by high speed winding machines like the autoconer.



Many types of cones are used in the industry. Various cones differ from each other from their package build and angle of taper. Most popular cones with their package built are given below:



Low Angled Taper **Wider Angle Taper** **Wide Angle Taper** **Pineapple Cone**

(i) Low angled taper cones having a taper of 2° 20′ to 3° 30′ are used for staple yarns where long lengths of yarn is required on the package. Such cones are very suitable for high speed winding and high speed warping machines.

(ii) Wider taper cones having a taper of 4° 20′ are used when the cones are to be dyed by using pressure dyeing.

(iii) Wide angles cones having a taper of 9° 15′ are used mainly for the supply of the weft knitting yarn

(iv) Pineapple cones have a taper of 3° 30′ just like low angled tapered cones, but their build is entirely different. These cones are produced by reducing the length of the yarn traverse as the package diameter increases.

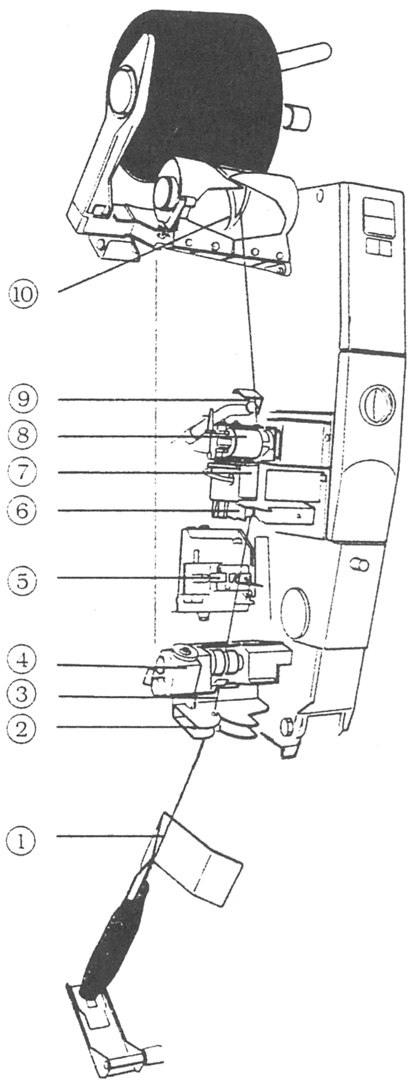
Based upon the type of these winding packages produced by the winding machines, winders are classified as:

(1) Cheese or Spool Winders
(2) Cone Winders

Whether the winding machine is old conventional type or is modern type, the basic principle of all the machines are same. If the winding machine produces end product as a cone (tapered side package) then it is called as cone winder and if its end product is a cheese or spool (rectangular side package) then it is called as cheese winder or spool winder.

Components of Winding Machine

The old conventional winders are quite simple machines where majority of the necessary mechanisms being of mechanical type. On the other hand, the modern automatic winding machines are equipped with variety of electronic devices and computerized control panels to achieve high speeds of winding at a better quality. Furthermore arrangement of automatic bobbin creeling, automatic doffing and auto joining of the broken threads are also provided on these modern winders. Illustration of a high speed winding machine is given below:



(1) **Balloon Controller**

(2) **Yarn Guide**

(3) **Pre-Clearer Guide**

(4) **Yarn Tensioner**

(5) **Splicer**

(6) **Electronic Clearer**

(7) **Cutting Device**

(8) **Waxing Unit**

(9) **Yarn Trap**

(10) **Grooved Drum**

Typically a modern high speed winding machine is divided into following zones:

(1) Creel Zone
(2) Tension Zone
(3) Clearing Zone
(4) Yarn Joining Zone
(5) Winding Zone

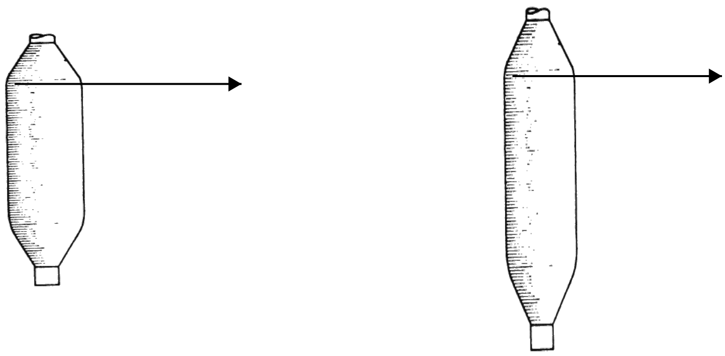
(1) **Creel Zone**

Creel is the part on which ring bobbins are held. The creel is so designed so that it should assist in continuous uniform unwinding of the yarn at high machine speeds which in case of modern winders can go up to 1500 metres per minute. Each creel also has some sort of balloon controller which is made up of metal and does not allow bigger balloons to get formed during unwinding. The unwinding of the yarn from the package is called as the withdrawal of the yarn or package. Two techniques might be used for withdrawal of the package :-

(i) Side End Withdrawal.
(ii) Over End Withdrawal.

(i) Side End Withdrawal

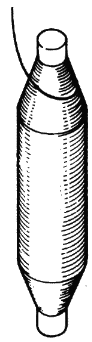
In this method, the package is mounted on a spindle and the yarn is removed from its side.



As long as the yarn is being removed, the package revolves. It is only suitable for slow speed machines because at high speed, the package wobbles that can cause the tension to increase. This method is associated with rectangular or parallel packages i.e. cheeses or spools.

(ii) Over End Withdrawal

In this method, the package is kept stationary and the yarn is removed from the top. This method is suitable for high speed machines. This type of withdrawal is mostly associated with tapered side packages i.e. cones. The taper in cones usually are given to assist easy withdrawal of the yarn.



(2) **Tension Zone**

Tension zone performs the following two main objectives:

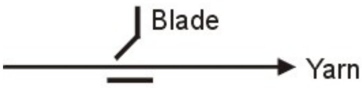
(i) To apply a uniform tension on the yarn so that uniform package with required density can be obtained. Greater the tension on the yarn, more compact and dense package can be obtained. However the amount of tension to be applied on the yarn depends upon the count.

(ii) The tension on the yarn helps to remove thin or weak places in the yarn. To remove thin places, a sufficient tension for a certain count of yarn is applied uniformly. This tension will cause the thin or weak places in the yarn to break however the regular yarn will not be affected. In this way, these faults are removed. The amount of tension applied should be about 10 to 15% of the single yarn strength.

The tension on the yarn is applied by passing it through a tensioning device or tensioner. Tensioners come in variety of shapes and techniques however conventionally a disc type tensioner is used in which the yarn is passed through two disc plates and a sufficient pressure is applied to the plates. The amount of tension produced in this case would be directly proportional to the amount of pressure on the discs. In modern winder more sophisticated yarn tensioning device is used which is controlled electronically through a computer control panel.

(3) <u>**Clearing Zone**</u>

The purpose of the clearing zone is to eliminate yarn defects such as thick places, thin places and slubs. In old winding machinery mechanical clearers are used. These clearers or slub removers are composed of fixed blade with very little distance left for the yarn to pass beneath or over it. As a thick place or slub comes, the blade cuts it off the surface of the yarn. Mechanical clearers are either flat blade or ring blade type as shown below:



Mechanical clearers are very difficult to adjust; they are not reliable and durable and make the yarn surface harsh and hairy. Due to these limitations they are no longer used on modern winder. Instead electronic clearers are used. The electronic clearers either work on optical or capacitance principles. These clearers are very efficient, reliable and durable as compared to mechanical type and even the slightest of variation can be detected and removed by them which is not possible in mechanical type.

When optical principle is used then we use photoelectric cells. A light source is generated by the emitter or the transmitter and is passed through the yarn and received on the other end by the receiver. The amount of light received after passing through the yarn is translated into an electric current. For example, for coarse yarn less light and for fine yarn more light will be received. The Electronic clearer is set for a particular count of yarn and if any slub or thin place comes on the yarn, it is detected by variation in the light and hence it is removed by the cutter.

In case of capacitance type electronic clearer, the yarn is passed over a capacitance device which constantly measures the capacitance of the yarn and translates that capacitance into an electric current. The capacitance of the yarn depends upon the moisture in the yarn which in turn depends upon the number of fibres in a cross-section i.e. for fine yarns, capacitance will be low and for coarse yarns it will be high. The clearer is set according to the count, when any variation in capacitance that exceeds a certain limit is detected, the cutter cuts the thread and in this way both slubs and thin places are removed.

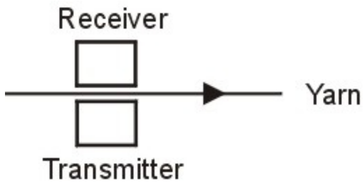
(4) **Yarn Joining Zone**

During the winding process, breakage of threads may take place. The breakage of threads may occur due to:

(1) The deliberate action of the mechanical type tensioner for removal of thin places.
(2) The deliberate action of the electronic clearer for the removal of thick and thin places.
(3) The result of extra force build-up on the yarn due to many reasons like friction, ballooning effect, etc.

As the yarn breaks, the stop motion installed on the machine causes the machine to stop immediately. In conventional winders, mechanical type stop motion is used where the yarn is passed through a lever which is lifted due to the tension in the yarn. As the yarn breaks the lever falls down which mechanically or electrically stops the machine.

The modern winders make use of optical sensors for stop motion. The yarn is passed through a pair of sensor having a transmitter and a receiver. The transmitter transmits light which can only be received by the receiver when there is no yarn between them i.e. when the yarn breaks. As soon as the receiver starts receiving the light, the machine is stopped immediately.



Piecing or Joining of Broken Threads

Whether the yarn is deliberately cut due to the action of clearer or it accidentally breaks, the stop motion installed on the machine will immediately stop winding. As soon as the machine is stopped, the two broken ends of the yarn must be pieced or joined together as soon as possible so that the machine can be immediately started again. The piecing of the broken ends can be carried out by following methods:

(a) Knotting
(b) Splicing

(a) Knotting

In this method, the two broken ends of the yarn are knotted together by a regular knot. The knotting of the threads may be carried out manually by hand or by automatic knotting machines. One or more than one automatic knotters may be used per winding machine. It is always desirable to use each separate knotter or each spindle, but this increases the machine cost considerably. So the general practice is to use one knotter for 10-12 spindles. The knotter will move or patrol these spindles in a reciprocating manner and whenever it finds any spindle stopped, it repairs the broken ends by knotting. Sometimes, only one knotter is used for the whole machine. In this case, the knotter can either reciprocate between the spindles or it can move continuously in a loop around the machine covering all the spindles.

The method of knotting is considered to be an old method and it has many drawbacks:

(i) The presence of knot in the yarn will increase its diameter at the point of a knot. This increase may be 3-4 times the actual yarn diameter.
(ii) The knot sometimes makes it difficult to pass the threads through various components of loom and needles of knitting machine.
(iii) Knots can be clearly visible in the fabric degrading its quality.
(iv) These knots also reduce the life of knitting needles and loom components through which the yarn is passed.

(b) Splicing

Splicing is a modern method of joining the broken ends. The machine component that does splicing is called as the splicer. The procedure of splicing is as follows:

(i) Both broken ends of the thread are collected by splicer arms by means of air suction.
(ii) Each broken end is untwisted by applying twist in the opposite direction to the twist in the yarn.
(iii) Both broken ends of the yarn are placed on each other.
(iv) They are joined together by twisting and slight stretching.

The use of splicing has many advantages over the knotting:

(i) The diameter of the spliced yarn does not increase more than 25% of the actual diameter.
(ii) The splices in the yarn are less visible in both the yarn itself and the fabric made out of that yarn.
(iii) The spliced yarn can easily pass knitting needles and loom components without damaging or increasing the wear of these components.

The most efficient system would have one splicer per spindle. Such arrangement will make the cost of the winding machine very high and also the cost of maintenance will increase. It is a general practice to have one splicer for small group of spindles e.g. one splicer for 10-12 spindles. Either the spindles move towards the splicer or the splicer moves towards the spindles. Commonly the splicer moves in a circular path or in a straight reciprocating path covering the specific number of spindles.

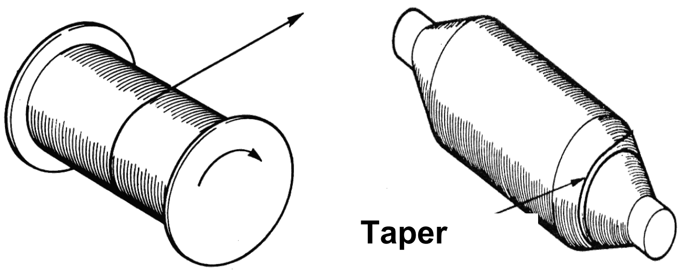
(5) Winding Zone

The yarn after being cleared from spinning faults has to be wound on packages of suitable shape, size and built. This is done at the winding zone. The winding packages can be either in the form of cheeses (rectangular side packages) or cones (tapered side packages). However within these two types of packages, the package built can vary depending upon the end use of the package. Two types of package builds are possible at the winding machine:

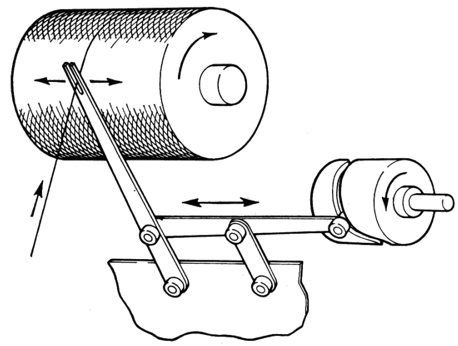
(1) Precision Package Built
(2) Non-Precision or Random Package Built

(1) Precision Package Built

The precision package built can be obtained by placing coils of thread side by side parallel to one another and at a small predetermined and precise distance. In order to obtain such package built, it is necessary that the package should have flanges on its sides; otherwise the package will not be stable and would collapse. If the package does not have flanges, then this package built can still be use by giving a small taper to the package on both sides



Precision Wound Package



Linear Traversing Guide

In order to place the successive layers of thread parallel to each other on the package, a to and fro movement must be given to the yarn by using linear traversing guides. In each revolution of the machine, the traversing guide moves by a very small precise distance so that the next layer of the thread may be wound parallel and close to the last layer. The distance between the two successive layers of thread is called as the pitch or gain. The density of the winding package depends upon the pitch. Minimum pitch would give the maximum dense package. The pitch can be determined and controlled by the linear movement made by the traversing guide in each revolution.

The winders that give precision built to the package are also called as spindle driven winder since drive to the package is directly obtained from a rotating spindle.

(2) Random Package Built

In this type of package built, the successive coils of the thread are wound at a considerable helix angle so that the layers cross each other to give stability to

the package. Here the pitch between the successive layers and the angle of wind of each layer is considerably high. Also the packages used do not have flanges on the sides. This high pitch and high wind angle does not make the package unstable.

Random Wound Package **Rotary Grooved Drum**

The winders that give random package built are also called as random winder. Since the random winders make use of grooved drum for winding, they are also called as grooved drum winders. The package on such winding machines is driven by the frictional contact of the rotating drum with the package. No traversing guides are used in this case because the grooves in the drum cause the yarn to traverse on the package.

Based on the type of package built given by the winding machine as mentioned above, the winder are also classified on this basis as:

(1) Precision Winders or Spindle Driven Winders
(2) Random Winders or Grooved Drum Winders

Whether the package is precision built or random built, following parameters of the package are important and can be changed according to the requirements:

(i) Size and weight of the package.
(ii) The compactness of the package.
(iii) In case there is a taper in the package, the angle of taper is also very important and is changed for different package requirement.

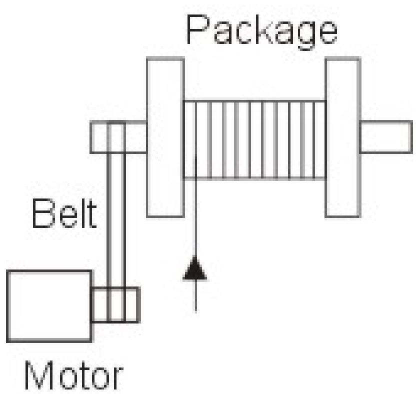
<u>The Type of</u>

The type of package built is largely dependent upon the type of driving method used for winding. In order for the winding to take place, the package tube is mounted on the driving shaft or spindle and is driven by one of the following methods:

(a) Positive or Direct Drive.
(b) Negative or Indirect Drive.

(a) <u>Positive or Direct Drive</u>

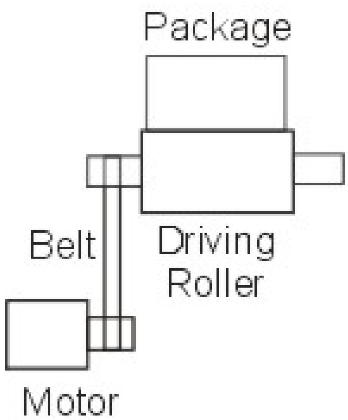
In positive or direct drive, the package is directly driven by the motor by means of gears, shafts, pulleys, etc. In this type of drive, the rotary speed of the package remains constant through out the package build.



The main disadvantage of positive drive is that as the diameter of the package increases, the surface speed of the yarn also increases. This causes the tension on the yarn to increase. The variation of the tension on the yarn from start of package winding to end varies; this gives variation in package build. Also towards the end of package winding, the increased tension may also cause the yarn to break. To avoid this with the direct drive, a PIV gear is used which reduces the rotary speed of the package with the same proportion as that of its increasing diameter so that the surface speed may remain constant and uniform winding from start till finish may be obtained.

(2) Negative or Indirect Drive

In the negative or indirect drive, the package is driven by the driving roller by a frictional contact. So this type of drive is also called as frictional type drive.



The main advantage of this type of drive is that the surface speed of the yarn will remain constant through out the package drive. But the disadvantage is that since this type of drive uses frictional contact, so the yarn may get damaged. The negative drive is usually implied using a grooved drum and no linear traversing guide is used to facilitate winding on the entire length of the package because the grooves of the drum also cause the yarn to traverse through the package length. The negative drive is sometimes also referred as grooved drum drive or random drive.

The cotton spun yarns are mostly wound by using the grooved drum type of drive with a random or non-precision package built. In case of the drum drive, the drum is mounted on the shaft or spindle that directly gets its drive from the machine. Each spindle is supplied with an independent motor for its drive that can produce a speed of up to 1500 meters per minute. The package is mounted on a cradle which not only holds the package but also applies considerable pressure against the winding drum to avoid any slippage in the drive. The cradle is lifted as soon as the yarn breaks or the ring bobbin is emptied so that the package drive may be disconnected.

Auto Creeling and Auto Doffing Devices

Removing of the supply package (ring bobbin) when it is emptied and replacing it with a new full supply package (ring bobbin) is called as the process of creeling. On old conventional machines this process is carried out manually by hand however on the modern winders, arrangements are given that automatically does the creeling process. The creeling arrangement does the following necessary tasks:

(i) Stops the machine when the supply package exhausts.
(ii) Removes the empty bobbin tube and ejects it into a special compartment.
(iii) Inserts a new supply package from the creel.
(iv) Performs the piecing of the thread.
(v) Restarts the winding process.

Similarly removing the full wound package (cone or cheese) when the required package size is obtained and replacing it with a new empty one is called as the process of doffing. The automatic doffing installed on the modern winders performs the following functions:

(i) Stops the machine when the required size of the package is wound.
(ii) Removes the full winding package and transfers to a conveyer belt.
(iii) Places an empty tube into the cradle
(iv) Pieces up the yarn on the new package.
(v) Restarts the winding process

THE ROTOR SPINNING PROCESS

In the production of short staple spun yarn, the rotor spinning technique is an excellent modern alternate to the old classical ring spinning method due to its high productivity advantage over the ring spinning. The rotor spinning is not only highly productive but also very cost effective at the same time. In addition to short staple spinning, long staple rotor spinning machines have also been manufactured only to produce coarse yarns from long staple manmade fibres. However wool fibres because of their scaly surface, crimp and natural greases are not possible to spin using this technique.

Rotor spinning was commercially introduced in 1967. In its early years, the rotor spinning was mainly used to produce coarse low quality yarns. However with modern developments, it is now possible to produce high quality yarns up to counts of 40 Nc. Furthermore the rotor speed has been successfully increased from early range of 40,000 rpm to 150,000 rpm. These latest developments have given rotor spinning technique capability of producing high quality yarns at a productivity rates of up to 10 times higher and as low as one third of the cost as compared to that of ring spinning technique. The biggest limitation faced by rotor spinning is its inability to produce very fine yarns that otherwise can easily be spun by using ring spinning. Despite of this limitation, rotor spinning is a very good competitor of ring spinning and is capturing the market considerably in coarse yarn counts.

The rotor spinning technique is quite different from the conventional ring spinning. The differences are in the following aspects:

- In ring spinning, the opened and cleaned fibre mass is converted into a strand form and a yarn is created by successive drafting and twisting at various spinning stages without disturbing the linear strand form of the fibres. Whereas in rotor spinning, the strand of fibres is first separated by vigorous drafting and is then recollected and twisted in a component of the machine called as a rotor.
- The feed to the rotor frame is given rarely in the form of card sliver or most commonly in the form of drawn sliver. Since rotor spinning is a true sliver to yarn conversion as compared to ring spinning where no additional roving process is required, the productivity rates are much higher; it covers less floor space and is less labour extensive.
- In ring spinning systems the package formation i.e. winding and twisting is an integral part of the spinning system whereas in rotor spinning, the package winding is quite separate from drafting and twist insertion.
- The rotor spinning produces fewer spinning faults like thick and thin places as compared to ring spinning, so rather than carrying additional winding and clearing process after spinning, the winding section of rotor frame directly produces suitable large packages required for subsequent processing with built-in clearers to remove spinning faults. This further makes the rotor spinning more economical and more productive.
- Instead of using the classical roller drafting, the rotor frame utilizes dispersion drafting technique. The method of twist insertion is also different. In rotor spinning twist is inserted by the rotation of the rotor whereas in ring spinning the rotation of the traveller around the ring inserts twist.

Functions of Rotor Spinning Process

Following are the important functions of the rotor spinning process:

(1) **Opening & Attenuation,** the fibres in a sliver form are vigorously opened up into individual fibre form using opening roller having its surface covered with sharp teeth or spikes. The vigorous opening of the fibres in this way also helps to reduce the linear density of the material. The amount of reduction in the linear density depends upon the yarn count to manufacture and can be controlled by the rate of feeding and degree of opening carried out. The drafting technique used here also called as dispersion drafting is quite different from the roller drafting technique used in ring spinning.

(2) **Cleaning,** during the opening of the fibres into individual fibre form, cleaning is carried out by removing trash particle and dust particles using trash removal devices. The cleaning at the rotor spinning is optional and is only used for more dirty cotton. It is very important that fibres reaching the rotor must be free from any trash particles or fragments because they can rapidly clog the rotor causing thick and thin places, neps and uneven compactness in the yarn.

(3) **Improving Evenness,** back doubling is used to make an even and homogenised rotor spun yarn. The term ‘Back Doubling’ refers to opening

of the fibres in individual form and recollecting them at the rotor for yarn formation. The evenness achieved by this method is far more than that achieved at the ring spinning.

(4) **Twisting,** in order to impart strength to the yarn twist is vital. Twisting is carried out by collecting the individually opened fibres and subjecting them to high speed revolving rotor. The centrifugal forces caused because of high rotary speed of the rotor cause the fibres to get collected around the wall of the rotor in form of a yarn and with one complete rotation of the rotor, one twist is imparted.

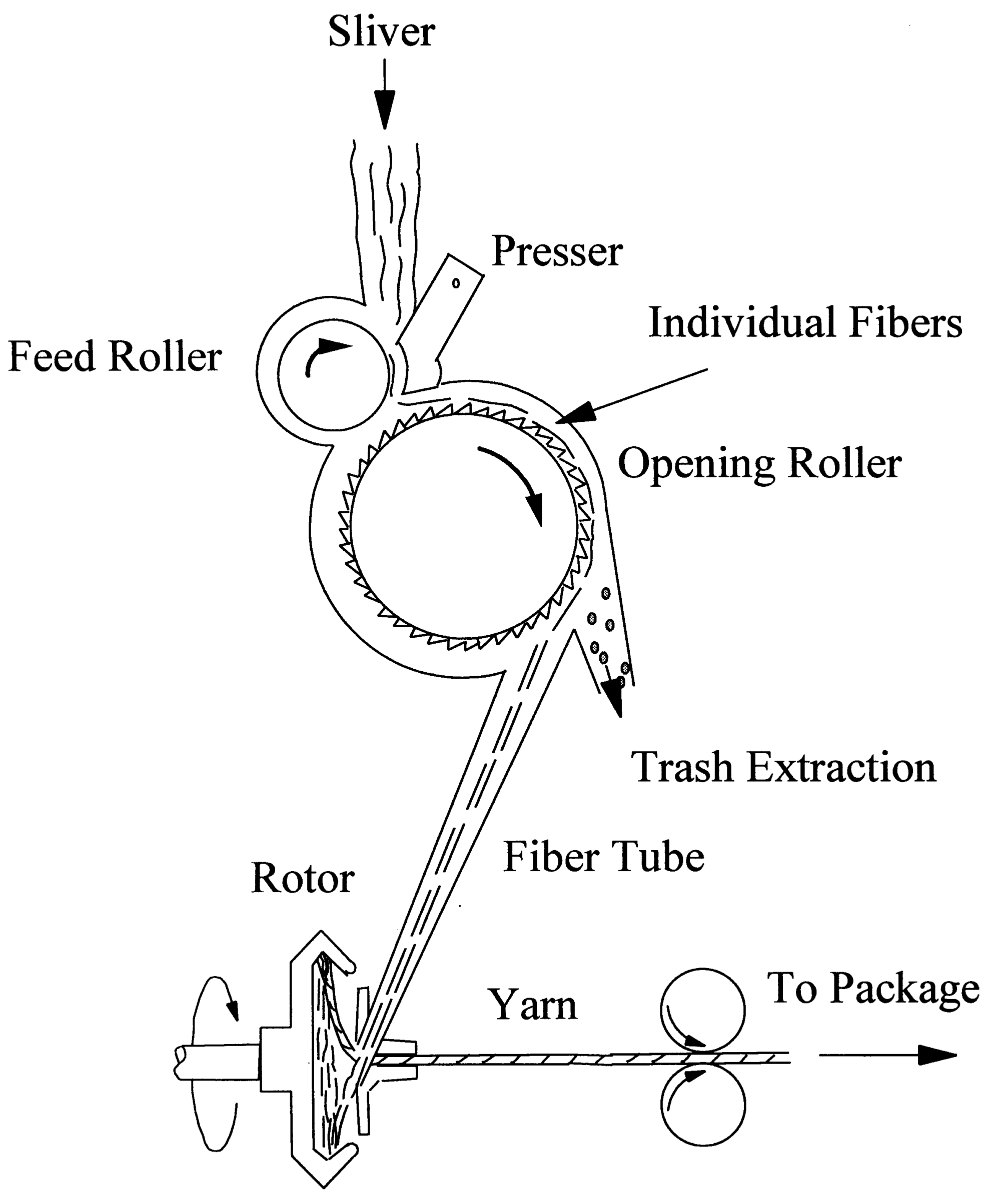
(5) **Winding,** the yarn produced by opening (drafting) and twisting is finally wound on finished packages. Unlike ring spinning where the package has lot of defects and also the size of the package is very limited due to ring / traveller arrangement, the winding portion of the rotor frame produces suitable bigger packages that can be directly used for next stage of processing i.e. weaving or knitting. In modern rotor machines, electronic clearing devices and automatic yarn piecing arrangements have also been provided.

Working Areas of the Rotor Frame

The rotor spinning process can be divided into following areas:

(1) Feeding
(2) Opening & Drafting
(3) Fibre Transport
(4) Fibre Reassembly
(5) Twisting
(6) Winding

An illustration showing a typical rotor spinning process is shown below:



(1) **Feeding Zone**

The feed to the rotor machine is either done in the form of card sliver or drawn sliver. Most commonly drawn sliver of either first or second passage is used as a feeding material to the rotor frame. The sliver is fed to the opening zone with the help of a feed roller. The rotation of the feed roller grips the fibres and presses is against the presser plate so that a controlled feed may be given to the opening zone of the machine.

(2) **Opening & Drafting Zone**

The separation of fibres from sliver to individual form is critical for uniform yarn formation. If fibres are not delivered to the rotor with proper individualization, the resultant rotor yarn will lack orientation and uniformity. The opening of the fibres is carried out with the help of a rotating opening or combing roller whose surface is covered with saw teeth. As the sliver is fed in the opening region, the fibres are caught by the teeth of the opening roller. Here the centrifugal forces and the aerodynamics of the system, transports the fibres from the teeth of the opening roller to the fibre transport tube. In the fibre tube an air stream is provided that further does the opening and ultimately deposits the fibres in the rotor.

As the fibres are separated from one another, the opening roller also performs cleaning. Cleanest possible fibres should be fed to the rotor machine, however at such high degree of opening, some fine trash particles and dust will be generated. The trash extraction unit is designed so that lighter fibres are allowed to be carried away with the air stream into the fibre transport tube while the heavier trash particles will directly fall due to their weight into the trash extraction duct.

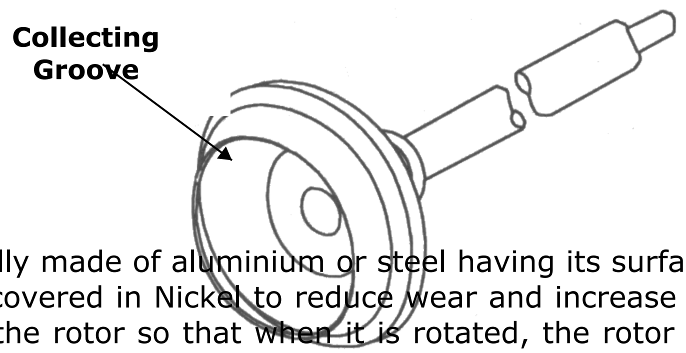
This extensive opening of the fibres results in drafting of the input sliver material and reduces its linear density. The type of drafting employed here is called as dispersion drafting which is quite different from the roller drafting technique used at the ring spinning frame. Usually a draft of range of 100 to 200 is applied during opening.

(3) Fibre Transport

The fibres opened up by the opening roller must be transferred to the rotor without getting disoriented. This is achieved by using a specially designed transport tube. The fibres are transported by this tube with help of air currents. The transport tube is slightly tapered to accelerate the air currents and fibres so that hooked surfaces caused by teeth of opening roller may be straightened out and fibres can be oriented.

(4) Fibre Reassembly

The fibres coming from the transport tube are accumulated inside the rotor. Rotor is the main component of the rotor spinning process. Rotor is just like a small metal cup with inclined walls having a conical shape. The inclination is essential so that the fibres coming from the fibre feed tube can slide downwards. The inner surface of the rotor is called as collecting groove. The diameter of the collecting groove also called as the rotor diameter depends upon the speed of the machine and fibre length. As a rule, the rotor diameter should never be less than 1.2 times the staple length of the fibres being processed.

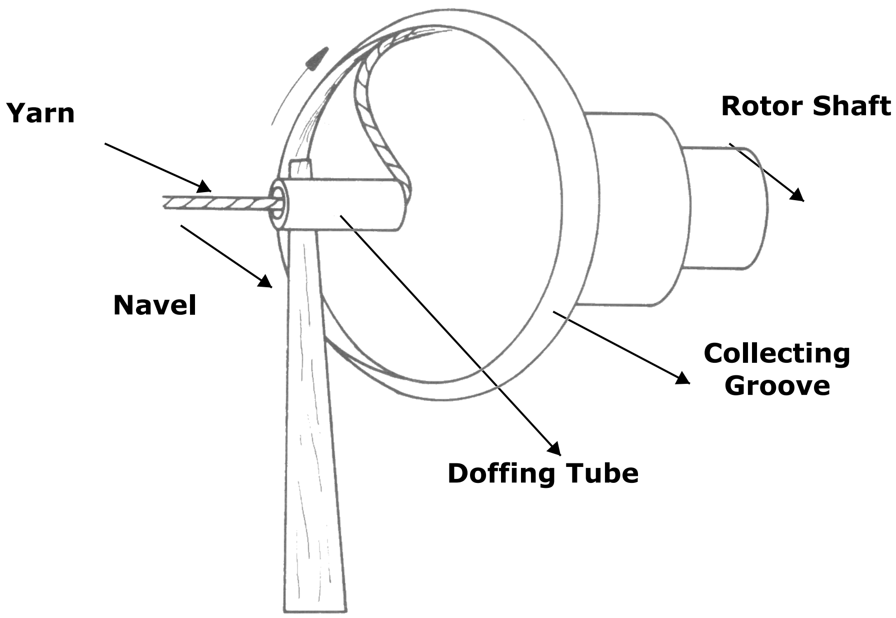


The rotor is generally made of aluminium or steel having its surface covered with diamond particles covered in Nickel to reduce wear and increase its working life. A shaft is fixed to the rotor so that when it is rotated, the rotor will also rotate. The rotor rotates inside a stationary cover or housing with the help of a bearing. In the middle of the rotor a withdrawal tube or doffing tube with specially designed mouth piece or navel is provided for the yarn to leave the rotor.

As the fibres reach the rotor rotating at extreme speeds, the centrifugal forces cause the fibres to be recollected as untwisted strand of fibres. It takes many layers of the fibres to make up a sufficient thickness of fibres necessary for yarn formation. This may happen over a period of many revolutions (approximately 100). The numerous doubling of the layers of fibres provide blending called as back doubling. This back doubling makes the rotor spun yarn very even with fewer thick and thin faults as compared to ring spun yarn.

(5) <u>Twisting</u>

The twisting occurs with the action of rotor, navel and the take-up rollers.



As individual fibres emerge simultaneously from the fibre feed tube, they slide along the inner wall of the rotor and are collected around the collecting groove. In this way a continual fibre ring is built up in the groove and this process is called as the back doubling. As the sufficient number of fibres has reassembled inside the rotor wall, further fibre feed will choke the rotor. However rotor's special aero-dynamical design and due to excessive centrifugal forces acting on the fibres, the yarn is allowed to extend from the rotational axis of the rotor to its outer surface and ultimately carries the yarn to the navel from where it can be drawn forward with the help of a take-up rollers.

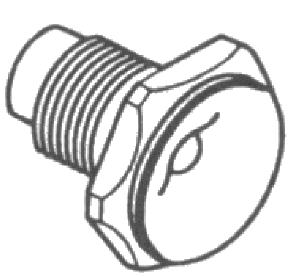
Each revolution of the rotor inserts one twist in the yarn. The twist travels from the back of the navel to the point where the fibres leave the rotor. When the twist in the yarn reaches the maximum level, the yarn end begins to rotate on its axis. It is necessary at this point to carry the yarn perpendicularly out of the navel with the help of the take-up rollers. Mathematically the amount of twist is calculated by the following formula:

Turns per inch = Rotor Speed (rpm) / Delivery speed of yarn ("/min)

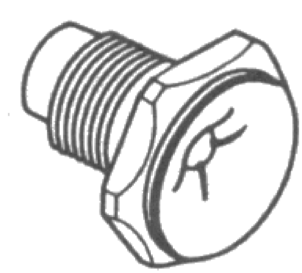
However the calculated twist always comes out to be 15 to 40% lower than the actual twist imparted on the yarn. This is due to the fact the fibre slippage occurs during the actual twist insertion.

Since the yarn travels through the navel and the doffing tube with a rolling action touching their surfaces, false twist is inserted in addition to the real twist inserted at the rotor. So the total twist inserted in the yarn is the sum of the real twist and false twist. The false twist provides more stability to the yarn however during the package winding the false twist is automatically removed and the final yarn only has the real twist in it. The false twist does have a considerable impact on the yarn characteristics. At higher rotor speeds due to more centrifugal forces, the amount of false twist inserted during yarn formation will be more. The increase in the false twist increases the amount of wrapper fibres in the yarn causing the yarn to have more protruding fibres and a harsher look and feel.

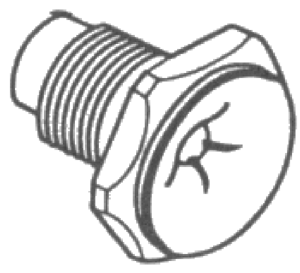
Since the yarn passes out of the navel in a rolling action touching its surface, the surface and design of navel has a great influence on levels of false twist and ultimate quality of the yarn. Based upon the type of the yarn to produce, different shapes and roughness of navels are available as shown below:



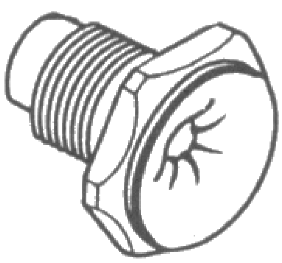
Smooth navel for smooth non-hairy yarns



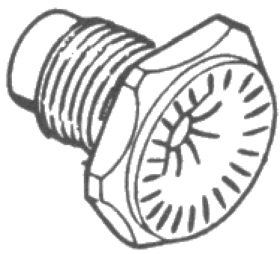
3-Groove navel for low yarn hairiness



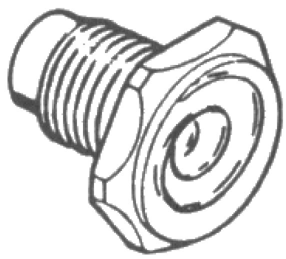
4-Groove navel for low yarn bulk



8-Groove navel for low twist yarn



8-Groove navel for high hairiness



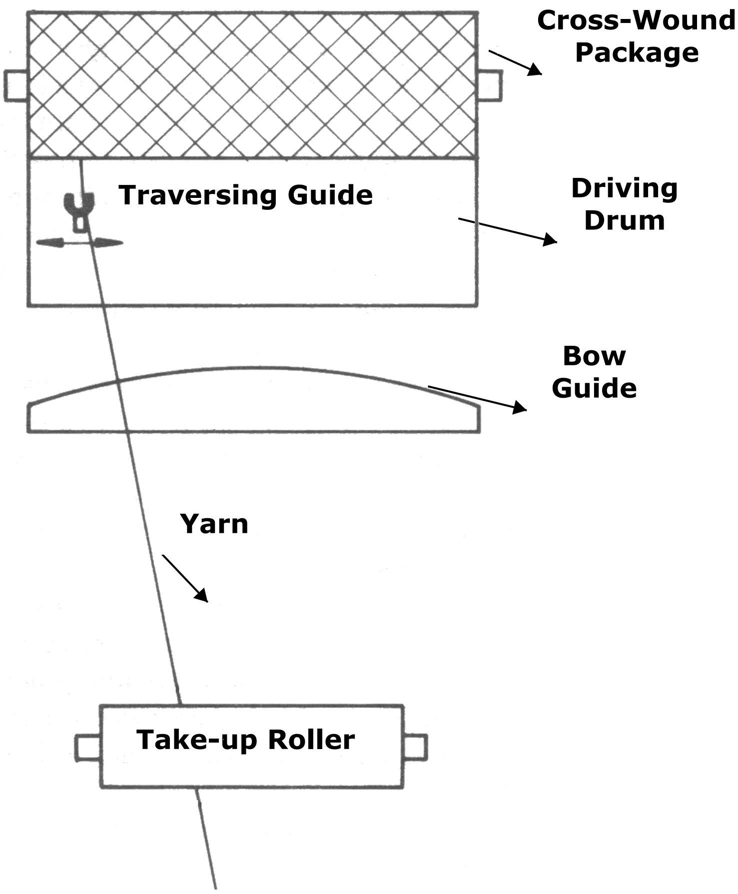
Ceramic spiral navel for Low bulk & low hairiness

In general as the number of grooves increases, the hairiness of the yarn also increases. Similarly rougher the surface of the navel, the yarn will have more false twist along with hairier, rougher and bulkier surface.

Just as the navel surface and design has influence on the yarn quality and handle, the design and surface of the doffing tube also can influence the levels of false twist and quality of the yarn.

(6) <u>Winding</u>

The yarn formed at the rotor leaves the rotor spin box and is finally wound into a finished package. Unlike the ring spinning frame where the size of the package is limited because of the ring / traveller arrangement, bigger cross wound packages are produced either in form of cheeses or cones. During the process of winding spinning faults are also removed to produce an even fault free packages that require no additional processes and can be directly used for weaving or knitting.



The yarn produced at the rotor is continuously pulled by the pair of take-up rollers placed just after the doffing tube and ultimately winds the yarn on the package. The package is driven negatively by the frictional contact of the driving drum. To wind the yarn evenly throughout the package length, a linear traversing guide is used. However in case a grooved driving drum is used, this linear traversing guide is no longer used as traversing is performed by the grooved drum itself.

Winding is only possible if the surface speed of the yarn being wound on the package is more than that at which the yarn is delivered. This creates a tension called as the winding tension. The winding tension controls the compactness of the package. More the winding tension, more compact and hard packages are formed and vice versa. In case the package is to be dyed, the winding tension is kept low as compared where normal weaving or knitting packages are formed. For knitting yarns, waxing devices are used to apply wax to the yarn so that the yarn is lubricated to reduce yarn to metal friction in the knitting needles so that the wear of knitting needles may be reduced.

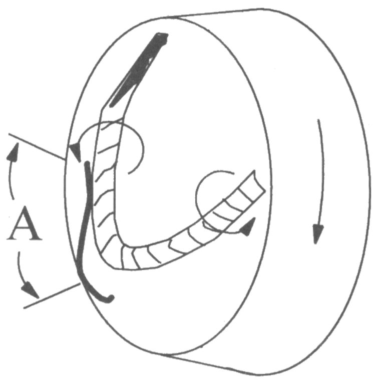
Electronic Clearing & Automatic Piecing Devices

The modern rotor spinning machines are also equipped with electronic clearers to remove the spinning faults and automatic piecing devices to repair the broken ends of the thread. Since the number of thick and thin places produced by the process of rotor spinning is far less as compared to the ring spinning, most commonly one piecing device is used for 10 to 12 rotors. The piecing devices either reciprocate in between the specified rotors or they move in an endless circular path around the rotors. As the piecing device finds a stopped rotor, in addition to automatic piecing, it will also open up the spin box and will clean the rotor with the help of a specially designed brush.

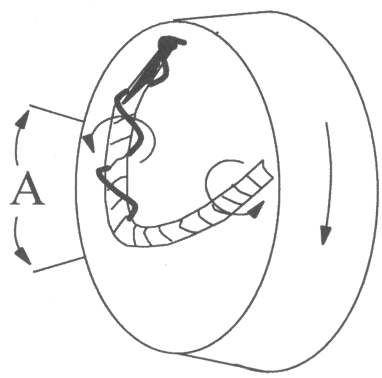
The automatic piecer works on pneumatic principle similar to the one used in automatic winding machines. The piecing is carried using splicing technique with the help of air currents and air suction.

Structure of Rotor Yarn

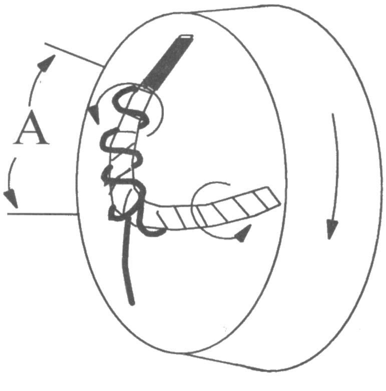
The inner core of the rotor spun yarn is similar to a ring spun yarn. However the outer surface of the yarn has its unique structural build up owing to the method of yarn formation. During the yarn formation the fibres are reassembled with in the collecting groove of the rotor and are twisted to form a yarn. During the twisting of fibres into a yarn, portion of fibres instead of being twisted into the inner yarn structure are wrapped around the outside of the yarn. These fibres are called as wrapper fibres or bridging fibres as shown below:



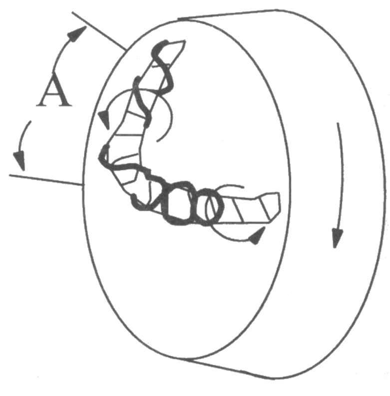
(A)



(B)



(C)



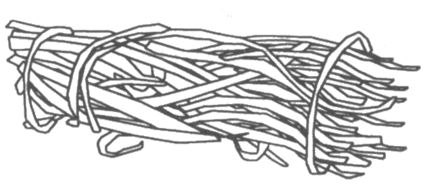
(D)

The wrapper fibres make the rotor spun yarn harsher and hairy in appearance. They also contribute to increased needle wear in knitting and increased wear to loom components in weaving. Fewer the wrapper fibres present in the rotor yarn, more it will resemble to the ring yarn and the better the rotor yarn will be.

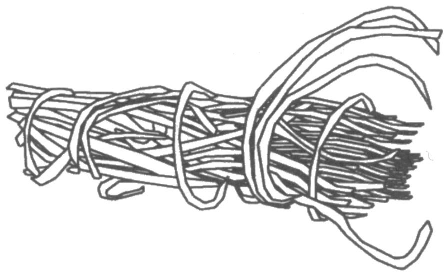
The formation of wrapper fibres depends upon many factors, most important ones are:

(1) **Rotor Speed**, with increasing rotor speeds, because of the centrifugal forces both the level of false twist and the yarn rotation at the navel increases and hence more wrapper fibres are wrapped around the main core yarn.

(2) **Rotor Diameter**, with smaller rotor diameters, the wrapper fibres are wound fewer times around the yarn core making it more hairy but less bulky (more compact) as compared to rotor yarns spun on larger rotor diameters as shown below:



Spun with larger rotor



Spun with smaller rotor

(3) **Fibre length**, longer the fibres being processed, larger rotor diameters are required otherwise the fibres will get damaged. So when larger rotor diameters are used at high speeds for longer fibres, the amount of wrapping fibres will increase.

(4) **Friction between fibre & rotor groove**, more the fiction generated between the two, more wrapping fibres will be generated.

(5) **Surface of navel**, rougher the surface of navel, more wrapping fibres are generated and vice versa.

The increase in the rotor speed is limited due to the amount of wrapper fibres generated. The speed of the rotor can be increased using smaller rotors because with smaller rotor diameter, less centrifugal forces are generated. This allows to further increase the rotary speed of the rotor and ultimately the productivity. For example, the centrifugal forces produced by a 30 mm rotor running at 120,000 rpm are approximately the same as that of 36 mm rotor running at 80,000 rpm. However this is also restricted by the fibre length because for a specific fibre length a specific rotor diameter has to be used.

In general all these factors related to wrapper fibre formation must be adjusted in such a way so that the wrapper fibre formation may be minimized. The wrapper fibres can not be entirely removed otherwise the productivity will suffer a lot, however excessive wrapper fibre formation should be avoided as it degrades the quality and appearance of the yarn.

Advantages of Rotor Spinning

(1) The rotor spinning produces yarn at productivity rates of 4 to 10 times as

compared to the ring spinning process.

(2) The cost of production of rotor spun yarn is quite low as compared to ring spun yarn and can be as low as one third.

(3) Additional processes of roving and winding/clearing is eliminated. That not only makes rotor spinning operation more economical but also the capital cost of machinery and floor space requirements are reduced.

(4) Due to dispersion drafting and back doubling process, rotor spinning generates fewer spinning faults like thick and thin places.

(5) The rotor spinning process is the first fully automated spinning process.

(6) Less energy is required to produce a yarn on rotor spinning system as compared to the ring spinning system.

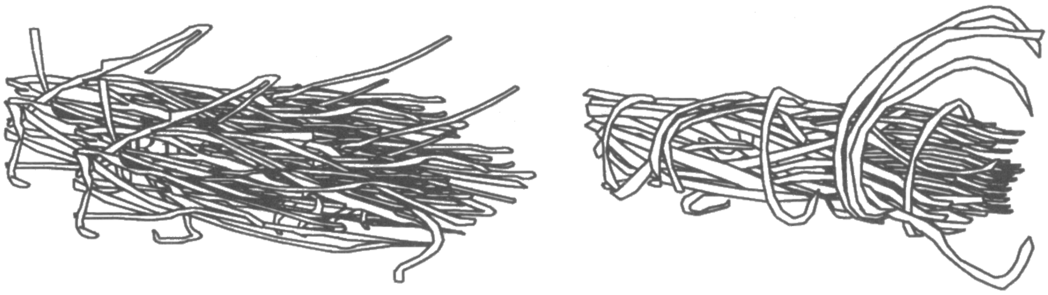
(7) During the fabric formation at knitting or weaving less fibres are abraded off the rotor yarn as compared to the ring spun yarn.

(8) The dyeability of the rotor spun yarn is better than the ring spun yarns.

Disadvantages of Rotor Spinning

(1) Although many developments are carried out in rotor spinning even now rotor spinning can not produce finer yarns otherwise easily possible to produce with ring spinning

(2) The presence of wrapping fibres in the rotor spun yarn gives it a harsher and hairier look.



Ring yarn Rotor yarn

(3) The rotor spun yarns have high pilling property as compared to ring spun yarn.

(4) The strength of the rotor spun yarn is less than that of the ring spun yarn (about 70% of the ring spun yarn).

(5) The rotor spun yarn causes more wear of knitting needles and loom components as compared to the ring spun yarn.

(6) The rotor spinning process is more complicated as compared to ring spinning and the know how of operation and maintenance is less as compared to ring spinning which is widely accepted and universal form of spinning.

(7) As far different varieties of yarns that can be produced, the rotor spinning system is a less flexible system as compared to ring spinning system.

(8) Rotor spinning system can not be employed for woollen and worsted fibres.

THE AIR JET SPINNING PROCESS

The air jet spinning technique was introduced in early 1980s as an excellent alternate to the ring spinning. The early design of such machine was capable of producing yarn at a production rate of about 160 meters per minute as compared to the ring spinning frame where the productivity ranges up to 15 to 20 meters per minute making it 8 to 10 times faster than the conventional ring spinning process. With new developments and better nozzle designs it is now possible to produce air jet spun yarns at production rates of up to 350 metres per minute making it about 20 times faster than ring spinning.

The air jet spinning is not only extremely fast but also produces extremely uniform yarns as compared to ring or rotor spinning. Furthermore the air jet spinning can produce much finer yarns as compared to the rotor spinning. The main disadvantage of air jet spinning is that so far effective spinning is restricted to 100% synthetic fibres or blends of synthetics with cotton. 100% pure cotton can only be processed in combed form. However even then the yarn produced has low strength as compared to the ring spun yarns. Another problem of spinning with cotton fibres is dust and dirt. The air nozzle of the air jet spinning system is sensitive to any dirt and dust present in the fibres and creates clogging and choking problems of the nozzle. At the moment cotton air jet yarns are only possible to spin from high quality longer, finer and cleanest fibres.

Another disadvantage of the air jet spinning is its inability to spin coarse counts of yarns because of its air jet spinning technique. The general range of counts that a air jet spinning system can produce ranges from 15 to 60 Nc. So yarn counts coarser than 15 Nc are not possible to spin using this technique.

Functions of Air Jet Spinning Process

(1) **Drafting**, the classical roller drafting technique is used for drafting under extreme controlled conditions to give a draft that ranges from 100 to 200. The older version of air jet spinning machines used to have 3 over 3 roller drafting arrangement with double apron control system. However the latest machines are based on 4 over 4 roller drafting arrangement again with the double apron system. The input material in case of processing synthetic fibres is given in form of a drawn sliver passed usually through three draw frame passages. However cotton fibres must be processed in controlled conditions and is usually carried out for high quality of fibres in the combed form.

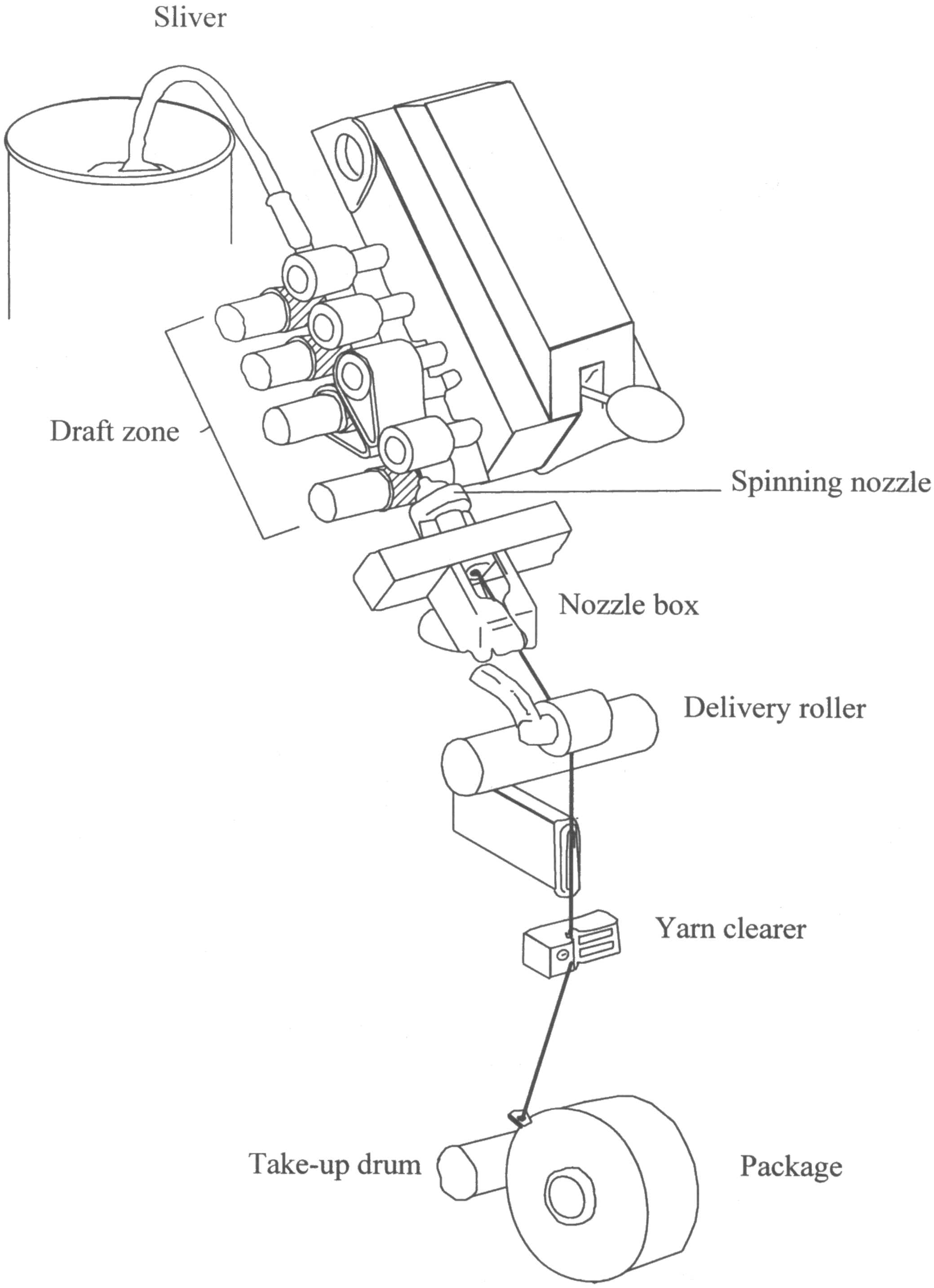
(2) **Twisting,** the main unique feature of the air jet spinning machine is the special twist imparting technique employed. False twisting is applied to the drafted fibre material with the help of nozzles that generates powerful air pressure to fibres to convert them into a yarn.

(3) **Winding**, the winding of the yarn takes place either in the form of a tapered packages (cones) or parallel packages (cheeses). At winding, yarn clearing and automatic piecing devices are also provided to automatically remove the spinning faults i.e. the thick and thin places and to piece the broken thread together.

Typically the air jet spinning machine is divided into four distinct working regions or zones.

(1) Creel Zone
(2) Draft Zone
(3) Nozzle Zone
(4) Winding Zone

A working illustration of a modern air jet spinning machine (Murata MJS 802) is given below:



(1) Creel Zone

The air jet spinning machines usually have 40 to 60 spinning positions. So the creel portion of the machine can hold these quantities of drawn sliver cans. Usually drawn sliver which has been passed through three passages of the draw frame is preferred as input material to have adequate fibre parallelization necessary for air jet spinning. The sliver coming from the creel portion passes over stationary creel rods usually made of plastic and is directed into the drafting arrangement.

(2) **Draft Zone**

The earlier version of air jet spinning machines, 3 over 3 roller drafting was used. However the latest air jet machines utilizes 4 over 4 roller drafting to achieve better and higher draft distribution. Conventionally the drafting rollers are numbered from front to back. So the front rollers would be pair # 1 and the back rollers, pair # 4. The in-feed sliver is directed to the back pair of rollers with the help of a special condenser or trumpet guide placed before it. All the top rollers are covered with special synthetic rubber coating while the bottom rollers are steel fluted. The top rollers are pressed against the bottom rollers with considerable nip pressure. The second pair of rollers are covered with double aprons to have a better control over the fibres during drafting and to suppress the drafting waves. Both the aprons used are short. Another trumpet guide or condenser is used in between the second and third pair of rollers to avoid fibre strand being torn apart during drafting.

The roller settings (spacing), cot pressure, apron height, apron spacing, apron pressure and condenser size within each draft zone can be adjusted to vary the yarn characteristics. Such a roller drafting arrangement permits drafts of 50 to 200 depending upon the required yarn fineness. However drafts of above 170 tend to create thin places in the yarn.

The 4 over 4 drafting has three draft zones namely break or back draft zone (between 4^{th} and 3^{rd} rollers), intermediate or middle draft zone (between 3^{rd} and 2^{nd} rollers) and the front or main draft zone (between 2^{nd} and 1^{st} rollers). Usually break draft in majority of the air jet spinning machines is kept fixed at 2. The suitable draft in the main zone is selected and the leftover draft is given in the intermediate zone. Since the total draft is a product of all individual drafts so mathematically:

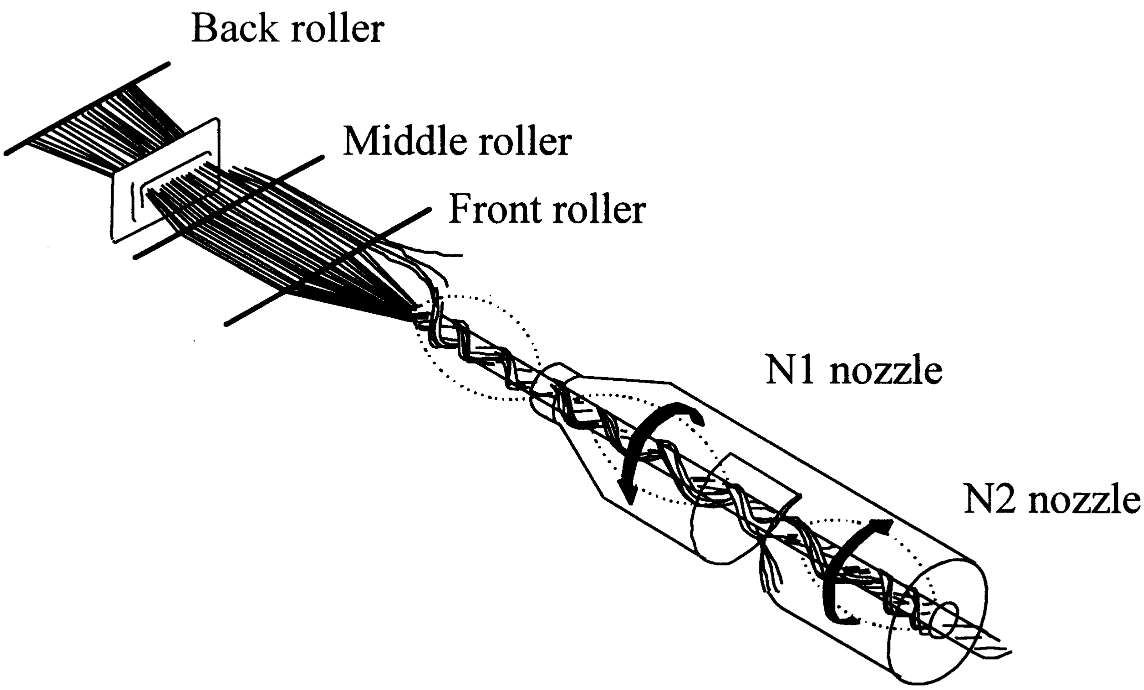
Total Draft = 2 x Intermediate Draft x Main Draft

The value of main draft chosen should be such that the intermediate draft may not fall below 1.15 otherwise spinning stability will be affected.

The linear density of the sliver after passing through the drafting rollers reduces considerably but the fibres are not separated from one another. The advantage of fibres not been individually opened up is that it is not necessary to recollect them as in the case of rotor spinning. However the disadvantage is that no back doubling occurs. This highly attenuated fibre strand is then passed through the spinning nozzle where false twist is imparted using power air generated by the nozzles.

(3) **Nozzle Zone**

In the nozzle zone sometimes one or two nozzles (varies from manufacturer to manufacturer) are used to impart the false twist to the attenuated fibre strand to produce a yarn. A typical two-nozzle arrangement is shown below:



Two nozzles (N1) and (N2) are used as depicted from the above illustration. The second nozzle (N2) is actually the false twisting element. The air pressure generated by the nozzle is so high that an air vortex rotates the air at a rate of 1 to 2 million revolutions per minute. Due to this high air vortex, false twist is inserted into the yarn that goes back to the nip of the front pair of drafting rollers. The other nozzle (N1) provides lower air flow but in opposite direction to that generated by nozzle (N2), causing the fibres in the spinning triangle to break free. These separated fibres are twisted in the direction of airflow produced by nozzle (N1). As the yarn exits the second nozzle the false twist is removed and the core fibres become aligned with the axis of sliver. But the fibres that were separated remain twisted around the core and are called as binding fibres. The untwisting of the core fibres cause the fibre strand to expand in size thus tightens the binding fibres. The important settings that can be altered in the nozzle zone are:

(1) Nozzles pressure.
(2) Shape of nozzles used.
(3) Distance between nozzle and front drafting rollers.

As the pressure of nozzle (N1) is increased, the percentage of binding fibres increases. This usually increases the yarn strength but the yarn becomes harsher. The increase in the pressure of nozzle (N2) causes the false twist to increase and ultimately the contraction and tightening of binding fibres at the exit of nozzle (N2) increases. This causes the breakage of binding fibres and ultimately the yarn hairiness increases.
By changing the shape of the nozzles the air vortex generated by it changes.

This helps to control the yarn characteristics like hairiness and bulk. The nozzles are made in various designs to achieve different yarn handle and character.

The distance between the nozzles and the front pair of drafting rollers control the evenness of the yarn. With more distance since the air pressure spreads out and the twist effect of the air reduces, the evenness of the yarn produced decreases. The spacing between the nozzle and front roller nip is also dependent on the yarn count. For coarser yarns in order to avoid choking of the nozzles, the distance is kept slightly more as compared when fine yarns are spun.

(4) Winding Zone

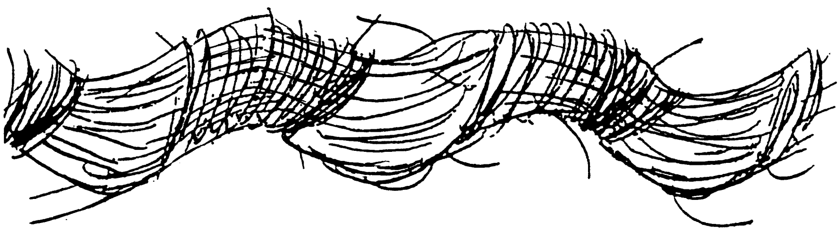
The yarn coming from the spinning nozzle is drawn off using a pair of take-up rollers or delivery rollers and is wound on large packages that can be directly used in knitting or weaving. The passage of the yarn also includes an electronic clearer that helps to remove spinning faults to produce a fault free package.

The package is usually driven indirectly by frictional contact of a driving drum. A traversing guide is also used to wind the yarn on the entire length of the package. However the traversing guide is not used in case grooved driving drum is used. The compactness of the package produced mainly depends upon the winding tension. A winding tension originates due to the fact that the surface speed of the yarn at the package is kept slightly higher than that at the delivery roller. Greater the winding tension, more compact package can be produced and vice versa.

The air jet spinning machines are either provided with automatic knotting or splicing units to automatically piece up the broken ends of the yarns. Knotting creates a stronger but bigger and more visible piecing whereas splicing creates a smaller, less visible but weaker joint.

Structure of Air Jet Yarn

Due the separation and wrapping of the binding fibres around the core yarn, the structure of the air jet yarn is flattened and wavy. The air jet yarn has central core made of mostly parallel fibres wrapped by the binding fibres as shown below:



The waviness in the yarn structure is mainly because of the contraction of the false twist and tightening of the binding fibres as the yarn exits the nozzles. This waviness makes the air jet yarn most suitable for weaving filling yarn (weft) because it can be propelled at greater speeds without breaking it. Greater the binding fibres present in the yarn strength increases but is also makes the yarn harsher. As the binding fibres are reduced the yarn becomes softer. Unlike the wrapper fibres of the rotor yarn, the binding fibres of air jet yarn should not be reduced considerably as they contribute towards the yarn strength.

Advantages of Air Jet Spinning

(1) The biggest advantage of the air jet spinning is its ability of producing yarn at high rates that can go up to 20 times more than that of the ring spun yarn.

(2) Because of lack of twist in the air jet yarn, it gives very low pilling property in the fabric.

(3) Air jet spun yarns are the most suitable yarns to be used for weaving filling yarn due to its wavy structure. This enables higher weft insertion rates on the loom during weaving.

(4) Air jet yarns have high degree of evenness

(5) The air jet spinning technique produces less spinning faults specially thin places.

(6) The air jet spinning process like the rotor spinning and unlike the ring spinning is fully automated system.

(7) Due to low levels of twist, the dye-ability of air jet yarns is much better as compared to ring spun yarn.

(8) During high speed fabric formation i.e. knitting and weaving the fibre shedding off the surface of the yarn is low as compared to the ring spun yarn.

(9) The process of roving and winding/clearing is not required and large fault free packages can be directly produced which is not possible at ring spinning due to limited ring/traveller arrangement.

Disadvantages of Air Jet Spinning

(1) Air jet spinning is mainly employed for producing synthetic and blended fibres. Cotton yarns can only be spun using this technique only in combed form under ideal conditions.

(2) Air jet spinning process can produce yarn counts of range 15 to 60 Nc. Yarn counts both finer and coarser than this range is not possible to produce.

(3) The lack of twist makes the air jet spun yarn 25 to 30% weaker than the ring spun yarn.

(4) The presence of binding fibres in the air jet yarn makes it much harsher as compared to the ring spun yarns.

(5) The fabric produced out of air jet yarns shrink more as compared to ring spun yarn because of the low twist levels.

Further Reading References

Yarn Definitions, Classification & Yarn Properties

- Eurotex – Introduction to Textiles (Volume 2) Pages 1 - 11
  By T.Rowe, K.P. Busby and others

- Textile Institute Short Staple Spinning Series (Volume 1) Pages 1 - 9
  By W. Klein

Principles of Short Staple Spinning

- Eurotex – Introduction to Textiles (Volume 2) Pages 13 - 18
  By T.Rowe, K.P. Busby and others

- Textile Institute Short Staple Spinning Series (Volume 1) Pages 10 - 24
  By W. Klein

- Short Staple Yarn Manufacturing Pages 17 - 54
  By McCreight, Feil and others

The Opening Room or Blow Room

- Eurotex – Introduction to Textiles (Volume 2) Pages 21 - 27
  By T.Rowe, K.P. Busby and others

- Textile Institute Short Staple Spinning Series (Volume 2) Pages 1 - 32
  By W. Klein

- Short Staple Yarn Manufacturing Pages 61 - 122
  By McCreight, Feil and others

The Carding Process

- Eurotex – Introduction to Textiles (Volume 2) Pages 28 - 33
  By T.Rowe, K.P. Busby and others

- Textile Institute Short Staple Spinning Series (Volume 2) Pages 33 - 58
  By W. Klein

- Short Staple Yarn Manufacturing Pages 123 - 178
  By McCreight, Feil and others

The Combing Process

- Eurotex – Introduction to Textiles (Volume 2) Pages 44 - 49
  By T.Rowe, K.P. Busby and others

- Textile Institute Short Staple Spinning Series (Volume 3) Pages 1 - 28
  By W. Klein

- Short Staple Yarn Manufacturing — Pages 209 - 236
  By McCreight, Feil and others

The Drawing Process

- Eurotex – Introduction to Textiles (Volume 2) — Pages 34 - 43
  By T.Rowe, K.P. Busby and others
- Textile Institute Short Staple Spinning Series (Volume 3) — Pages 29 - 40
  By W. Klein
- Short Staple Yarn Manufacturing — Pages 179 - 208
  By McCreight, Feil and others

The Roving Process

- Eurotex – Introduction to Textiles (Volume 2) — Pages 50 - 54
  By T.Rowe, K.P. Busby and others
- Textile Institute Short Staple Spinning Series (Volume 3) — Pages 41 - 59
  By W. Klein
- Short Staple Yarn Manufacturing — Pages 237 - 259
  By McCreight, Feil and others

The Ring Spinning Process

- Eurotex – Introduction to Textiles (Volume 2) — Pages 55 - 58
  By T.Rowe, K.P. Busby and others
- Textile Institute Short Staple Spinning Series (Volume 4) — Pages 1 - 46
  By W. Klein
- Short Staple Yarn Manufacturing — Pages 259 - 301
  By McCreight, Feil and others

The Winding & Clearing Process

- Short Staple Yarn Manufacturing — Pages 302 - 310
  By McCreight, Feil and others

- Weaving: Conversion of yarn to fabric — Pages 32 - 84
  By P.R. Lord & M.H. Mohammaed

The Rotor Spinning Process

- Eurotex – Introduction to Textiles (Volume 2) — Pages 59 - 62
  By T.Rowe, K.P. Busby and others
- Textile Institute Short Staple Spinning Series (Volume 5) — Pages 24 - 49

By W. Klein

- Short Staple Yarn Manufacturing Pages 311 - 371
  By McCreight, Feil and others

The Air Jet Spinning Process

- Textile Institute Short Staple Spinning Series (Volume 5) Pages 12 - 15
  By W. Klein

- Short Staple Yarn Manufacturing Pages 373 - 423
  By McCreight, Feil and others