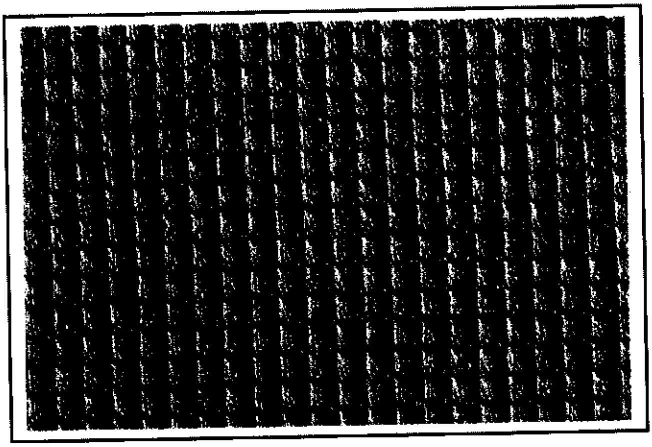
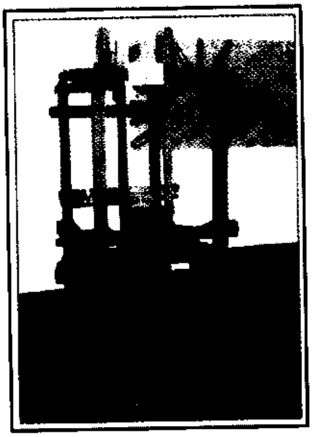
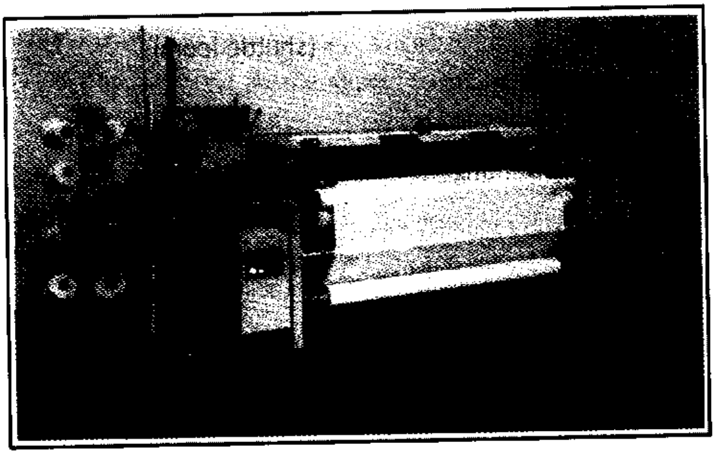


WOVEN FABRICS AND WEAVING TECHNOLOGY

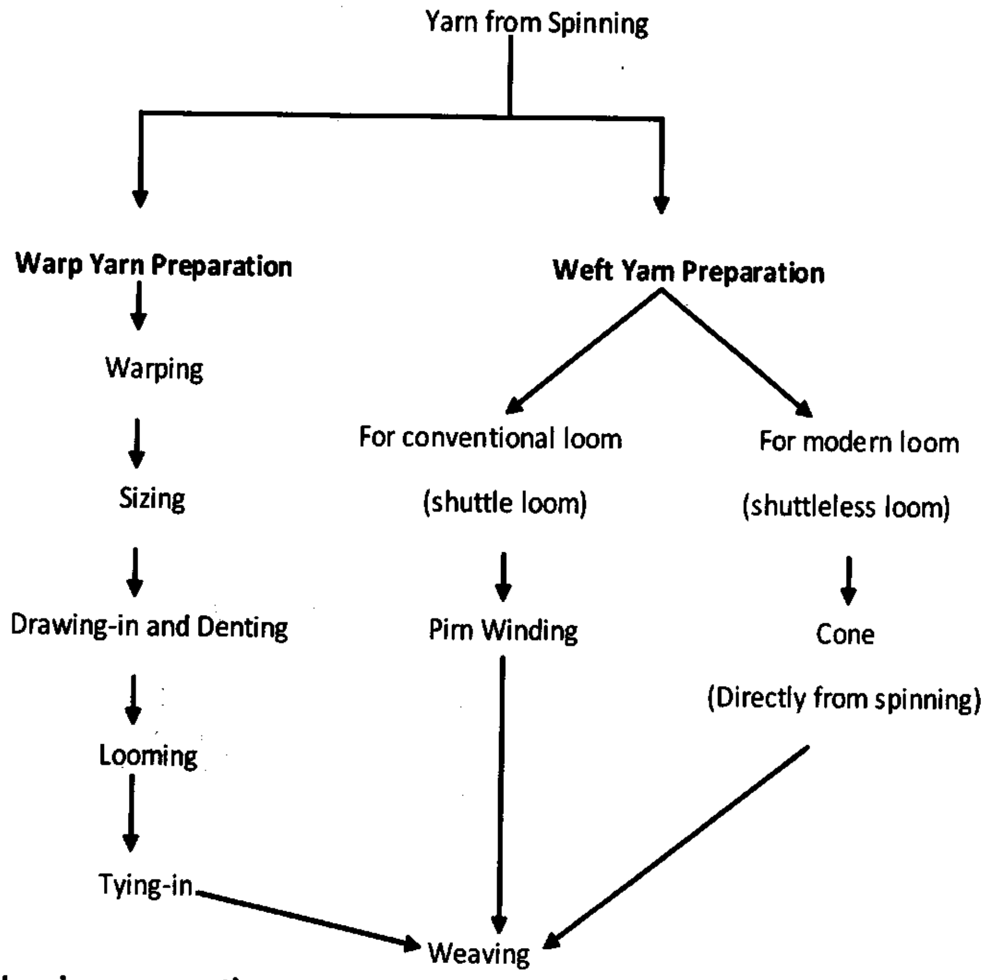




Woven Fabrics:

Woven fabrics are composed of longitudinal or warp threads and transverse or weft threads, interlaced with one another according to the class of structure and form of design that are desired.

Process Flow To Manufacturing Woven Fabric:



Weaving preparation:

Yarn is the basic building block in weaving. Therefore, after yarn manufacturing, the next successive steps would be to weave the yarn into a fabric. However, in practice, the condition of yarn produced on the spinning machine is not always good enough to be used directly for fabric formation. Package size, yarn surface characteristics, and other factors make it necessary for both weft yarn and warp yarn to be further processed for efficient fabric formation. These preparatory processes are called weaving preparation.

Warp and weft yarns are subjected to different conditions and requirements during weaving. Therefore, the preparation of warp and weft yarns is different. Warp yarn is subjected to higher stresses which requires extra preparation. The weft yarns are not subjected to the same type of stresses as the warp yarns and thus are easily prepared for the weaving process. Depending on the spinning method, the weft yarns may not be prepared at all, but rather taken straight off the spinning process and transported to the weaving process. This is the case with open-end (rotor), air-jet and friction spinning systems which provide a large single-end package suitable for insertion during weaving. However, ring spun yarns need to go through a winding process for several reasons that are explained below. The process used to prepare yarns for weaving depend on yarn type as well.

Winding is the major preparation process for weft yarn. Warp preparation includes winding, warping, sizing and drawing-in or tying-in.

Spun yarn quality characteristics that are most important for good weaving performance include short and long-term weight uniformity, imperfections, tensile properties and hairiness. It should be noted that variation in a property is almost always more important than the average value of that property. Regardless of the processes employed, a second concept of quality has to be embraced. Not only must the quality of the yarn itself be maintained and enhanced, but also the quality of yarn packages is extremely important to further processing.

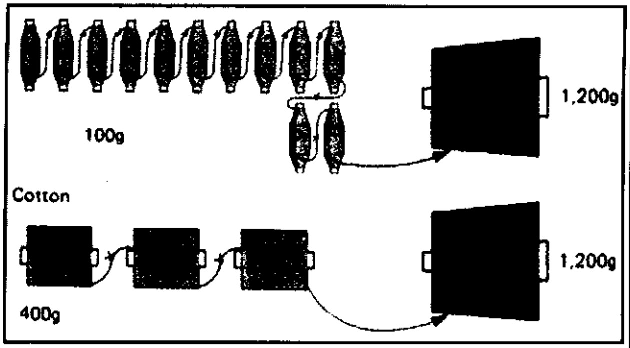
The cost of repair a yarn failure is much less if it occurs prior to the weaving process. In addition, a yarn failure during weaving also increases the chances for off quality fabric. Many if not most of the quality problems encountered during fabric forming are directly related to mistakes made during yarn manufacturing or yarn preparation for weaving.

Since winding is common for both weft and warp preparation, it will be discussed first for both yarn systems. The weaving process is particularly abusive to lengthwise yarns in a woven fabric; therefore, the technology surrounding the preparation of warp yarn for weaving is given special attention.

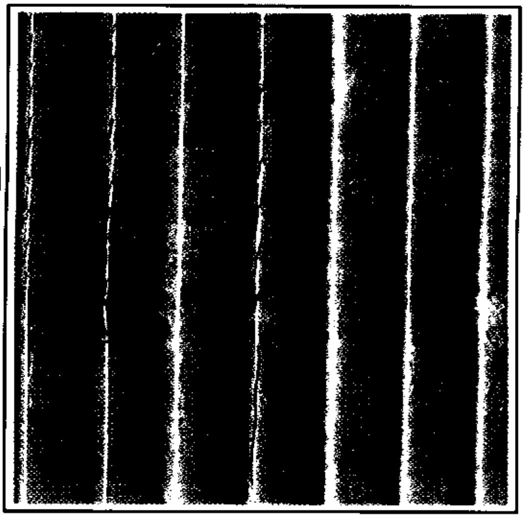
Winding:

Winding is basically transferring a yarn from one type of package to another. This simple definition may make the winding sound like a trivial process; however, it is an important and necessary process that performs the following functions especially for ring spun yarns.

- Winding produces a yarn package that is suitable for further processing. Ring spinning produces small packages of yarn (called spinner's packages or bobbins) which would be depleted relatively quick during weft insertion or warping. Therefore, the amount of yarn on several small packages is combined by splicing or knotting onto a single package. Knotting has been replaced by splicing in modern winding machines.



Building large packages



Yarn Faults

- The winding process provides an opportunity to clear yarn defects. Thin and thick places, slubs, neps or loose fibres on the yarn are cleared during winding and, thus, the overall quality of the yarn is improved. Staple yarns require this clearing operation most because they may have these kinds of faults more often.

The increasing use of newer spinning technologies resulted in a situation where the old concept of yarn clearing and package quality now has become a part of the spinning process rather than part of a separate winding process. Properly formed packages of defect-free spun yarn are an even more critical factor. Package considerations include condition of the package core, the proper provision of yarn transfer tails; properly formed splices or knots; elimination of internal defects such as slubs, sloughs, tangles, wild yarn, scuffs and ribbon wind; and elimination of external defects such as over-end winding, cobwebs, abrasion scuffs, poor package shape or build, proper density (hardness) and unwindability.

Winding Process:

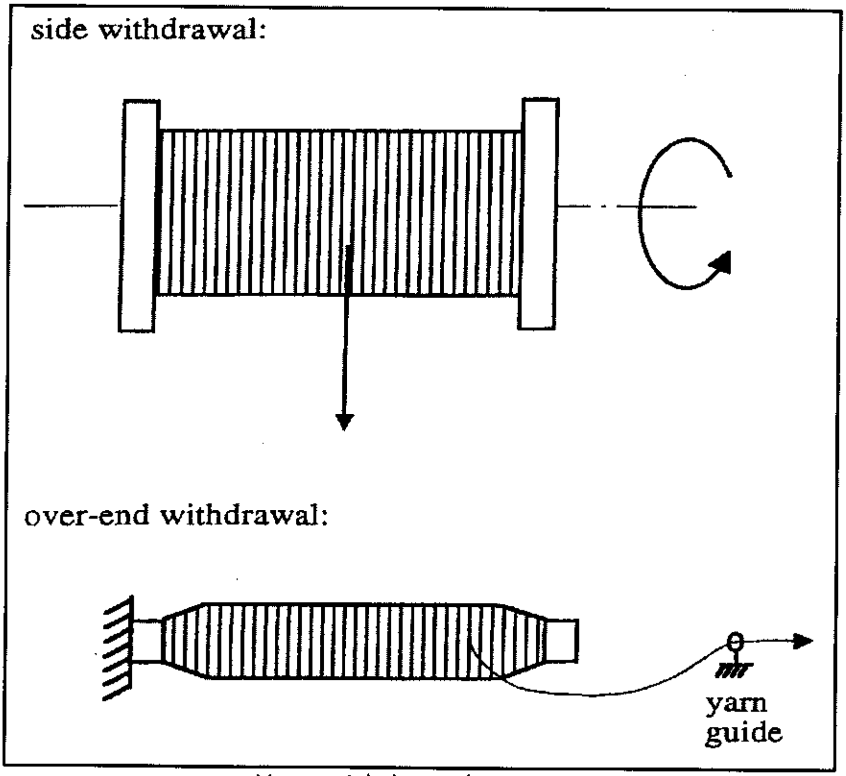
There are three main regions in winding; those are shown in the following figure.

a) Region 1:

Unwinding of yarn from the spinning package – The yarn package is held in the creel in an optimum position for unwinding. Yarn withdrawal can be done in two ways:

- **Side withdrawal:** In this method the spool is rotated and therefore the yarn does not rotate during withdrawal. As a result, the yarn twist does not change, which is an advantage.

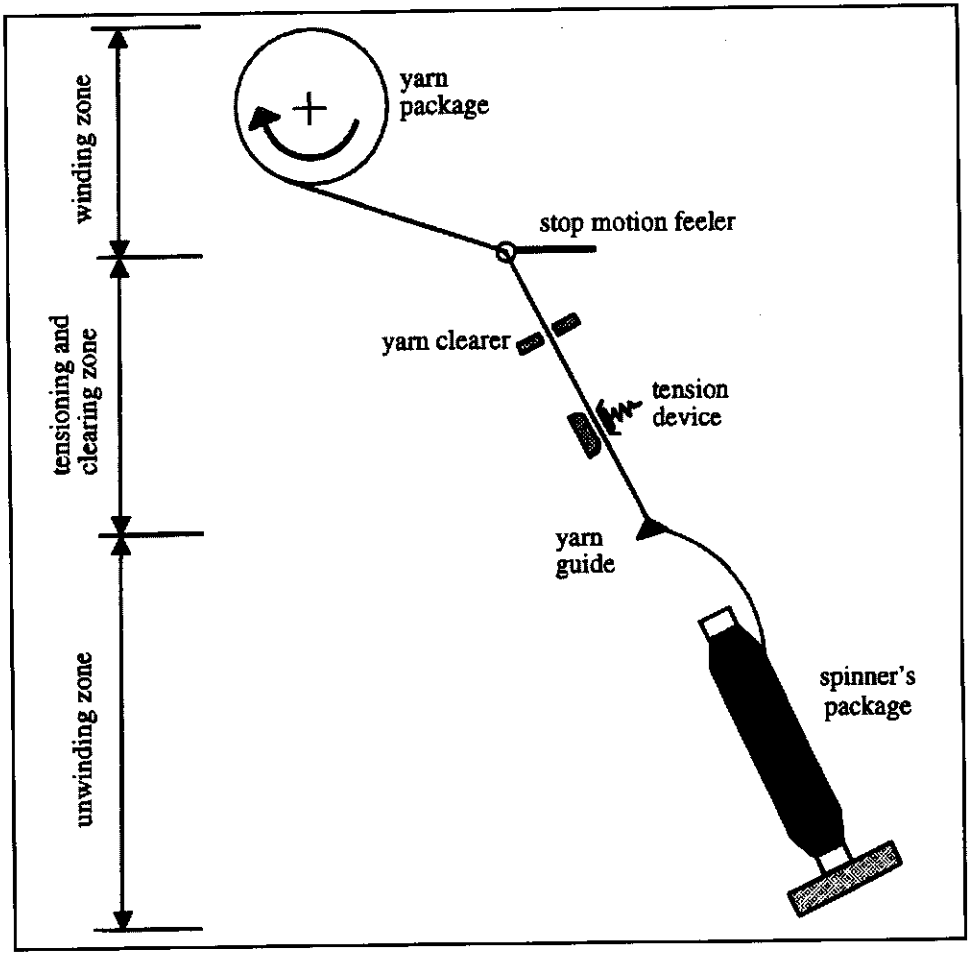
Since the yarn does not rotate, the spool must rotate for side withdrawal. This requires additional energy and equipment, which is a disadvantage. At high winding speeds, due to inertia, the rotation of the spool can cause yarn tension variations. Upon start-up, higher tensions may be developed because the winder must overcome spool inertia.



Yarn withdrawal system

- **Over-end withdrawal:** In this system, the spool does not rotate. Therefore, the problems associated with rotating a spool are avoided. The method is simple and does not require driving the spool.

The disadvantage of this system is ballooning which is due to the way the yarn is withdrawn and unwound from the package at high speeds. Centrifugal force causes the yarn to follow a curved path leading to ballooning upon rotation of the yarn. Ballooning leads to uneven tensions in the yarn. Each time one complete wrap of yarn is removed from the supply package, the twist in that length changes by one turn. This change may be insignificant for regular round yarns, but in cases where flat yarns of metal, polymer or rubber are used, even one twist is not allowed since yarns must remain flat. These yarns cannot be unwound using the over-end method; therefore, the side withdrawal method must be used.

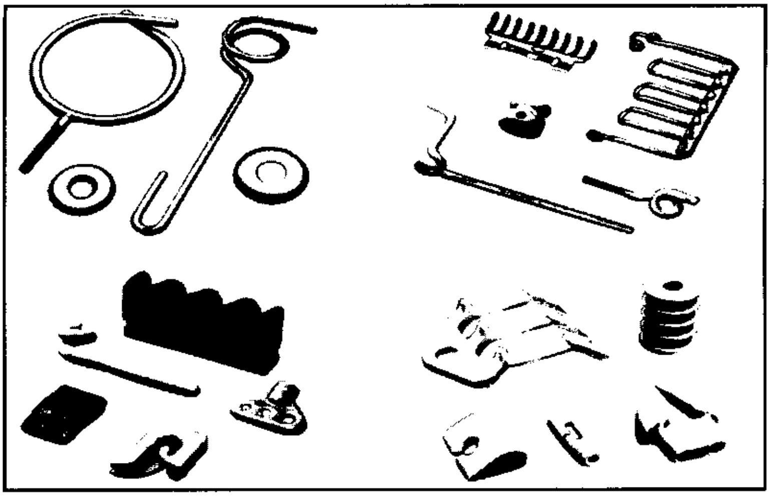


Schematic of winding process

b) Region 2:

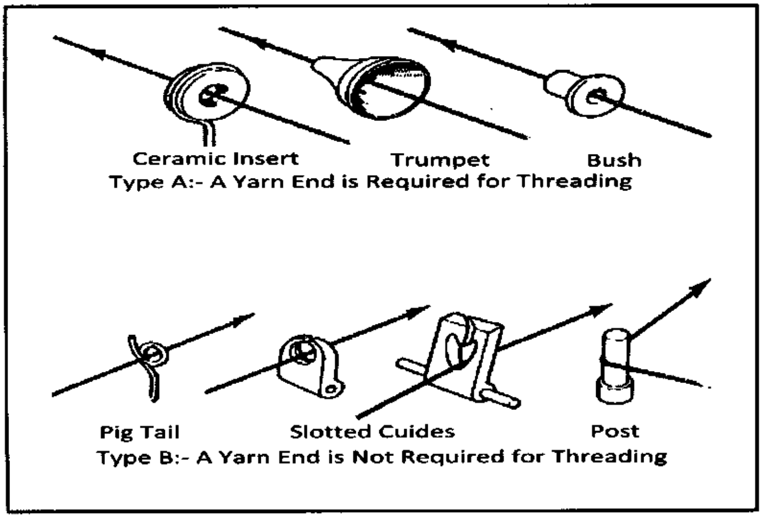
The tensioning and clearing region – In this region, proper tension is given to the yarn for a desired package density and body. The typical components of this region are a tension device, a device to detect thick and thin spots in the yarn (clearing device) and a stop motion. The stop motion causes the winding to stop in case of yarn breakage or the depletion of a supply package. The yarn is directed into this region by a guide.

There are two types of guides: closed and open. Closed guides require a yarn end to thread, and open guides do not. Open guides, however, give less positive guiding. Engineering issues here are guide smoothness, abrasion between yarn and guide causing yarn damage. If the guide is too rough, damage of yarn due to abrasion will occur. On the other hand, if the guide is too smooth, friction may develop. Guides are usually made from hard stainless steels or from ceramics.



Various types of yarn guides: top left – wire hard chromed, top right – plasma ceramic coated, bottom right – alumina sintered, bottom left – hard porcelain.

Wire guides are easier to manufacture to any shape. The chromium layer can be satin finished or mirror polished depending on the need. Ceramic-coated metal guides are especially good for synthetic fibres. These guides combine wear resistance of ceramic compounds with ductility of metals while allowing complex shapes to be made. As a result, there is no need for inserts, clamps or gluing. Alumina sintered yarn guides with mat surfaces are recommended for synthetic and mixed yarns (nylon, polyester, etc.) while alumina sintered yarn guides with polished surfaces or ground polished surfaces are generally used for natural fibres (silk, wool, cotton, etc.). Porcelain yarn guides are produced with mat or mirror glazes. They are resistant to wear of natural or synthetic fibres and yarns.



Types of yarn guide

Tension Device:

The tension device maintains a proper tension in the yarn to achieve a uniform package density. It also serves as a detector for excessively weak spots in the yarn that break under the added tension induced by the tension device.

There are three major types of tension devices; those are shown in the following figure.

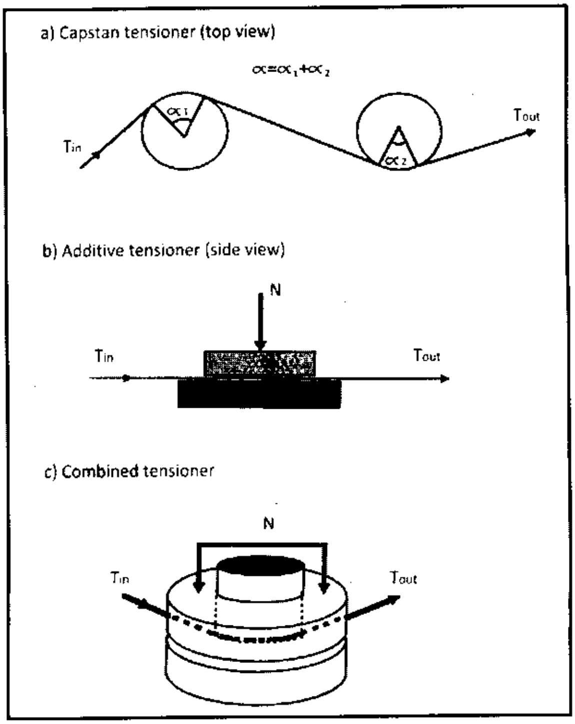
- **Capstan (or multiplicative):**

The output tension depends on the input tension, coefficient of friction between the yarn and the post (μ), and the total angle of warp (α):

$$T_{out} = T_{in}\, e^{\mu\alpha}$$

Since μ, α and e are constants, T_{out} is a constant multiple of the incoming tension T_{in} (this is the reason why Capstan is called multiplicative). If T_{in} is zero, so is the T_{out}.

Changing μ, α, the number of guides and/or T_{in} changes the output tension. μ can be changed by changing the post material or yarn surface characteristics.



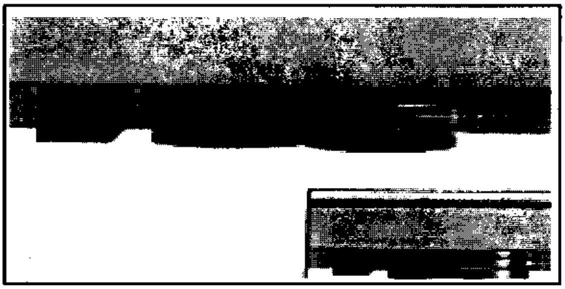
Principles of basic tensioning devices

- ***Additive tensioner:***

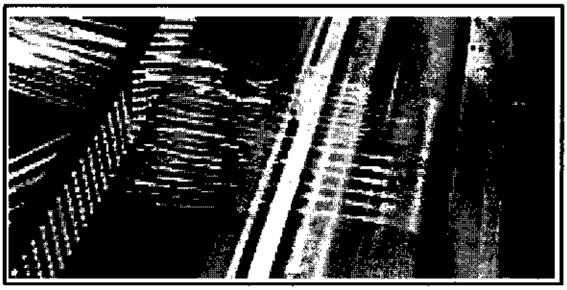
In this system, a dead weight or spring is used to apply a normal force (N) to change the tension. The output tension is calculated by:

$$T_{out} = T_{in} + 2\mu N$$

Since μ and N are approximately constants for a given system, T_{out} is obtained by simply adding a constant to T_{in}. If T_{in} is zero, there is still an output tension $T_{out} = 2\mu N$. T_{out} may be changed simply by changing the normal force N.

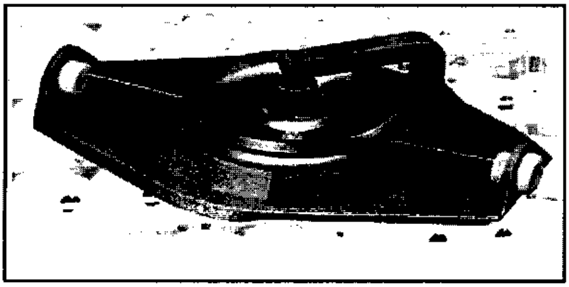


Roller tensioner



Tension roller unit

Capstan tensioner (for fine yarn)



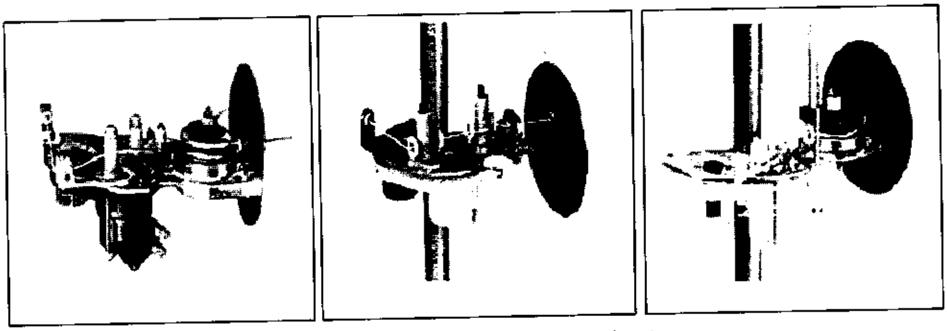
Disc tensioner

- **Combined tensioner:**

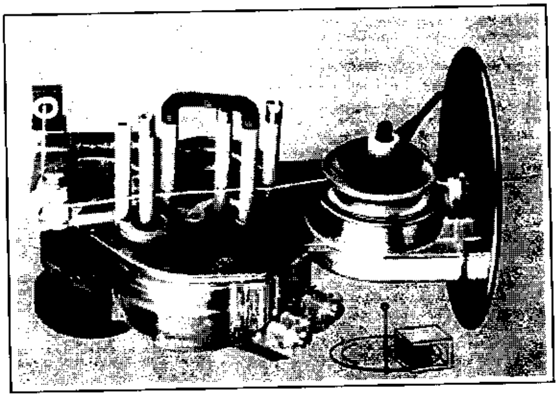
This is the most common type, which consists of atleast a disc, and Capstan type tensioner. Tension is changed by normal force and/or wrap angle.

$$T_{out} = T_{in} + T_{in}\, e^{\mu\alpha} + 2\mu N$$

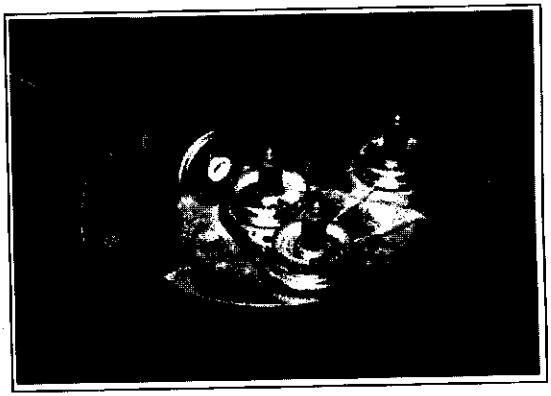
$$= T_{in}\,(1 + e^{\mu\alpha}) + 2\mu N$$



Various yarn tensioning devices



Compensating yarn tension regulator



Post and Disc tension devices

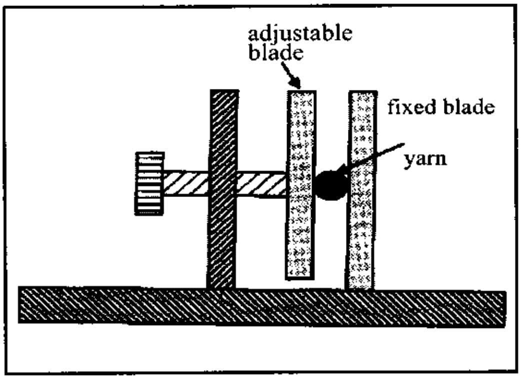
Yarn Clearers:

The purpose of a yarn detector is to remove thin and thick places. Yarn detectors are usually two types: mechanical and electronic.

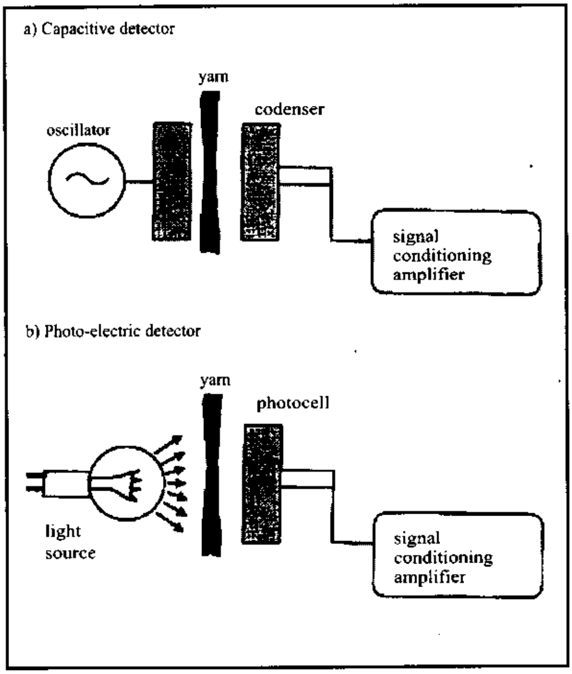
A mechanical clearer may be as simple as two parallel blades. The distance between the plates is adjustable to allow only a predetermined yarn diameter to pass through. A thicker spot on the yarn (slub) will cause the tension on the yarn to build up and eventually break the yarn. Consequently, this type of device can only detect thick places in the yarn.

The clearers of today's technology are more sophisticated and contain electronics which continuously monitor the yarn to detect thin and thick places. Electronic detectors are mainly two types: capacitive and photo-electric. In a capacitive type detector, the variation in the mass of the yarn passing through the plates changes the capacitance of the unit. It should be emphasized that the system measures the mass of the yarn. The signal is not based on the physical dimensions of the yarn. When the generated signal reaches a certain value, the yarn is cut.

In a photo-electric detector, the yarn passes between a light source and a photocell. Any fluctuation in yarn thickness causes the fluctuation of light coming to the photocell, which changes the resistance of the photocell. This resistance change is detected by a signal conditioning amplifier which can be set to send a signal to cut the yarn and stop the winding process.



Principle of mechanical yarn clearer



Principles of electronic yarn clearers

The latest yarn clearing systems can also detect foreign fibres. These fibres are classified and eliminated during the winding process. As a result, the quality of the yarn can be improved during the winding process.

Stop Motion:

The purpose of a stop motion is to stop winding when the yarn breaks or runs out. Stop motions vary from machine to machine. In general, a mechanical stop motion consists of a counter weighted or spring loaded sensing device which is held in an inactive position if the yarn is present. Breakage or running out causes the absence of this restraining yarn and allows the sensing device to activate. Electronic stop motions simply sense the existence of the yarn without mechanical contact.

c) Region 3:

The winding region – In this region, the yarn package which is suitable for further processing is wound. Many types of package configurations can be obtained including cone, tube or cheese, dye tube or spool depending on the next stage of processing.

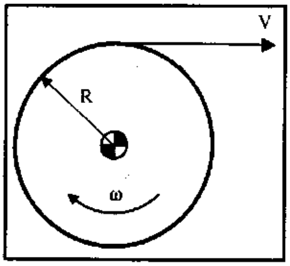
The basic requirement of winding is uniform tension on the yarn. Uniform tension is necessary for consistent winding and yarn uniformity with respect to properties that are functions of tension. If the tension on yarn passing the tension device is constant, the tension in the package should be constant provided that the yarn speed is constant, i.e., the tension on the package is only a function of the yarn speed.

The yarn is wound on the package by only rotating the package. Consider a disc of radius R, rotating at an angular velocity ω. Then, the linear velocity (or the tangential speed) of any point on the circumference of the package is:

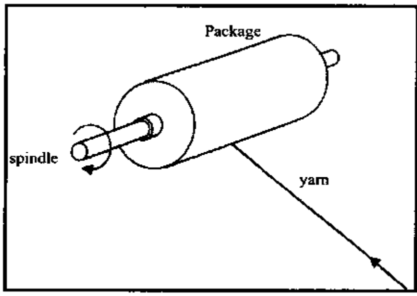
$$V = \omega R = \text{the yarn linear velocity}$$

$$\text{Therefore } V = f(\omega \text{ and } R)$$

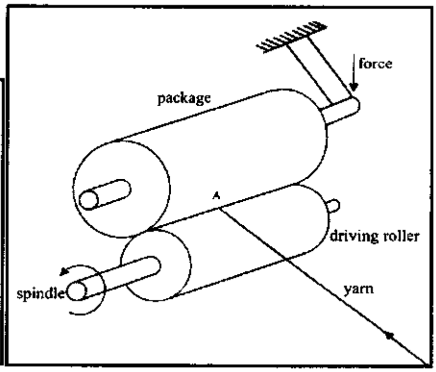
The rotation of the package may be accomplished in two ways: Spindle drive and Friction drive.



Rotating package



Spindle drive of a package



Friction drive of a package

- **Spindle drive winder:**

  In this system, the spindle, which holds the package, is driven directly. There are two variations of this system: constant speed winders and variable speed winders.

  Constant speed winders:

  The spindle is driven at a constant speed,
  i.e., ω = constant. Since $\omega = 2\pi n$, then n (rpm) is constant.

Therefore, $V = \omega R = f(R)$

As more yarn is wound on the package, R increases, hence V increases. This is not a desired situation, as explained below.

Since T = tension = $f(V)$, a change in yarn velocity causes a change in tension. Therefore, the tension will vary throughout the package. This problem can be overcome by using the second type of the spindle drive systems in which the spindle speed is varied.

Variable speed winder:

In the equation $V = \omega R$, this time ω is variable. As R increases (i.e. more yarn on the package), ω will change to keep V = constant. Although R and ω are variables, the product ωR = V = yarn velocity = constant.

Change ω, a variable speed motor or a variable speed connection is needed which increases the cost. Therefore, this system can be justified only for very delicate yarns. A simple way to achieve this is to use the second type of winder.

- **Friction drive winder:**

In this system, the spindle, that carries the package, is free to rotate and the package is driven through surface friction between the package and a driven drum or roller.

At the point of contact A (assuming no slippage), yarn, friction drum and package have the same velocity, i.e.

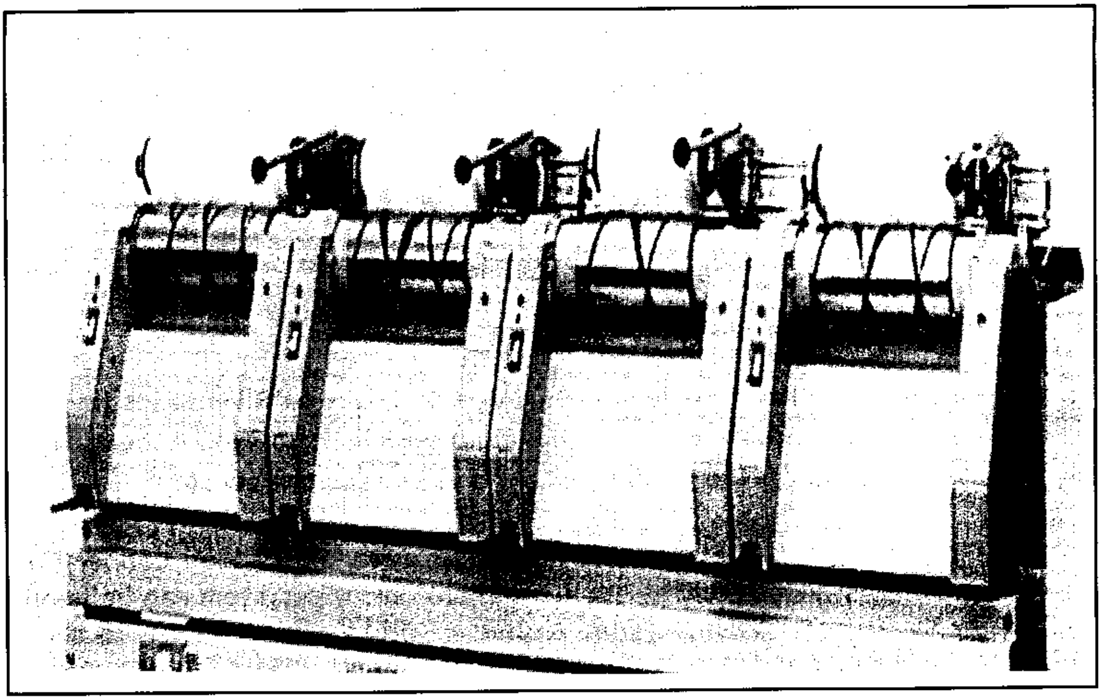
$$V_y = V_d = \omega_d R_d = \text{constant } (\omega_d, R_d \text{ are constants})$$

Thus, a constant surface speed on the package and therefore an almost constant yarn winding speed are obtained. This system is widely used for staple yarns.

Traversing Mechanisms:

A traversing mechanism is used to distribute the yarn axially along the package. The distribution of the yarn should be done evenly on the package.

In the friction drive winder (only), a traversing groove cut into the friction drum is used, which is shown in the following figure. The yarn will fit into the groove and travel back and forth along the length of the package as the drum rotates.



Typical winding machine (Grooved roller for yarn traverse)

In the spindle drive winder (also in some friction drive), a reciprocating traverse is used, i.e. an externally driven guide carries the yarn back and forth across the package.

Types of Packages:

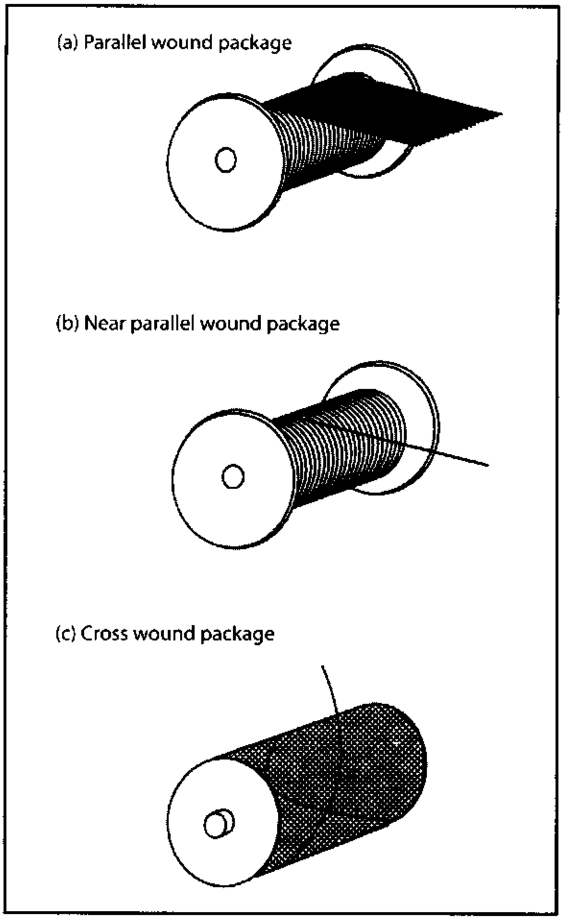
Based on the winding pattern, yarn packages can be grouped under three categories: parallel, near-parallel and cross-wound packages.

- **Parallel wound packages:**

  These packages are similar to warp beams; there are many yarns, which are parallel to each other. For these packages, flanges or shoulders are necessary to prevent yarn instabilities. The application of this type of package is limited.

- **Near-parallel packages:**

  In this type of package, there is usually one yarn end that is wound on the package. A near parallel wound package is not self-supported. Therefore, for stability, the ends of the package need tapering, flanges or shoulders.



Types of packages

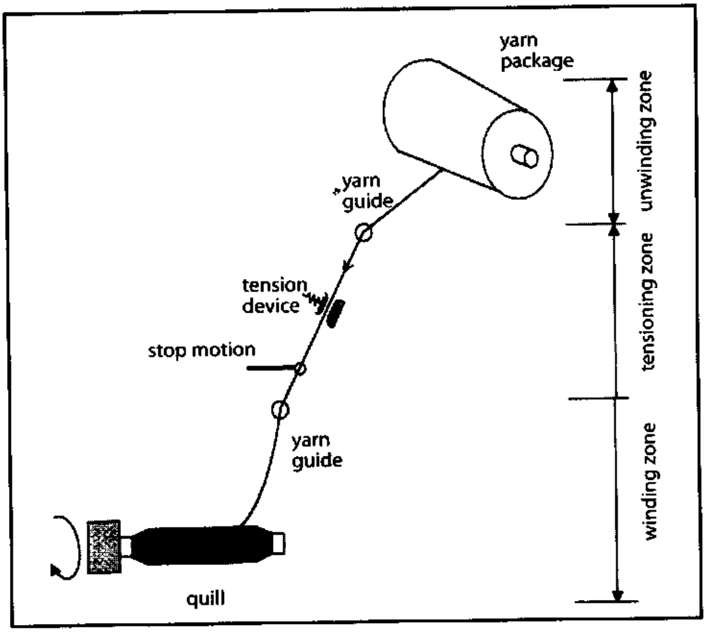
- **Cross-wound packages:**

  A single yarn end is wound on the package at a considerable helix angle, which is generally less than 80^0. This type of winding provides package stability and, therefore, there is no need to taper or flange the edges. Thus, a cone or tube could be used in the winding process.

The ratio of winding speed (V_w) and traversing speed (V_t) determines the package type for near-parallel and cross-wound packages. If V_t is very large, relatively fast successive layers of yarn will be laid at distinct angles to each other, producing a cross-wound package. If V_t is slow, successive layers will be very close to parallel to each other, producing a near parallel-wound package. Sloughing-off is a condition where many coils of yarn unwind from the package at a time. It depends on what is called a critical winding angle. The package forms can be conical or cylindrical, as required by the subsequent processes.

Pirn Winding:

A pirn or quill is a weft bobbin that is placed inside a shuttle in shuttle weaving. As the shuttle travels back and forth across the width of the shuttle loom, the weft yarn is unwound from the pirn through the eye (for ordinary shuttle) or slot (for automatic shuttle) of the shuttle and laid in the shed. The yarn on the pirn is tapered at one end such that the yarn withdrawal takes place continuously without entanglement.



Schematic of pirn winding

Winding of a pirn is different from the regular winding process. In quilling, the yarn is transferred from a larger package to the smaller pirn, which is shown in the following figure. Also, the inspection of yarn is not part of the process, therefore, there is no yarn clearing zone.

The traverse mechanism is also different because of the different geometry of the pirn. The traverse here does not go back and forth along the package. It only builds yarn on one part of the package at a time, which is shown in the following figure. Therefore, pirn building is somewhat similar to the building of a bobbin on a ring spinning frame. This type of winding helps reduce ballooning effects, maintain uniform tension, and reduce the possibility of slough-off.

The machines that are used to wind pirn are called "quillers" or pirn winding machines. These machines are automatic, which means that when the pirn is filled, it is doffed and an empty pirn is placed on the spindle automatically. With the elimination of shuttle looms, the pirn winding process is also disappearing.

Winding Machine:

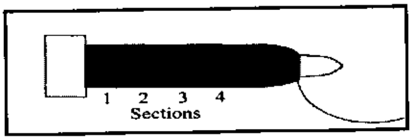
Cross winding machines are used for cross winding of tubes, cones and bobbins with one or two flanges. Yarn laying and package drive are achieved by a grooved drum. In cross-winding, the stability of the package is provided by the acute crossing angle. The package ends can be tapered as well. A near parallel winding machine with four winding positions and automatic doffing also available. The yarn traverse is controlled by a cam driven gear. Today's winding machines allow use of different size bobbins with different flange diameters, overall lengths and winding widths on the same machine. For winding of industrial yarns such as aramid, carbon or glass yarns and monofilaments, specially designed yarn guide elements are used. A spindle speed of 5000 rpm is possible.

Today yarn singeing machine with gas burners of stainless steel, traveling blower and gas / air mixing station with variable mixing ratio is also available.

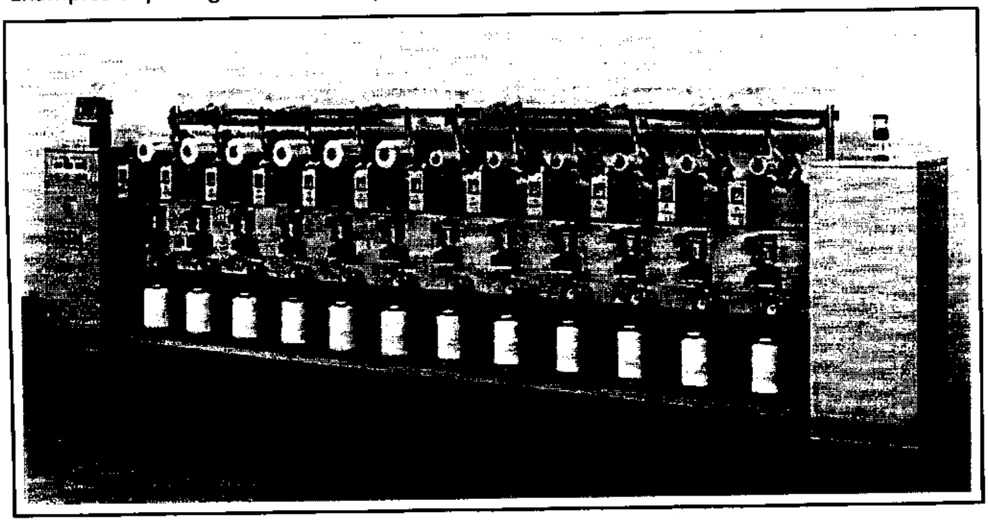
Precision Winding:

In precision winding, the position of the yarn as it is laid on the package is controlled very precisely to increase the density of the package. The following figure shows a precision winding machine. In this particular machine, the yarn positioning system is all-electronic. With the electronic system, freely programmable package building is possible, which is shown in the following figure.

Examples of packages made with precision winding



Yarn deposition on a pirn



Precision winding machine with a servomotor

Problem:

How long will it take for a winder to wind 3.00 lbs of 16 N_e yarn if the winder operates at 745 yd/min. with the efficiency 95%?

We know that,

Time, t = length / speed

$$= \frac{L}{V}$$

Here, L = Length of yarn in the package

Speed, V = 745 yd/min.

Weight of the yarn in the package, W = 3.00 lbs

Yarn count, N_e = 16

We know that, Yarn count, $N_e = \frac{L \times w}{W \times l}$

Therefore, $L = \frac{Ne \times W \times l}{w}$

$$= \frac{16 \times 3.00 \times 840}{1}$$

= 40,320 yds

$$\therefore t = \frac{40320}{745}$$

= 54.12 minutes (assuming no breaks or stops)

To consider the effect of efficiency,

Therefore, $t = \frac{54.12}{0.95}$

= 56.97 minutes.

WARP PREPARATION

The preparation of warp yarn is more demanding and complicated than that of the weft or filling yarn. Each spot in a warp yarn must undergo several thousand cycles of various stresses applied by the weaving machine. Weaving stresses include dynamic extension / contraction, rotation (twist / untwist), and clinging of hairs. Additionally, there are metal-to-yarn and yarn-to-yarn flexing and metal-to-yarn and yarn-to-yarn abrasion stresses. Modern weaving machines have placed increased demands on warp preparation due to faster weaving speeds and the use of insertion devices other than the shuttle. Warp yarn must have uniform properties with sufficient strength to withstand stress and frictional abrasion during weaving. The number of knots should be kept to a minimum. The knots should be standard type and size such that they fit through the heddle eyes and reed dents. Sizing agent must be applied uniformly on the surface of the yarn. The yarns on the warp sheet must be parallel to each other with equal tension.

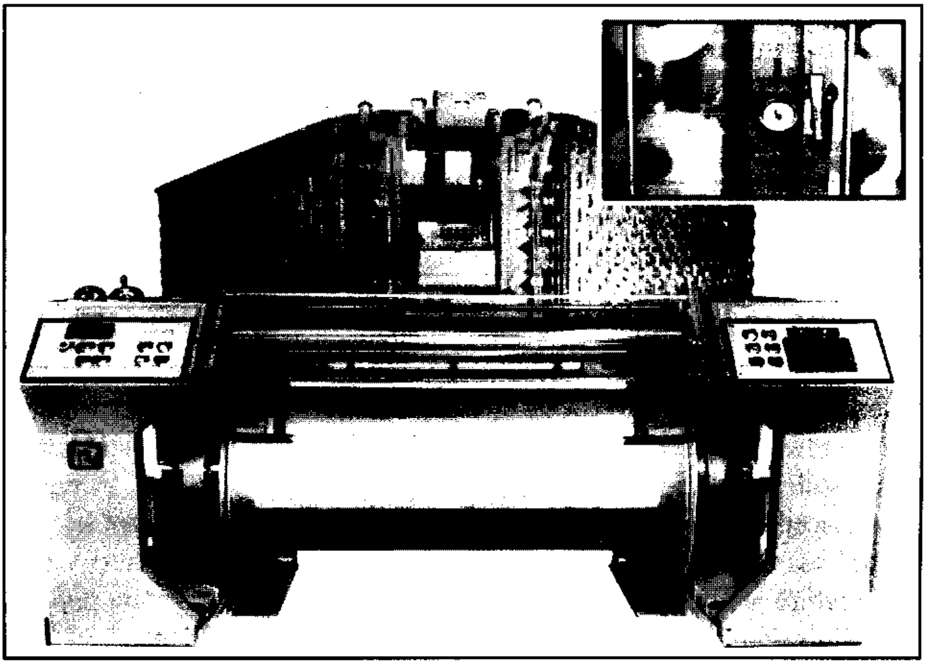
Warp preparation involves winding, warping, sizing and drawing-in or tying-in. The purpose of warp winding is to form a package of good quality yarn that is large enough to be used in the creel of a warping machine. Winding of yarn for warping is usually done at relatively high tension.

Warping:

Warping section for warp yarn preparation:

In general terms, warping is transferring many yarns from a creel of single-end packages forming a parallel sheet of yarns wound onto a beam or a section beam. Today's warping machines can process all kinds of materials including coarse and fine filament and staple yarns, monofilaments, textured and smooth yarns, silk and other synthetic yarns such as glass. Usually a static eliminator device is recommended for yarns that can generate static electricity.

The warp beam that is installed on a weaving machine is called a weaver's beam. A weaver's beam can contain several thousand ends and for different reasons it is rarely produced in one operation. There are several types of warping processes depending on the purpose. It should be noted that the warping terminology is quite different in different regions and sometimes the same term may be used to identify different processes in different regions or industries.

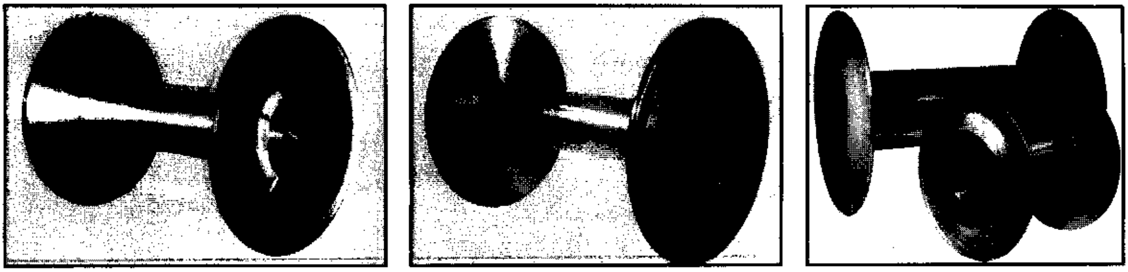


Warping is aimed at preparing the weaver's beam to be set up on the weaving machine. Warping carries out following operations:

- Creation, out of a limited number of warp threads (creel load), of a warp composed of any number of threads with the desired length;
- Arrangement of above-mentioned threads according to the desired sequence;
- Manufacturing of a warp beam with said characteristics.
- If the creeling capacity is equal or higher than the number of warp threads, the warping would simply entail the direct winding on the warp beam of the threads coming from the creel. Generally this condition does not take place and, even with creels of high capacity, the number of creeling positions never corresponds to the number of threads, which is always by far higher than the number of bobbins, which the creel can contain.
- This problem has been solved by dividing the warping operation into two phases:
- 1st phase: unwinding of the threads from the bobbins and their winding on intermediate carriers, till attainment of the required total number of warp threads;
- 2nd phase: simultaneous rewinding of all these threads and subsequent winding on the weaver's beam; the contemporaneity of these two operations is the prerequisite to produce a beam where all threads show same tension and length.

Depending on the kind of intermediate carrier used, the industrial warping process can be carried out according to two different technologies:

Sectional warping (Indirect or conical drum or dresser warping)
Beam warping or direct warping (preparatory beam warping).



Examples of Warp Beam

Direct Warping or High speed warping:

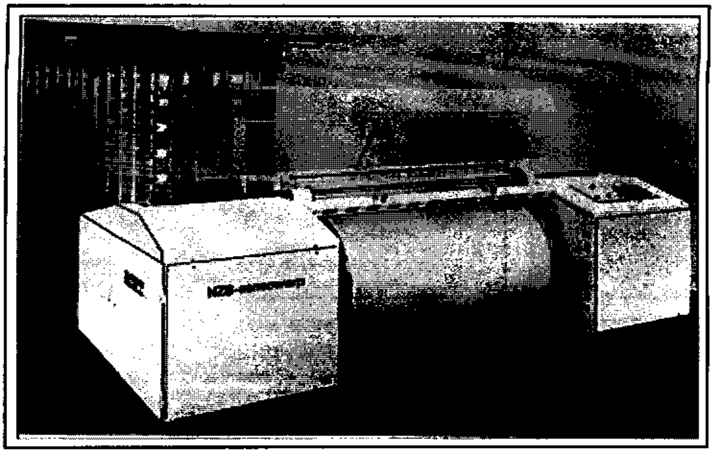
In direct warping, the yarns are withdrawn from the single-end yarn packages on the creel and directly wound on a beam.

Direct warping is used in two ways:

- I. Direct warping can be used to directly produce the weaver's beam in a single operation. This is especially suitable for strong yarns that do not require sizing such as continuous filaments or monofilaments and when the number of warp ends on the warp beam is relatively small. This is also called direct beaming.

- II. Direct warping is used to make smaller, intermediate beams called warper's beams. These smaller beams are combined later at the sizing stage to produce the weaver's beam. This process is called beaming. Therefore, for example, if the weaver's beam contains 9000 warp ends, then there would be – say – 9 warper's beams of 1000 ends each. If this weaver's beam were to be made at one stage, the creel would have to have 9000 yarn packages, which is hardly possible to manage and accommodate. Usually 8 to 10 ends per inch are recommended on section beams for sizing purposes. Beam hardness is recommended to be 50 – 60 ; hardness should be achieved with tension, not from packing roll pressure.

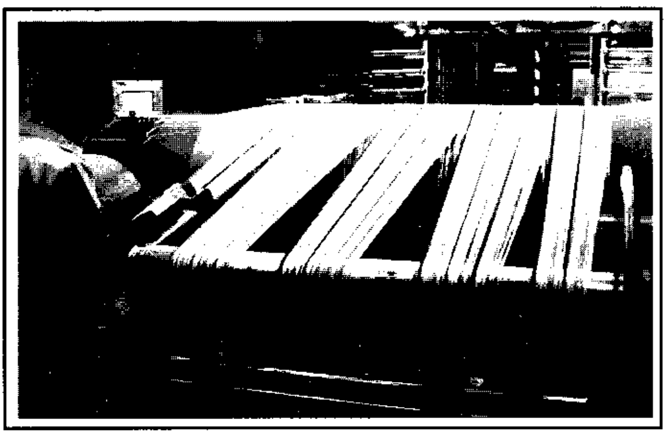
  Direct warpers are used to warp all conventional staple fibres, regenerated fibres and filaments. In direct warping, a flange beam is used. Since all the yarns are wound at the same time, the flanges provide sufficient yarn stability on the beam. The typical beam flange diameters are 800, 1000, 1250 and 1400 mm with working widths of 1400 to 2800 mm. Machine specific options include tape applicator, static eliminator, windscreen, comb blowing and dust extraction devices, yarn storage and inspection units, oiler, tension roller unit, beam removal unit and control platform. An expanding zigzag comb which is used to control the width of the beam and keep the yarns parallel and straight.



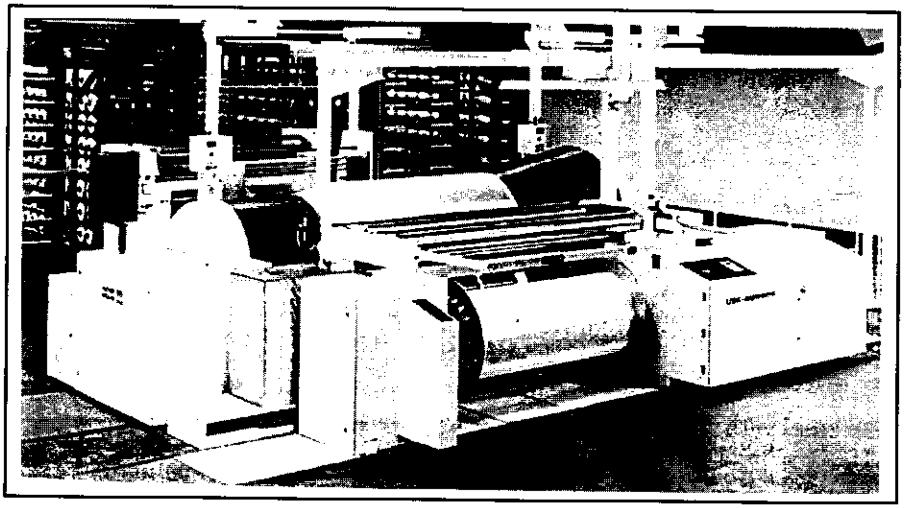
Direct or High speed warping

Indirect or Section Warping:

In indirect warping, a section beam is produced first as shown in figure. Other names used for section warping are pattern warping, band warping or drum warping. The section beam is tapered at one end. Warp yarn is wound on the beam in sections, starting with the tapered end of the beam. Each section has multiple ends that are traversed together slowly during winding along the length of the section to form the angle. Due to the geometry of the yarn sections, the last section on the beam will have a tapered end that will make the whole yarn on the beam stable. It is important that each layer on the beam contain the same number of yarns. The same length of yarn is wound on each section which is measured by a measuring roller. The warping speed can be adjusted in the range of 20 to 800 m/min; however, residual elongation will be reduced at high speeds.



After all the sections on the beam are wound completely, then the yarn on the beam is wound onto a regular beam with flanges, before sizing. This process is called beaming. Sometimes a section beam is also used in the sizing stage.



Indirect or Sectional warping

With today's computerized sectional warping systems, once the basic style information is entered, the computer automatically calculates the following:

- number of sections on the beam and width of each section
- carrier lateral movement speed and automatic positioning of each section start point
- automatic stops for leasing
- calculation of the correct feed speed irrespective of the material and warp density.

The computer can also monitor the following:

- automatic stops for predetermined length
- operating speed regulation of +/- 0.5% between warping and beaming
- beaming traverse motion
- memory of yarn breakage during warping for beaming

Other typical features of a modern sectional warper are:

- feeler roller to apply material specific pressure to obtain exact cylindrical warp buildup
- lease and sizing band magazines
- constant warp tension over the full warp width
- automatic section positioning with photo-optical section width measurement
- pneumatic stop brakes
- warp tension regulation for uniform buildup
- automatic warp beam loading, doffing and chucking

Warping Machines:

A typical warping machine has three major components: creel, headstock and control devices.

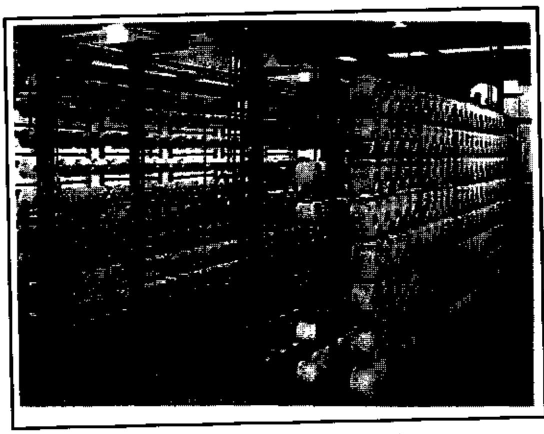
I. Creel:

There are various types of creels. The most common creel types are:

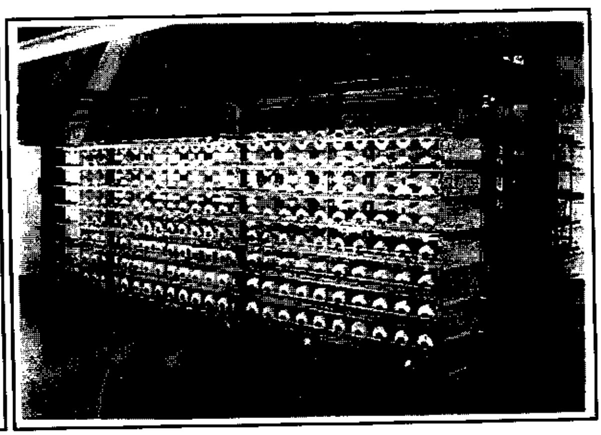
- parallel standard creel with fixed package frame (single end creel)
- parallel creel with package trucks
- parallel creel with swiveling package frame sections (for cotton, viscose, polyester/cotton, wool colored)
- parallel creel with reserve packages (magazine creel, for synthetic filaments)
- parallel creel with unrolling draw-off for polypropylene, monofilaments
- V – creel with reversible frames
- V – creel with reversible frames and automatic knotter (for cotton, viscose, polyester/cotton)
- V – creel with traveling packages.

Parallel creels are used for sectional warping and direct warping; V – creels are used for direct warping.

In single end creel, there is only one package for each warp end. Since creeling takes a considerable time, the package size should be such that a number of beams can be made from one creel. Also, usually more than one creel is used such that once a creel is depleted; the next one would be readily available to continue warping. Depending on the space requirements, this is done either by moving the headstock or by moving the creels. If the headstock is movable, then usually two creels are used which are called duplicated creels. If the headstock is fixed, again two creels will be enough but a third creel place is needed in which to move the empty creel. This is known as a truck creel or trolley creel.



Swivel Frame Creel



Trolley creel

Trolley creels are suitable for both sectional and direct warping. The creel generally has a rectangular tube construction. The trolley creels have wheels for easy maneuvering; however, they are stabilized to prevent tipping over.

In a magazine creel, usually a two-package creel is used. The tail end of the running package is attached to the leading end of the reserve package. This allows continuous warping operation. With a yarn splicer, the undesirable effects of knots can be avoided. Normally a magazine creel with two pivoting spindles: a working spindle and a reserve spindle. When one set of spindles is in operation, the empty packages are removed from the reserve set, which is then filled with new packages. The creel can be loaded from the center aisle or from the outside. They are ideal if long yarn lengths are to be unwound, if the packages do not have measured yarn lengths or if residual packages are used.

In the swivel frame creel, empty packages can be replaced on either side from the center aisle. This creel is suitable for confined spaces. A foot pedal is used to swivel the frame 180^0 to allow the empty side to be recreeled. Swivel creels can have a V shape as well.

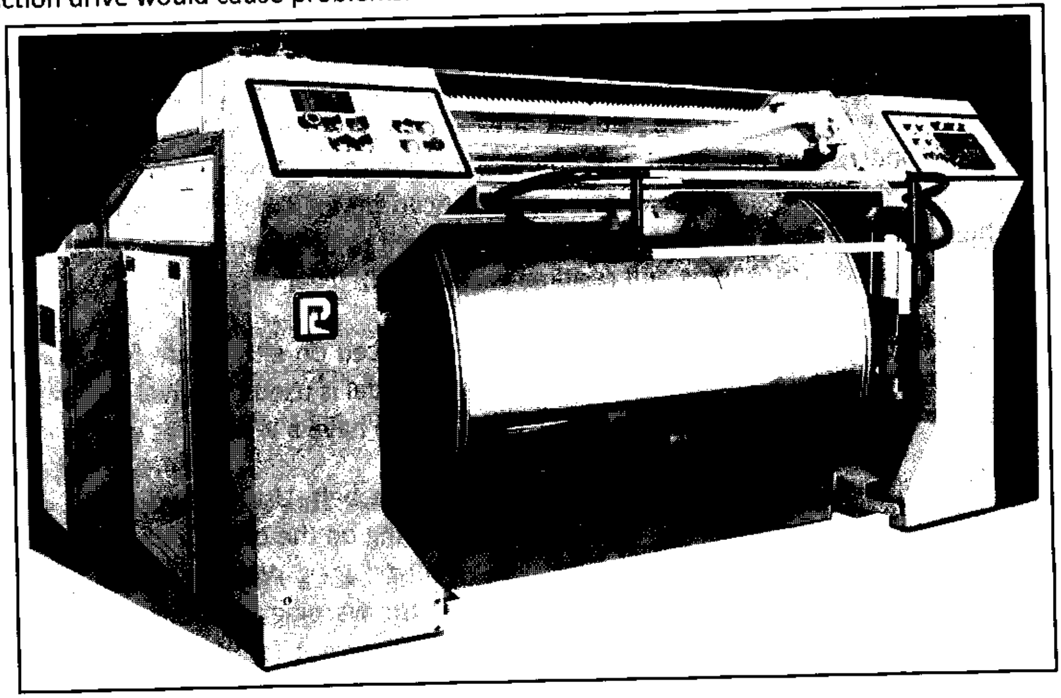
In traveling package creels, the creel is like a continuous belt. Usually two creels form a V shape. When the full packages are being used for warping on the outside position (active or run position), the empty inner side can be filled with packages. When the full packages are emptied, the side with the full packages is brought to the warping area (outside) by rotation and the warping continues without much interruption except for threading of the warp ends. After rotating the creel, the groups of yarn from the vertical rows are threaded and pulled to the warper where each yarn is positioned in the designated comb dent. The V configuration is especially suitable for warping of staple yarns at high speeds. Other advantages of V - creel are:

- no need for yarn guide
- uniform yarn tension across the whole beam
- free yarn run from the creel to the warping machine
- low yarn tension

In cases where overhead unwinding cannot be tolerated, a roller creel is used. In the roller creel, the package rotates and side withdrawal of yarn takes place. This type of creel is used especially for carbon filaments, aramid fibres, tape yarns and monofilaments.

II. Headstock:

The yarn speed should be kept as constant as possible during warping. In indirect (sectional) warping, a constant speed drive is generally sufficient in providing approximately uniform yarn speed on the surface of the beam. This is because the thickness of the yarn built on the beam is relatively small compared to the beam diameter such that the surface speed does not change much . In direct warping, the change due to yarn buildup on the beam is significant. Therefore, in direct warping, mechanisms that are similar to the ones used in winding are utilized to attain uniform yarn speed; surface friction drive and variable speed drive are commonly used. For some filament yarns, variable speed drive is chosen since friction drive would cause problems.



Today's headstocks are equipped with advanced design features such as precision direct drive, advanced electronics, smooth doffing and programmable breaking. Automatic hydraulic doffing is accomplished with the operation of one button. Programmable pneumatic braking provides a constant stopping distance regardless of the operating speed or beam diameter. The length of the yarn wound on the beam is controlled with a measuring roller and counter device. The density of the yarn can be controlled by tension, pressure or both. Frictional drive usually results in higher yarn density. In spindle drive, yarn tension and a hydraulically activated pressure roller are used to control density. Some headstocks are designed to run more than one beam width.

III. **Control Devices**

Similar to winding, warp yarns are threaded through tension devices, stop motions, leasing rods and the reed. Uniform tension is necessary so that all the warp ends behave the same way. The tension on the warp yarns is kept relatively low. Every end requires a tension controller which is usually located close to the package.

A quick response, advanced stop motion is necessary for warping. Due to the high inertia of the beam, it is difficult to stop the beam suddenly once an end is broken. However, the beam must be stopped before the broken end reaches the beam. The stop motion electrically links each warp end to the warper braking system; when a warp end breaks, the *warper stops. Powerful brakes are used for this purpose. A light indicates the location of the* broken end. The warping process is generally irreversible, unwinding of the beam would cause yarn entanglement. The stop motion device, which can be mechanical or electronic for quick response, is usually located near the creel.

In an electronic, motion sensitive stop motion device; the electronic eye detects movement of individual ends to trigger a warp stop when there is no yarn movement.

To avoid static buildup, especially with manmade fibres, different methods can be used including chemicals, ionization of air or humidification of air. Fans are used to prevent lint accumulation when warping staple yarns.

SIZING OR SLASHING

Sizing section also for warp yarn preparation

Although the quality and characteristics of the warp yarns coming out of the winding and warping processes are quite good, they are still not good enough for the weaving process for most of the yarns. The weaving process requires the warp yarn to be strong, smooth and elastic or extensible to a certain degree. To achieve these properties on the warp yarns, a protective coating of a polymeric film forming agent (size) is applied to the warp yarns prior to weaving; this process is called sizing or slashing. Sizing is not a value added process in woven fabric manufacturing. This is because, after the fabric is woven, the size materials will be removed from the fabric during the finishing operation, which is called desizing.

The main purposes of sizing are as follows:

- to increase the strength of the yarns
- to reduce the yarn hairiness that would cause problems in weaving process
- to increase the abrasion resistance of the yarns against other yarns and various weaving machine elements
- to reduce fluff and fly during the weaving process for high speed weaving machines.
- To increase the weaveability of the warp yarn, this is the main goal of sizing.

The ultimate goal of sizing is to eliminate or reduce warp breaks during weaving. Warp breaks are caused either by high tension or by low strength in the yarn. High tensions in the warp are caused by large shed openings, lack of proper tension compensation, high beat-up force and inadequate let-off. Knots, yarn entanglement and high friction also cause tension buildup.

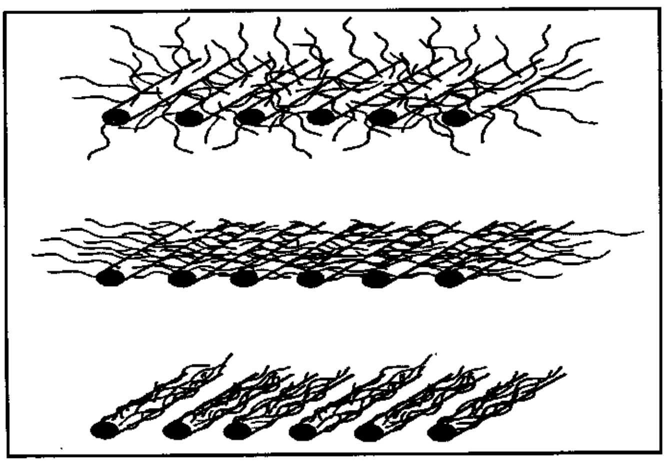
Sizing is a complementary operation which is carried out on warps formed by spun yarns with insufficient tenacity or by continuous filament yarns with zero twist. In general, when sizing is necessary, the yarn is beam warped, therefore all beams corresponding to the beams are fed, as soon as warping is completed, to the sizing machine where they are assembled. Sizing consists of impregnating the yarn with particular substances which form on the yarn surface a film with the aim of improving yarn smoothness and tenacity during the subsequent weaving stage. Thanks to its improved tenacity and elasticity, the yarn can stand without problems the tensions and the rubbing caused by weaving.

There is not just one sizing 'recipe' which is valid for all processes, on the contrary the sizing methods change depending on the type of weaving machine used, on the yarn type and count, *on the technician's experience and skill, but above all on the kind of material in progress. The* only common denominator of the various sizing materials is that they have to be easily removable after weaving in order to allow carrying out without problems the selected finishing cycle. The substances used as sizing material are potato flour, starches, glues, fats but also talc and kaolin, when a particularly thick size is requested.

It should be noted that only warp yarns need to be sized. This is because, as mentioned earlier, warp yarns are subject to harsher treatments than filling yarns during the weaving process on the weaving machine. Therefore, the filling yarns will be free of size and no special finishing considerations are necessary for these yarns in the fabric. Often, around 80% of yarn failures in weaving are caused by 20% or less of the yarns in a warp which are called repeater ends. The slashing process deals with enhancing individual warp yarn properties not with improving the characteristics of the warp sheet. If done improperly, slashing can worsen yarn sheet characteristics.

Several spun yarn properties are positively affected by sizing. Figure shows the effect of sizing on a typical staple yarn sheet. Good sizing should reduce hairiness, improve strength and abrasion resistance while keeping the yarns separated. Elongation is reduced in a controlled manner. Flexibility is reduced but reasonably maintained. If the sizing is not done correctly, the long hair fibres protruding from one yarn will be glued together with the fibres from the other yarns. This will cause damage of the size film when the yarn sheets are separated back into individual yarns at the separator rods on the slasher which will reduce the strength and cause a yarn break. The fibres should be kept to the body of the yarn such that hairs and fibrils do not interfere with the weaving process.

Factors influencing yarn hairiness include hairiness generated by the winding process, spinning tensions, location of the yarn on the spinning package, yarn balloon shape, yarn twist, spindle speed, yarn count, percentage synthetics in a blend, end spacing at slashing, size add-on, slasher creep speed and bottom squeeze roll cover.



Control of yarn hairiness with sizing,
top: unsized; middle: improperly sized; bottom: properly sized.

A practical understanding of the importance of size penetration, size encapsulation, yarn hairiness, residual yarn elongation and yarn abrasion resistance is essential to good sizing practice. It is important that the size film must coat the yarn surface without excessive penetration into the body of the yarn, because if the size material is penetrated deep in the yarn, complete desizing would not be possible. Therefore, only enough penetration should occur to achieve bonding of the size film to prevent removal during weaving.

The following terms are used related to sizing:

- Size Concentration: the mass of oven dry solid matter in size paste
- Size Take-up (size add-on): the mass of paste taken up in the size box per unit weight of oven dry unsized yarn
- Size Percentage: the mass of oven dry size per unit weight of oven dry unsized yarn.

There is an optimum level of size add-on that gives the minimum warp end breakage. Excessive size kakes the yarn stiffer and less extensible; yarns with too little size will not be strong and smooth enough for weaving. Therefore, too little or too much sizing causes an increase in warp end break. Optimum size add-on gives the best results for weaving.

Although sizing is done mainly to increase the strength of the yarn, some strong yarns such as continuous filaments still need sizing. This is because sizing keeps the slack and broken filaments together in low twist yarns which otherwise would protrude from the body and rub against the machine elements, leading to entanglement, development of fuzz balls and end breaks.

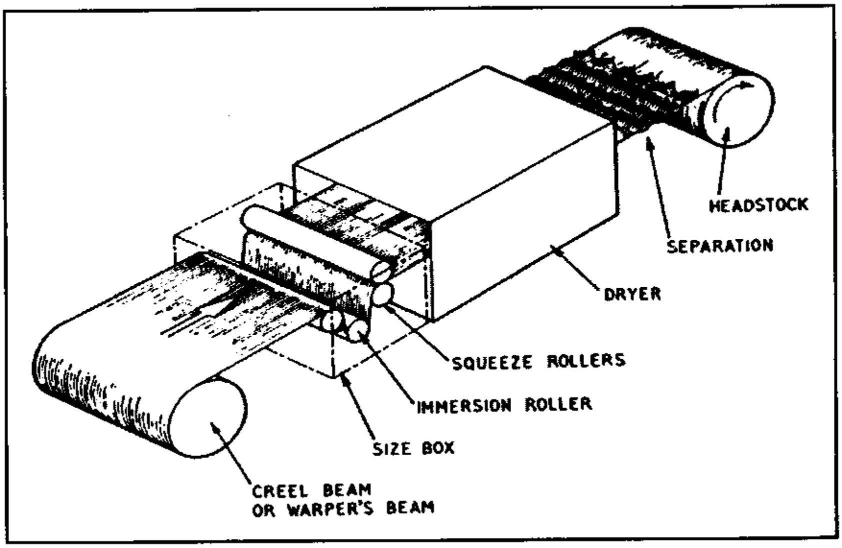
Other points to consider in sizing:

- Slasher creel tension control is critical especially with MJS and open-end yarns. Maximum tension should not exceed 5% of breaking strength (15 – 20g for ring spun yarns and 12 – 15g for open-end, MJS and MVS yarns). With coarse yarns, sometimes 30g is allowable.
- The amount of size picked up is affected by the viscosity of the size mix as well as the yarn structure. The viscosity of the mix is controlled by the recipe, amount of solid content in the size liquor and the type of sizing product, mechanical mixing level, temperature and time of boiling. Flat filaments, textured and spun yarns pick up size differently.
- Yarn spacing at the slasher size box and on the drying cylinders is very important
- The choice of size for staple yarns is usually based on cost. For filament yarns, the size material is chosen based on the compatibility with the fibre.
- Running the slasher at creep speed, which is sometimes necessary, generates a very undesirable condition for proper sizing and should be minimized in every way possible.
- Stretch of warp yarns during sizing should be controlled accurately to maintain residual elongation in the yarn which is needed for good weaving. Back beam – size box stretch should not exceed 0.5%.
- Water-soluble sizes can cause problems in water jet weaving.

- Process studies to determine causes for inefficiency should be conducted with strict cause analysis techniques by an experienced practitioner and not as part of a typical stop frequency study for job assignments.
- Guide rollers should be kept free from nicks, burrs and sharp edges, especially for MJS yarns. They should be sanded / polished frequently.
- Pre-wetting yarns prior to sizing can reduce the amount of required size add-on for the same performance, especially for cotton yarns.

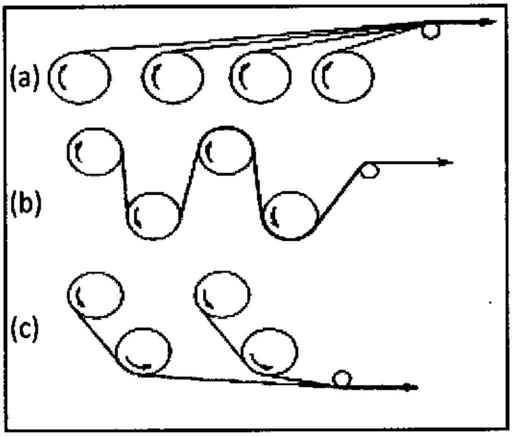
Sizing machine:

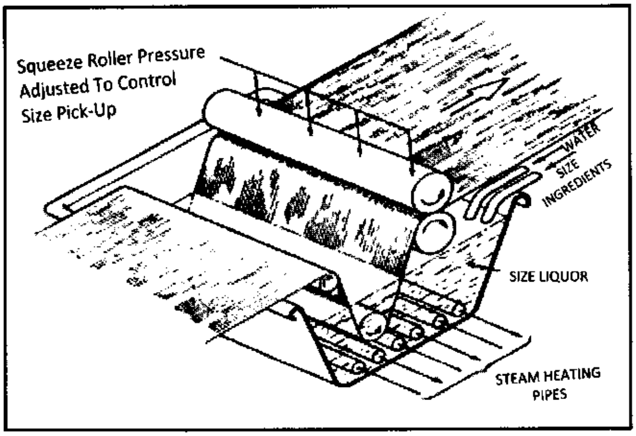
A sizing machine is used to apply the size material to the warp yarns. The first sizing machine was built in 1803 in England. The major parts of the sizing machine are the creel, size box, drying units, separation unit, beaming and various control devices.



Warp sizing (simplified)

The size box is probably the most important section of the sizing machine. During the sizing process, the sheet of yarns is passed through the size box which contains the hot water solution or mixtures of sizing agents. The yarns pick up the required quantity of size solution in the size box, any excess size is squeezed off as the yarns pass through squeeze rolls. Depending on the size material, warp quality and density, single and double immersion rolls and single squeeze and double squeeze configurations are used. Multiple size boxes can also be employed. In general, single box sizing machines have two squeezing rollers and two box machines have a single roller in each box. It is important that the rollers provide uniform squeezing pressure. The squeezing system determines the degree of size pick up to a large extent. While providing size consistency, the roll pressure should be adjusted to get around 125 to 130% wet pick up for cotton yarns, 110 to 115% for poly/cotton and 95 to 105% for polyester. On average, MJS and open-end yarns pick up around 10 to 15% more wet size than a comparable ring spun yarn. Therefore, about 10% more water should be added to get the same add-on. The bottom rollers are usually made of steel and the top rollers are rubber coated.





Beam creel arrangements

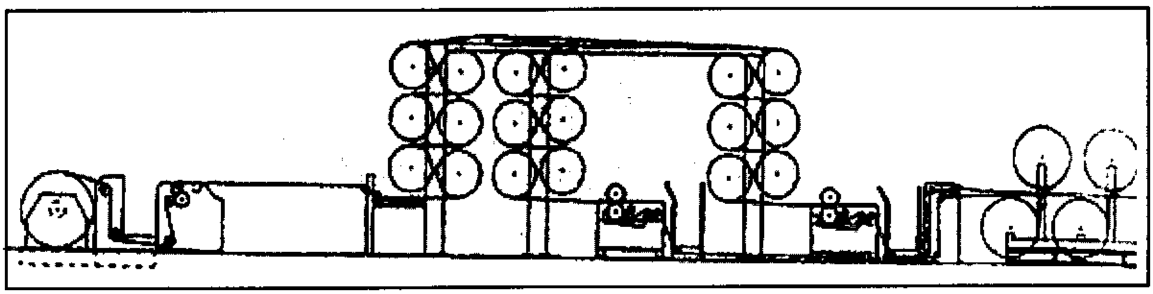
Section of a size box

Temperature of the size box is important for proper size pick up. For 100% polyvinyl alcohol (PVA) sizing, a temperature of 160 to 170^{0}F (70^{0}C) is recommended. Constant size temperature can be obtained in two ways:

1. Direct heating in which steam is injected into the size.
2. Indirect heating in which steam flows in pipes around the double walled size box.

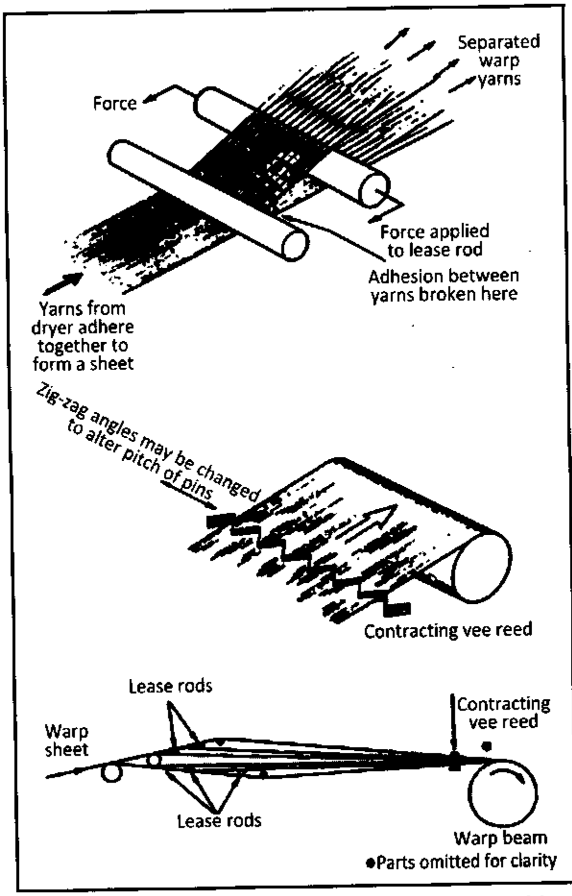
A cooker is used to prepare the size and the shearing action in the cooker is important for uniform mixing. Powdered size from silos, big-bags or sacks is metered into weighing stations and then transferred to the cooker.

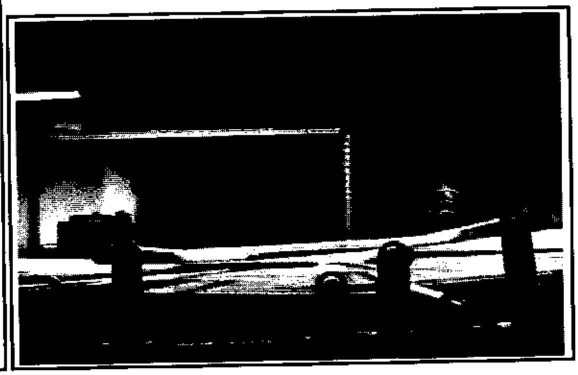
After the size box, the yarns go through the dryer section. The wet yarns are dried by using hot air, infrared radiation or cylinder drying. Cylinder drying is done using steam heated hot rolls which are called drying cylinders. Some-times, a combination of drying methods is used on the same machine. Quite often, the wet yarns (usually filament) are predried using hot air or infrared and drying is completed with drying cylinders.



Schematic of a typical sizing or slashing machine

Due to the nature of sizing, the yarns in the sheet may be stuck together at the exit of the dryer section. Therefore, they are separated into individual ends by using bust rods. First, the individual sheets of yarns from each section beam are separated followed by pins in the expansion comb to separate the yarns within each sheet. Then the yarns are wound onto a loom beam for weaving (weaver's beam).





Typical leasing system

Beam arrangements in the creel are usually two types:

1. Groups of 2, 4, 6 or 8, one to four tiers
2. Staggered, two-tier arrangement

Some sizing machines can have up to 24 beam positions. The beams can be controlled in groups or individually. The let-off can be individual let-off, single group let-off or wrap-round let-off.

DRAWING-IN AND TYING-IN

Drawing-in:

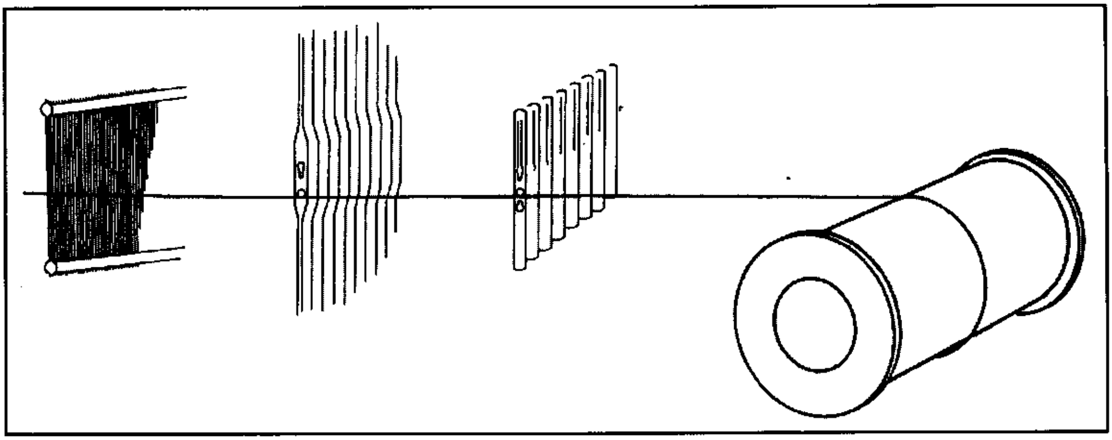
After sizing, the sized warp beam is prepared to be placed on the weaving machine. High fashion fabrics generally have high density which increases the demand on the quality of shed opening. As a result, warp leasing is becoming more popular. Different lease combinations can be selected with the automated leasing machines.

Drawing-in is the entering of yarns from a new warp into the weaving elements of a weaving machine, namely drop wires, heddles and reed, when starting up a new fabric style. Tying-in the new warp ends to the depleted warp is done when a new pattern is not required.

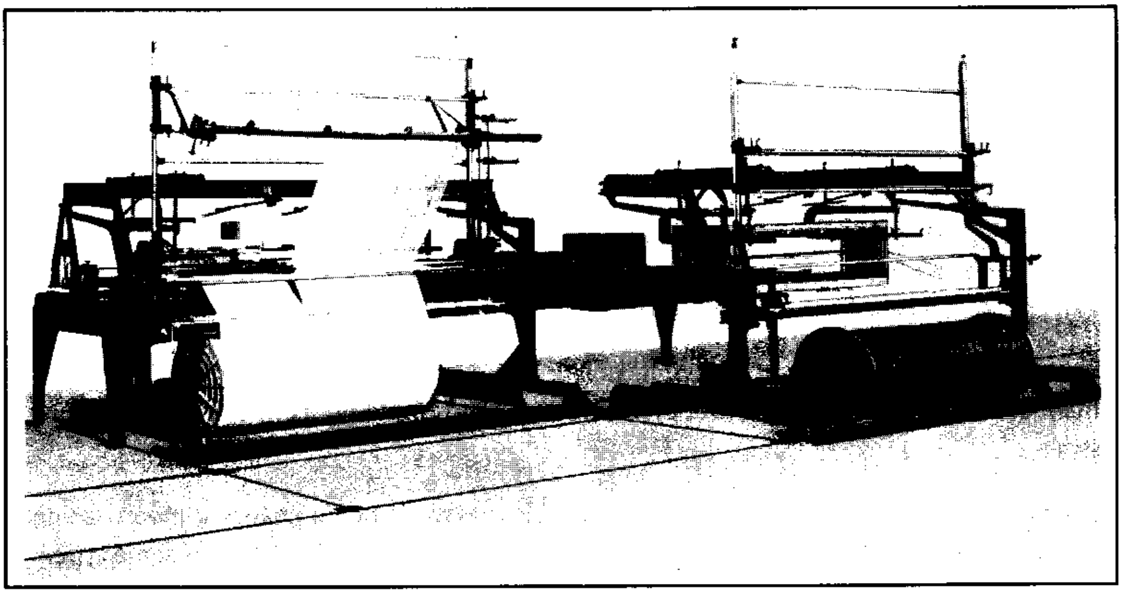
A drop wire is a narrow metal sheet that is hung in the air by the tensioned warp yarn. If the warp yarn is broken or slacken (loose), then the drop wire drops and touches a metal bar that extends along the width of the machine. This contact between the drop wire and metal bar closes an electrical circuit and shuts down the machine immediately. There is a drop wire for each warp yarn.

Pinning machines are used to pin open drop wires on warps. Since the pinning speed is high (up to 200 wires per minute), these machines are economical for more than 3000 warp ends.

After drop wire, the warp yarn goes through the heddle eye (there is only one warp yarn per heddle eye). This is done according to a plan called drawing-in-draft. Then the yarn is threaded through the reed spaces. A reed space is the opening between two dents (metal) in a reed. In general, one, two or three warp yarns are passed through one reed space. The reed plan specifies the number of yarns per reed space. The number of yarns depends on the diameter of the yarns and the dent opening; each yarn should be able to move freely up and down in the reed space independent of the other yarns.



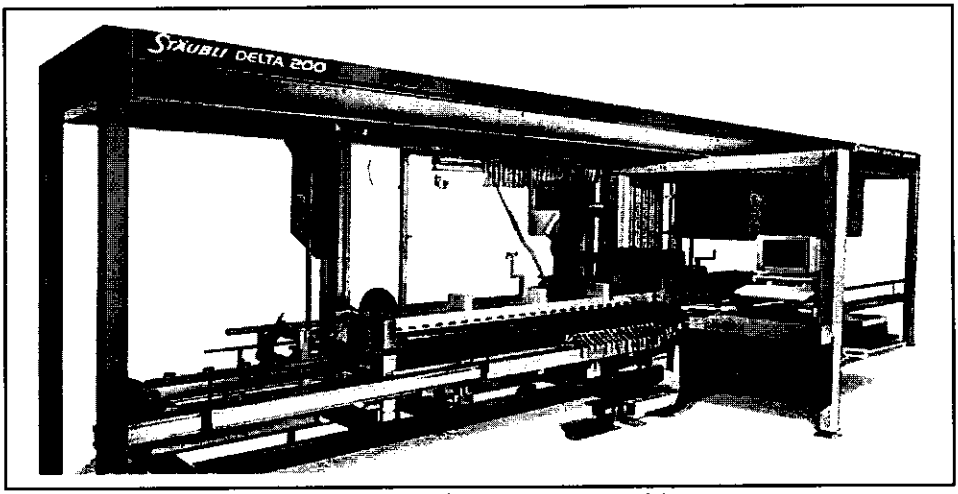
Schematic of Drawing-in



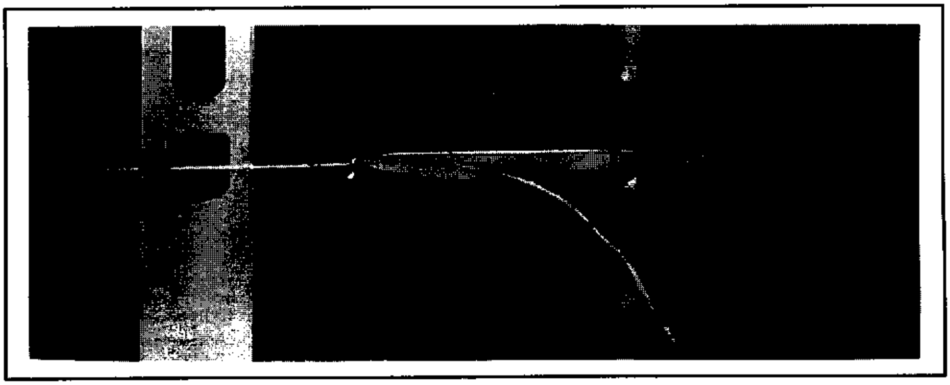
Warp Drawing-in System

In the manual mode of drawing-in, one person sorts the warp yarn and the other draws it through fron the other side. The sorting step can be automated by a reaching machine.

Today, the drawing-in and tying-in processes are fully automated. Drawing-in is done using robot-like machines. A special type of heddle is needed for automated drawing-in. The warp ends, taken from the warp sheet, are fed individually to the drawing-in element; heddles are separated from the stack and brought to the drawing-in position; a plastic knife opens a gap in the reed and a hook draws-in the warp end through the heddle and reed in one step.



Fully automated Drawing-in machine



Automatic drawing of warp end through drop wire, heddle eye and reed

Automatic drawing-in increases speed, flexibility and quality in weaving preparation compared to manual drawing-in. A drawing rate of 50,000 warp ends per 8 hours (200 ends per minute) is possible.

Changing style means producing a new fabric style, weaver's beam changing means going on weaving the same fabric style just replacing the empty beam with a full beam of same type.

Drawing-in consists of threading the warp yarns through the drop wires, the healds and the reed. Depending on the styles of the produced fabrics and on the company's size, this operation can be carried out manually, by drawing-in male or female workers.

Tying-in:

After the depletion of a warp beam on the weaving machine, if there will be no change in design, then the drawing-in process needs not be repeated. The ends of the old warp beam (now a fabric beam) are cut and the ends of the new warp beam are tied to the corresponding ends of the old beam which is called tying-in process. Then, the warp ends are pulled through the heddle eyes and reed until the knots are cleared.

A small portable robot is used on or off the weaving machine for tying-in. A typical warp tying machine can knot single or ply yarns from 1.7 to 80 N_e (340 – 7 tex). They can knot cotton, wool, synthetic and blend warp yarns as well as yarns of different thicknesses. Typical knotting speed of a knotter is from 60 to 600 knots per minute.

With continuous filaments and bulky yarns, a non-slip double knot is recommended which can be handled by knotting machines. Some automatic tying machines can knot extremely short tails of yarns (5mm). Tape yarns and monofilaments require a slightly different tying machine. Tape yarns of up to 8 mm width can be tied. The knotting speed is typically 60 to 450 knots per minute. The number of warp ends to be tied together can be preprogrammed; once this number is reached, the knotter stops automatically. A dual knotting system is used on a double beam weaving machine; the knotters work from left to right and from right to left simultaneously.

The warp welding machine is used to weld the warp end layer with a plastic foil after drawing-in which provides simple insertion through the weaving machine. This results in time saving at the machine startup. After drawing-in with a brush beam the ends protruding from the reed are aligned parallel and stretched evenly. An approximately 5cm wide plastic foil is placed on top of the lower welding bar and a longer piece of plastic foil is placed on the warp yarns above the lower piece of plastic foil. By moving the upper welding bar down, the plastic foils are welded together with the warp yarns in between.

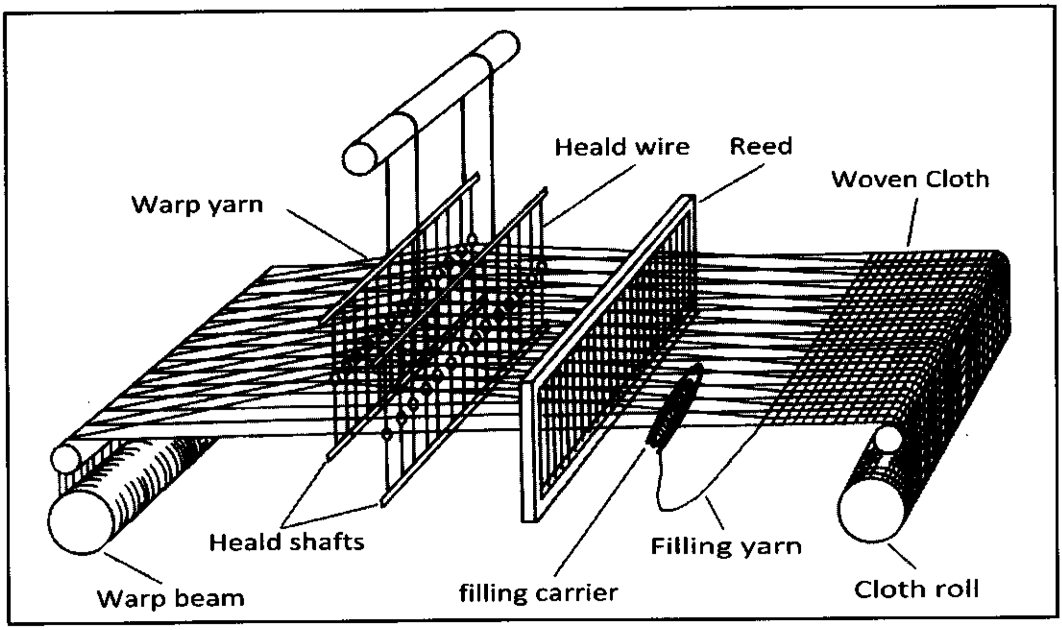
Several points should be considered during drawing-in and tying-in. Improper splicing and / or knotting can become critical to good weaving performance. The straightness of individual warp yarns and their freedom to act independently as they pass through a weaving machine are important for quality weaving. Yarns that are crossed and tangled cannot proceed without excessive stress and yarns that are restricted or influenced by drop-wire activity, heddle spacing, harness interference or reed spacing will not weave at top performance.

FUNDAMENTALS OF WEAVING

Weaving Principle:

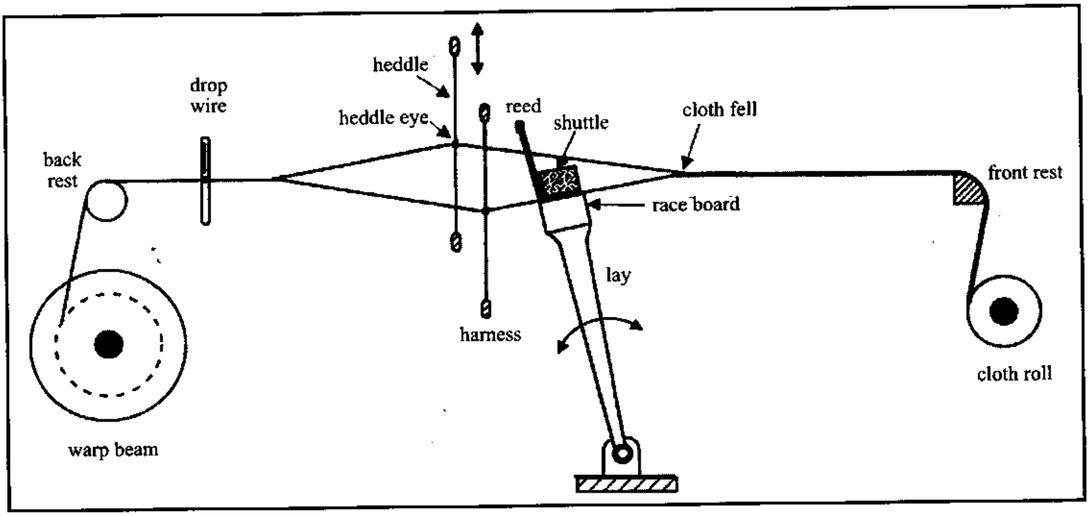
The following figures show a schematic of weaving. The warp yarns are stored on a beam called a weaver's beam or warp beam (also called a loom beam) and they flow to the front of the machine where the fabric beam is located. The filling yarn is withdrawn from a single package and inserted between the sheets of warp yarns, which are perpendicular to the filling yarn.

The warp beam, which holds the lengthwise yarns, is located at the back of the machine and is controlled so that it releases yarn to the weaving area of the loom as needed. This function is the let-off motion, the first of four primary loom motions. The heald wires or heddles are wire or metal strips that allow control of the individual ends; an end is pulled through the eye located in the center of each heddle. The individual heddles are mounted in a harness or heald shaft that allows the warp yarns to be controlled in groups. A loom has at least two harnesses or heald shafts, and most have more. The number of harnesses on a loom helps determine the complexity of the fabric design that can be produced.



Basic structure of a weaving machine

In a two-harness loom, every other warp yarn across the width of the fabric is in one harness. When that harness is raised, half of the warp yarns rise to produce an opening between the two sheets of warp yarns. This opening, known as the shed, produces a path through which the filling is inserted. The loom motion is called shedding, and the order in which harnesses are raised and lowered produces a pattern in the fabric. In looms containing more than two harnesses, the sequence for drawing ends through heddles and mounting heddles in harnesses becomes more intricate. In many cases, groups of harnesses are raised and lowered together. A very good fabric designer is needed to plan the drawing-in of a warp and the sequencing of harness movements in a 32-harness loom.



Cross section of shuttle loom along the warp direction

The third basic loom motion is picking or weft insertion. For many years, weft yarn was laid across the shed with a shuttle. In today's weaving machines, another device, such as a jet of air or water, a rapier, or a small projectile, is used to place the pick. Then each filling yarn must be packed against the previously placed pick. This is accomplished by using a reed, which is parallel to the harness, to press the pick into position. This is the beat-up motion, the fourth and final primary loom motion. The three motions such as shedding, picking and beat-up is called weaving cycle or loom cycle.

The cloth beam, or cloth roll, located at the front of the loom, holds the completed fabric; as each pick is beaten into position, the fabric just produced is rolled onto the take-up beam. This take-up motion is the final loom motion; because let-off and take-up occur simultaneously, the loom motion is usually referred to as "let-off and take-up".

Most fabrics are produced on weaving machines with eight or fewer harnesses; elaborate fabrics, however, require many harnesses and the special attachments required to control groups of harnesses, or they have mechanisms similar to computer controls that move each individual warp yarn to produce complex patterns. These more elaborate shedding mechanisms such as dobby and jacquard shedding mechanism.

Basic weaving motions:

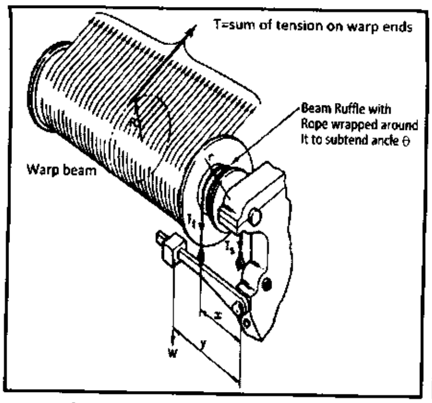
Although there are many mechanisms on a modern weaving machine for various purposes, there are five basic mechanisms that are essential for continuous weaving as follows:

Warp let-off, shedding, pick insertion or picking, beat-up and fabric take-up.

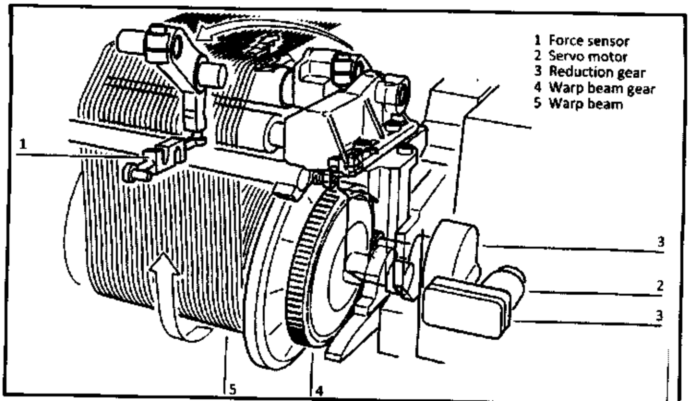
1. **Warp Let-off:**

Warp let-off mechanism releases the warp yarn from the warp beam as the warp yarn is woven into the fabric. The let-off mechanism applies tension to the warp yarns by controlling the rate of flow of warp yarns. The mechanism should keep the proper tension on the warp yarns which controls the crimp rates of warp and weft yarns. Uniform tension is essential in weaving. Increasing the warp tension decreases the warp crimp and increases the filling crimp in the fabric. The crimp ratio of warp and weft affects the fabric thickness. Yarn diameters being the same, equal warp and weft crimps result in the lowest thickness of the fabric.

Let-off mechanisms can be classified as negative and positive. In negative let-off mechanism, the tension on the warp yarns provides the driving force against friction forces in the let-off motion. The tension of the warp is regulated by the friction between the chain or rope and the beam ruffle. The negative friction type of let-off mechanisms were mainly used for non-automatic weaving. In positive let-off mechanisms, the warp beam is turned at a rate which depends on the yarn length between the warp beam and cloth fell. A separate mechanism is used to apply constant tension on the warp yarns as the warp is depleted.



Negative let-off mechanism



Schematic of warp let-off mechanism on a typical air-jet weaving machine

Let-off mechanisms can also be classified as mechanical or electronic. Most modern weaving machines have electronic let-off. Electronic warp let-off provides a positive and controlled release of warp yarn from full to empty beam which results in a consistent warp tension. It is good for preventing fabric defects such as pick density variation and stop marks. Weaving tensions should be maintained at minimum levels for best weaving performance.

The electronic let-off system can be equipped with a pulley mechanism or a reduction gear mechanism. The linear and positive letting off of the warp beam can be provided by a magnetic reading of the whip roll position. Electronic warp let-off systems have programmable movements with a tenth of pick accuracy to eliminate stop marks. They have the capability to release the yarn tension at the stop of the weaving machine and recover it at the starting of the machine by a number of picks ranging 1/10 of a pick to 50 picks. This way, the overstretching of the yarn, which is the major cause of defects during the standstill time, is prevented. The system can follow any movement of the machine, such as the forward slow motion (jogging) and pick finding motion. With the electronic let-off mechanism, since brake and coupling linings are no longer needed, spare parts cost is reduced.

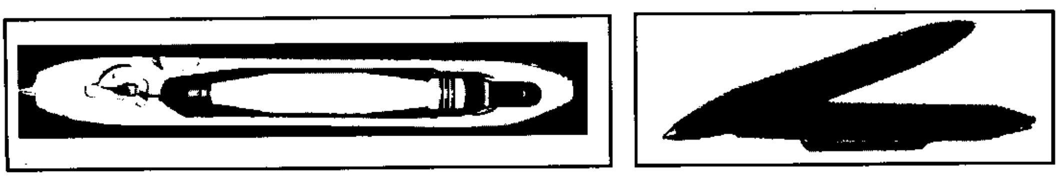
2. **Warp Shedding:**

Shedding is the movement of some warp yarns up and some down to make an angled opening for the weft yarn to be inserted through. This opening is called "shed". Before the insertion of the next weft yarn, the warp sheet has to be rearranged according to the fabric design pattern so that the required fabric structure is produced.

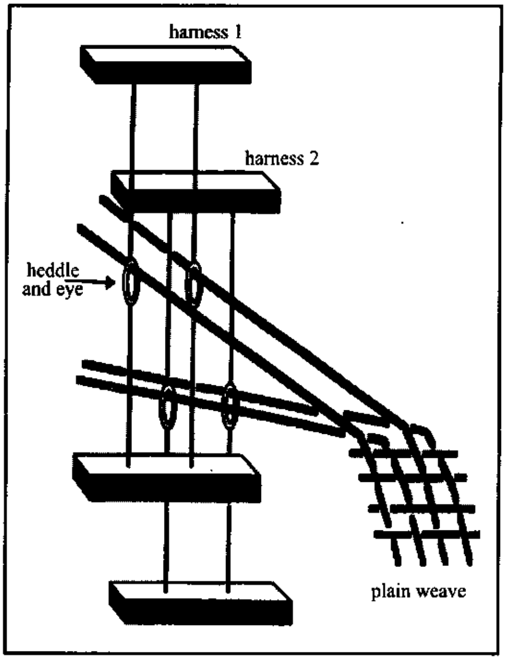
3. **Weft Insertion or Picking:**

After each shed change, the weft yarn is inserted through the shed as shown in the following figure. It is possible to select and insert different weft yarns one after another. These weft yarns can be of different colour, weight, etc., and a selection mechanism is used for this purpose. Depending on the machine type, several different weft yarns can be used in the same fabric. The selection mechanism presents the proper weft yarn to the yarn carrier for insertion of each yarn.

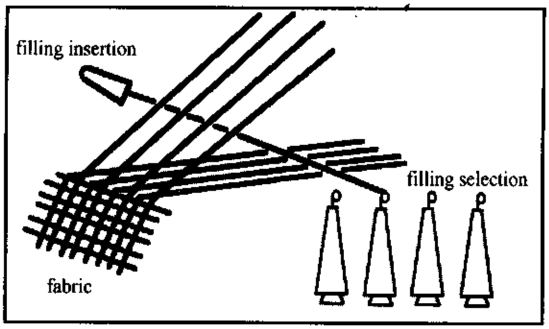
Weaving machines are usually classified according to the weft insertion mechanism. The major weft insertion systems that are used today are air-jet, rapier, projectile and water-jet, which are called shuttleless weaving machines.



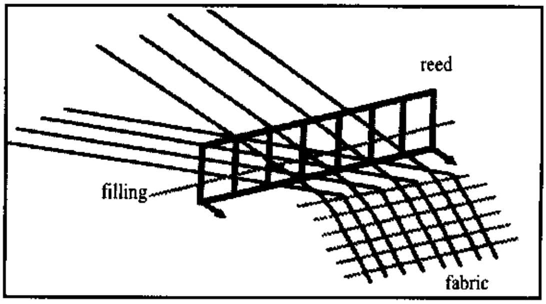
Shuttle with a pirn



Elements of warp shedding motion

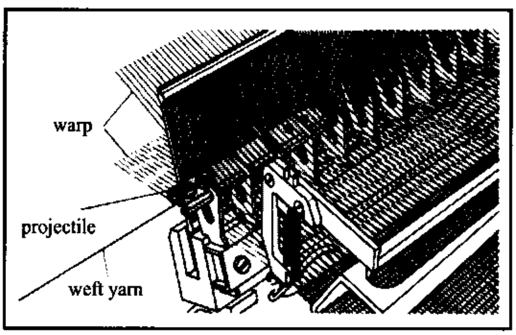


Selection and insertion of filling yarns i.e. Picking

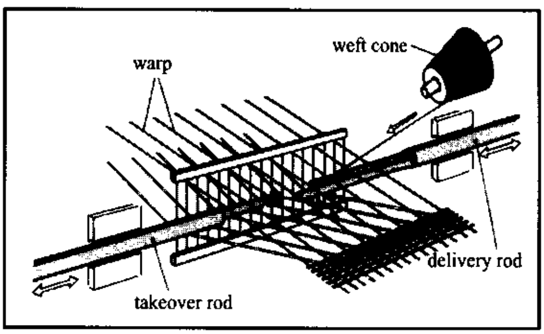


Schematic of beat-up process i.e. Beating

A gripper projectile transports a single weft yarn into the shed. Energy required for picking is built up by twisting a torsion rod. On release, the rod immediately returns to its initial position, smoothly accelerating the projectile through a picking lever. The projectile glides through the shed in a rake-shaped guide, braked in the receiving unit, the projectile is then conveyed to its original position by a transport device installed under the shed. The projectile's small size makes shedding motions shorter which increases operating speeds over wide widths of fabric, often weaving more than one panel of fabric with one insertion mechanism.



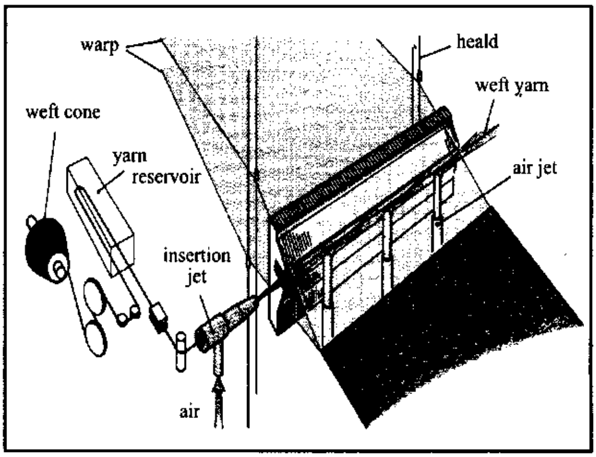
Weft insertion by Projectile



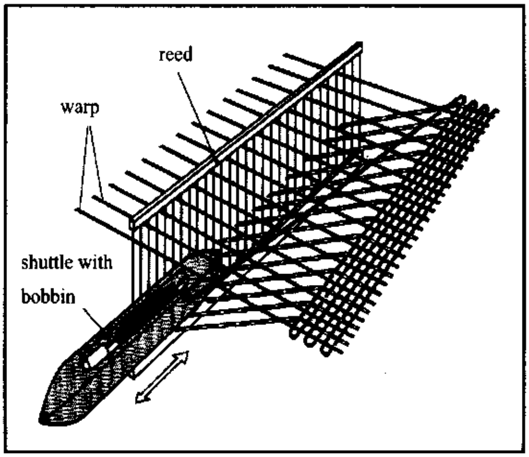
Weft insertion by Rapier

The above figure illustrates weft insertion by two flexible rapiers with weft carriers, a giver and a taker. The weft is inserted half way into the shed by one carrier and taken over in the center by the other carrier and drawn out to the opposite side of the fabric. A special crank gear drives the oscillating tape wheels to which the rapier tapes are attached. In the shed, the tapes move without guides. The grippers assume the correct clamping position automatically. Different versions of rapier insertion systems are also available.

The most popular method of weft insertion is illustrated in the following figure where a jet of air is used to "blow" the weft yarn into the shed. This small mass of insertion fluid enables the mechanism to operate at extremely high insertion rates. The picks are continuously measured and drawn from a supply package, given their initial acceleration by the main air nozzle and boosted or assisted across the fabric width by timed groups of relay air nozzles. The other fluid system uses water as the insertion medium, but the use of a water-jet is generally limited to hydrophobic yarns such as nylon or polyester filament.



Weft insertion by Air-jet



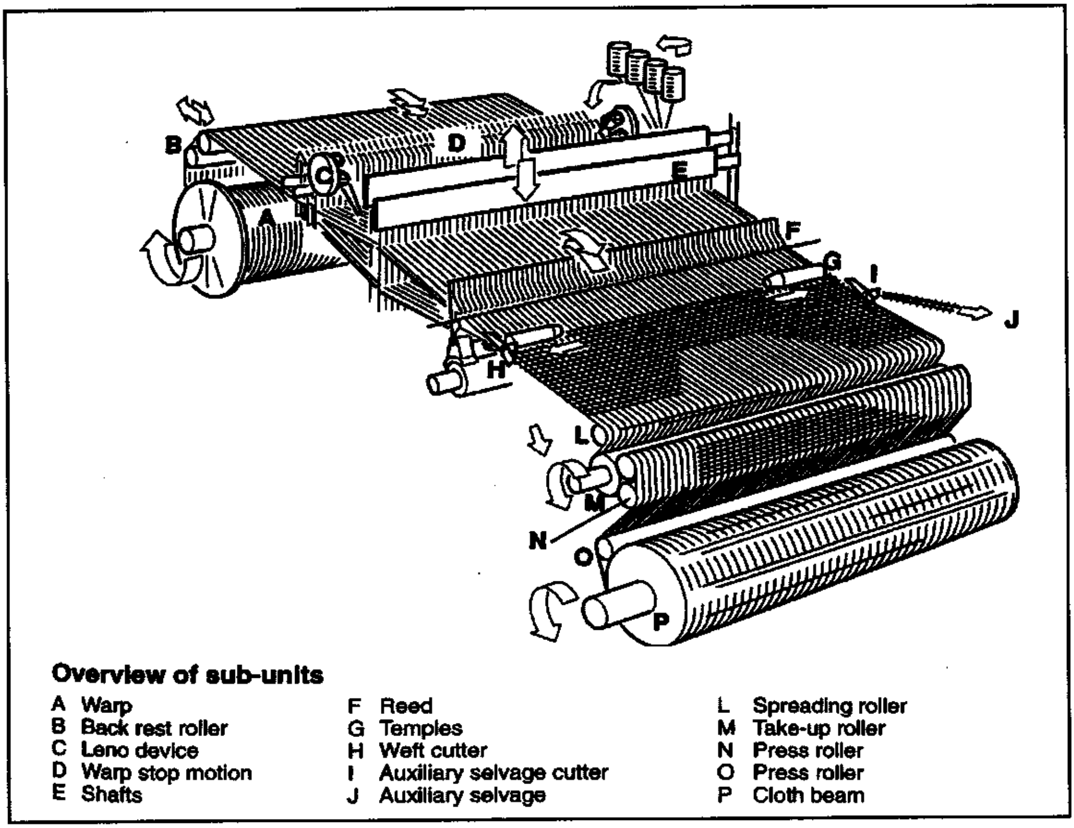
Weft insertion by Shuttle

A shuttle loom uses a shuttle to store and carry the yarn back and forth across the loom. Shuttle looms have become obsolete in manufacturing of traditional woven fabrics due to several reasons, including low production rate, high noise, safety concerns, limited capabilities, etc. Nevertheless, the shuttle loom is still used as a reference point for the modern shuttleless weaving machines. Besides, some industrial woven fabrics are still being made on specially designed shuttle looms.

Yarn Accumulators or Feeders:

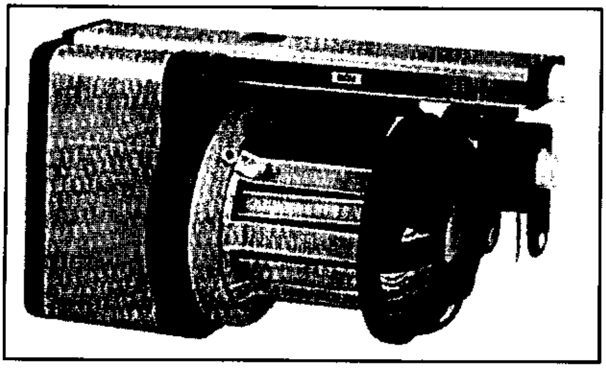
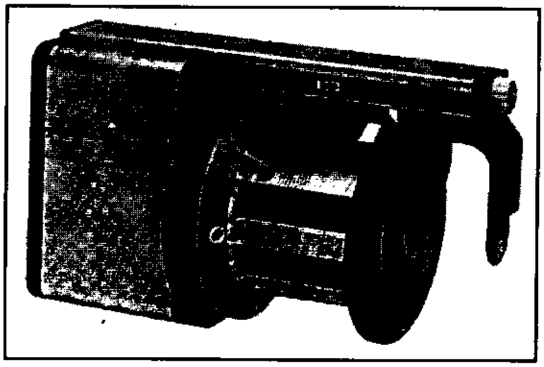
Yarn feeders or accumulators are used to wind a predetermined yarn length to make it ready for insertion. Their main purpose is to supply weft yarn to the weaving machine smoothly and at a constant and proper tension. There are various types of feeders used. The selection of a feeder depends on several factors:

- maximum speed delivered
- yarn count
- winding direction (S or Z)
- yarn reserve control

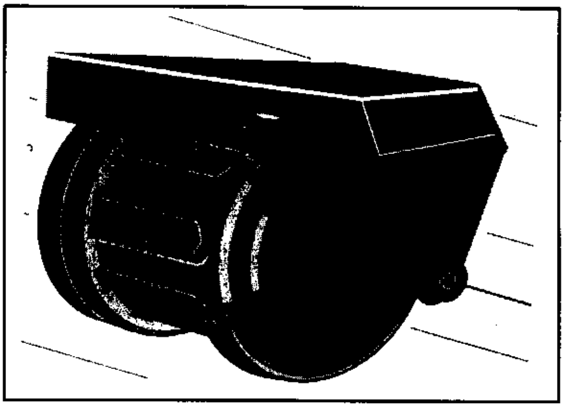


Schematic of a typical air-jet weaving machine

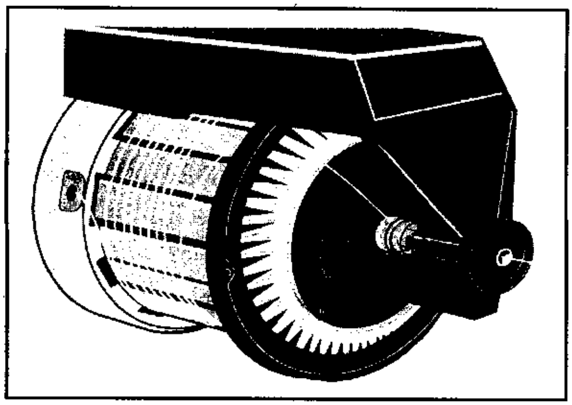
Maximum speed depends on the yarn count range. Reserve control can be done mechanically or electronically by means of photocells. The threading through the feeder can be done manually or pneumatically. The tensioning of the yarn is controlled by a breaking device which can be of different types including bristle, metal lamella, flex brake and coaxial output tensioner. The figure (flex brake) shows the membrane and the endless beryllium copper tensioning strip. The flex is used to replace the brush ring and output tensioner in conventional brake systems. The figure (Coaxial output tensioner) shows the yarn travels through two tensioning discs mounted in the feeder nose. An adjustable tensioning spring regulates the base force exerted by the discs, which allow the setting, and maintaining of tension levels. During the weft insertion process, the "Coaxial output tensioner" compensates yarn tension fluctuations. Weft breakage at the feeder entry is detected electronically to stop the weaving machine. For heavy yarns, a balloon breaker can be fitted in front of the feeder instead of the normal eyelet.

Yarn feeders for rapier and projectile weaving machine (courtesy of Nuova Roj Electrotex)



Flex brake (courtesy of IRO)



Coaxial output tensioner (courtesy of IRO)

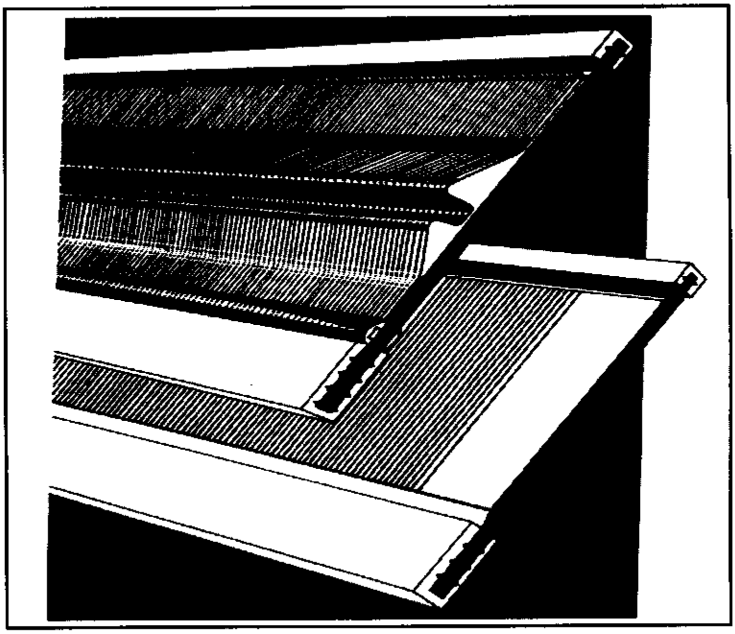
During weaving of fine woolens and linen yarns, usually a lubricant is used which is supplied by a liquid dispenser. The purpose of the lubricant is to reduce weft breakages and increase weaving machine speed and weaving efficiency. A liquid dispenser is placed between weft yarn package and feeder, which allows an even distribution of liquids, wax, oil, moisturizers and anti-static lubricants on weft yarns during weaving. The weft yarn is coated when it passes over a motor driven rotating cylinder that is immersed in a liquid reservoir.

To improve the fabric appearance, i.e., to compensate yarn count fluctuations and colour irregularities, a one-one-weft insertion from two bobbins instead of weft insertion from only one bobbin is recommended.

4. Beat-up:

When the weft yarn is inserted through the shed, it lies relatively far from its final position. This is because the insertion device (air-jet, projectile, rapier, etc.) cannot physically fit at the acute angle of the shed opening. This final position is called fell, which is the imaginary line where the fabric starts. Therefore, the newly inserted weft yarn needs to be brought to its final position by pushing through the warp sheet. Beat-up is the process of pushing the last inserted weft yarn to the cloth fell by using a device called reed as shown in the above figure. For all practical purposes, the fabric is not formed until beat-up occurs.

Reed is a closed comb of flat metal strips (wires). These metal strips are uniformly spaced at intervals that correspond to the spacing of warp ends in the fabric; therefore, the reed is also used to control warp yarn density (closeness) in the fabric. Warp density is expressed as either ends per inch (epi) or ends per centimeter (epc), which affects the weight of the fabric. The spaces between the metal strips are called "dents". The reed holds one or more warp yarns in each dent and pushes them to the cloth fell. After beating up the weft yarn, the reed is withdrawn to its original rest position before the insertion of the next pick. The following figure shows a regular reed and a profiled reed. Profiled reed is used in air-jet weaving machines. In shuttle looms, the reed also guides the shuttle.



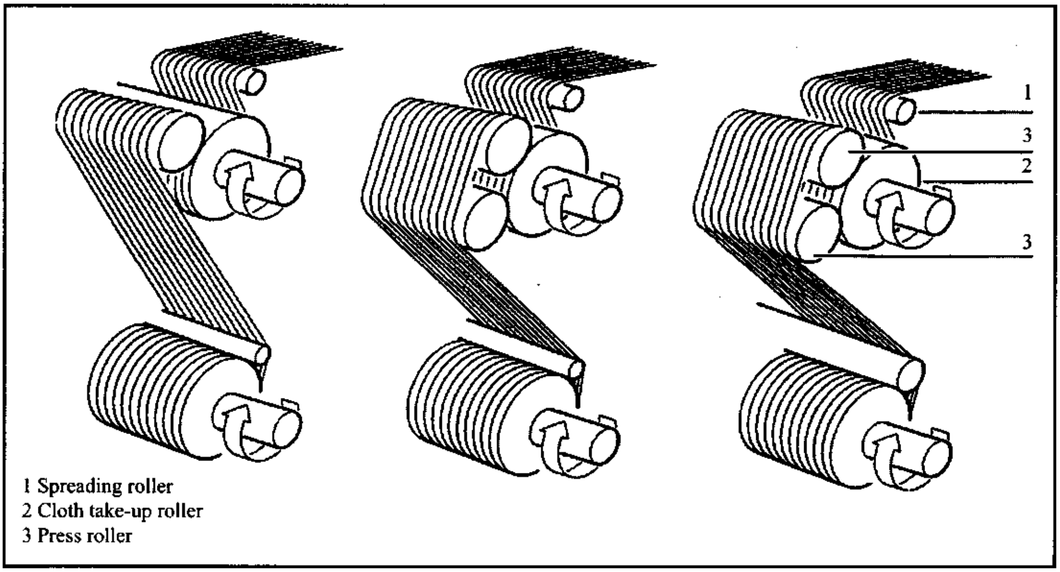
Regular Reed (bottom) and Profiled Reed(top)

The shape and thickness of the metal wires used in the reed are important. Reed selection depends on several considerations including fabric appearance, fabric weight (ends per unit width), beat-up force, air space requirement and weave design.

Reeds are identified by a "reed number" which is the number of dents per unit width. Specifying the number of ends per dent with a certain reed number dictates the construction (density) of ends per inch in the fabric on the loom. It should be noted that interlacing causes a natural contraction of yarns in the fabric such that density of warp ends off the loom will be higher than in the reed; generally about 5% higher depending on the weave, tensions and yarn sizes involved.

5. Take-up:

As the fabric is woven, it should be removed from the weaving area. This is achieved by the take-up motion. The fabric take-up removes cloth at a rate that controls weft density (picks per inch i.e. ppi or picks per centimeter i.e. ppc). Two factors determine weft density: weaving machine speed and rate of fabric take-up. Generally, the pick insertion rate of a weaving machine is fixed at the time of purchase based on the range of fabrics it is intended to produce, the type of insertion mechanism and the weaving machine width. There is two types of take-up mechanism, such as positive take-up mechanism and negative take-up mechanism. Following figure shows the positive fabric take-up mechanism on a typical Air-jet weaving machine. Weaving machine speed is expressed as picks per minute (ppm) and rate of take-up as inches per minute (ipm) or centimeter per minute (cm/min). Warp density and weft density together are referred to as the "construction" of the fabric.



Schematic of fabric take-up mechanism on a typical Air-jet weaving machine

The following relations exist:

Reed number = Number of dents / inch or number of dents / cm

Weft density (ppi or ppc) = $\dfrac{Machine\ \ speed(picks/\min)}{Take-up\ \ speed(inch/\min\ \ or\ cm/\min)}$

Warp density (epi or epc) = Reed number × ends / dent

Fabric Construction = Warp density × Weft density

It should be emphasized that both the ends and picks contract because of interlacing causing construction on the loom and off the loom to be different. Subsequent fabric finishing steps also introduce changes in the fabric construction, which must be considered in setting up loom specifications.

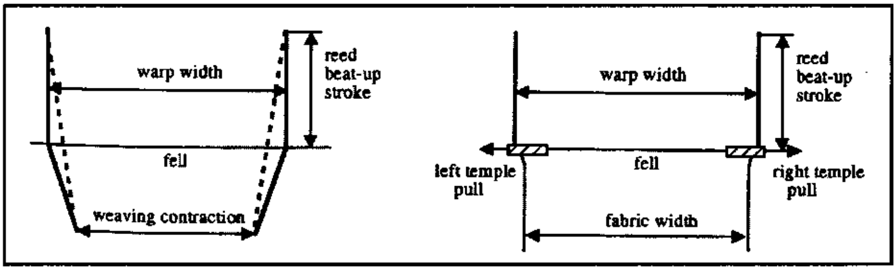
Auxiliary weaving motions or functions:

In addition to the five basic motions of a loom, there are many other mechanisms on typical weaving machines to accomplish other functions. These include:

- A drop wire assembly, one wire for each warp yarn, to stop the machine when a warp end is slack or broken.
- A tension sensing and compensating whip roll assembly to maintain tension in the warp sheet.
- A mechanism to stop the machine when a weft yarn breaks
- Automatic pick finding device reduces machine downtimes in case of weft yarn breakages.
- Weft feeders to control tension on each pick.
- Pick mixers to blend alternate picks from two or more packages
- Weft selection mechanism for feeding multi-type weft patterns.
- Weft selvedge devices such as trimmers, tuckers, holders and special weave harnesses for selvedge warp ends.
- Weft replenishment system to provide uninterrupted weft insertion by switching from a depleted to a full package.
- A temple assembly on each selvedge to keep fabric width at the beat-up as near the width of the warp in the reed as possible.
- Sensors to stop the machine in the event of mechanical failure.
- A centralized lubrication control and dispensing system.
- A reversing mechanism to avoid bad start-ups after a machine stop.
- A colour coded light signal device to indicate the type of machine stop from a distance.
- A production recording system.

Fabric width:

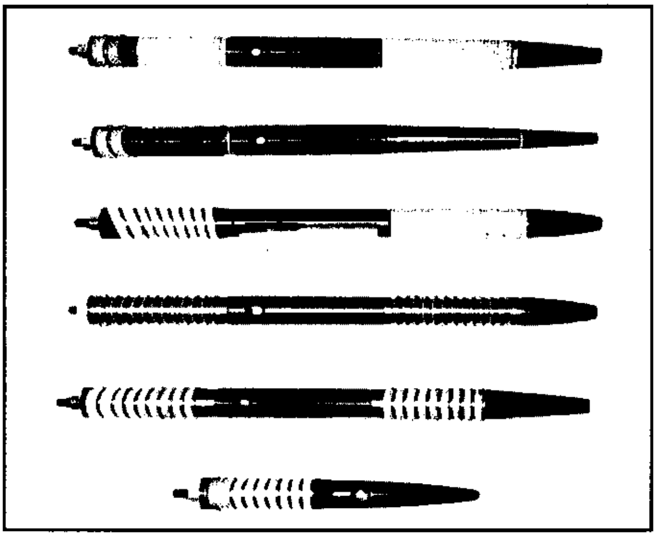
At the moment it is woven, the fabric width is equal to the reed width as shown in the following figure. However, as the weaving continues and fabric gets away from the reed, the fabric starts narrowing due to several factors (it should be noted that there are certain fabrics which do not get narrower, e.g. glass fabrics). These are weaving design, fabric construction and weaving tensions. The interlacing pattern of the weave design affects the crimp level in the fabric and crimp on the weft yarn causes the fabric to contract in width direction. Fabric construction, i.e., the number of weft and warp yarns per unit length, also affects fabric crimp and therefore fabric width. High weaving tensions, especially in the warp yarns, cause fabric to shrink. Warp yarns closest to the selvedges of the fabric undergo more stress due to widthwise contraction of the fabric toward the center, causing linear angular displacement of these outermost yarns.



Function of Temple in weaving

The narrowing of fabric width should be prevented, by using a temple on each side of the machine. Control of fabric contraction by the temples of the machine is another critical aspect of good weaving performance. A temple is a metallic device that keeps the fabric stretched by applying a force along the weft direction. There are various temple types as shown in the following figure. It is also possible to have a temple across the full width of the fabric. Full width temples ensure uniform fabric quality over the entire weaving width with delicate fabrics and easier operation. The full temple has the following advantages:

- Uniform warp and weft tension over the entire width.
- Uniform fabric characteristics over the entire width.



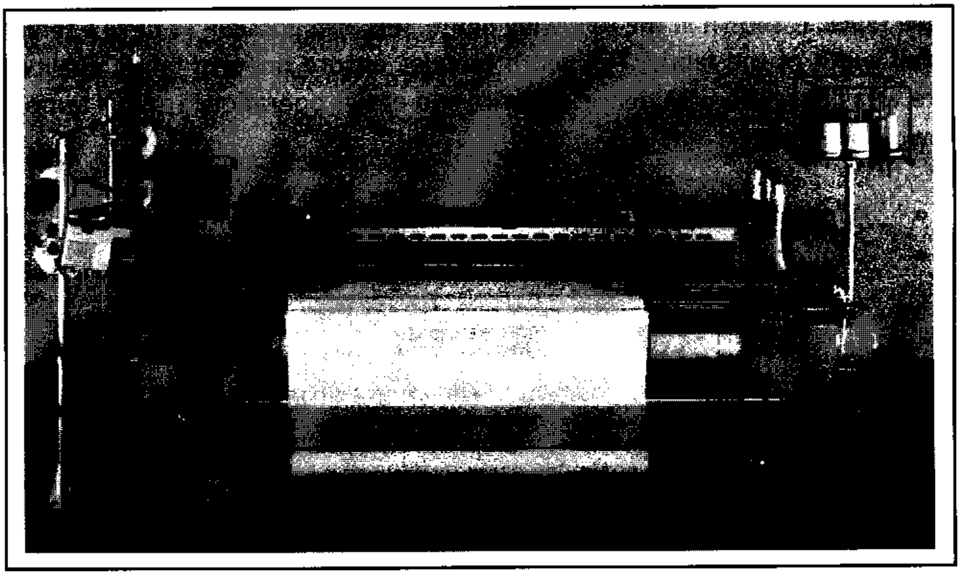
Different Temples used in weaving machine

- No fabric drawing defect.
- No damage to fabric by needle rings.
- Rapid changeover from full width to cylindrical temples.

Weaving machine or Loom:

Weaving is done on a machine called a loom. All the weaves that are known today have been made for thousands of years. The loom has undergone significant modifications, but the basic principles and operations remain the same. Warp yarns are held taut within the loom, and weft yarns are inserted and pushed into place to make the fabric.

In primitive looms, the warp yarns were kept upright or horizontal. Backstrap looms, used for hand weaving in many countries, keep the warp yarns taut by attaching one beam to a tree or post and the other beam to a strap that fits around the weaver's hips as the weaver stands, squats, or sits. Weft yarns are inserted by a shuttle batted through raised warp yarns. To separate the warp yarns and weave faster, alternate warp yarns were attached to bars that raised the alternate warp yarns. A toothed device similar to a fine comb pushed the filling yarns in place. Eventually, the bar developed into heddles and harnesses attached to foot pedals so the weaver could separate the warp yarns by stepping on the pedals, leaving the hands free for inserting the weft yarns.



During the Industrial Revolution, mass-production high-speed looms were developed. The modern loom consists of two beams, a warp beam and a cloth or fabric beam, kolding the warp yarns between them. Warp yarns that are sufficient for the length, width, and density of the fabric to be woven are wound carefully onto a warp beam. The warp will be raised and lowered by a harnessheddle arrangement. A harness is a frame to hold the heddles. The harness position, the number of harnesses, and the warp yarns that are controlled by each harness determine the weave pattern or interlacing. A heddle is a wire with a hole or eye in its center through which a warp yarn is threaded. There are as many heddles as there are warp yarns in the cloth, and the heddles are held in two or more harnesses. Each warp yarn passes through the eye of only one heddle. The selection of the specific heddle and harness is a major factor in determining the structure of the fabric. The above figure (basic structure of a weaving machine) illustrates how a simple two-harness loom is used to raise one harness while the other harness remains in its original position. With this arrangement, the yarns from a shed through which the weft is inserted.

The carrier used for transporting the weft yarn may differ from one kind of loom to another. The different devices used form the basis for classifying different types of looms. The name of the loom often refers to the carrier used to insert the weft yarn. Originally, these carriers were fairly large, somewhat oval wooden shuttles with a bobbin of yarn in the center. Within the industry many people refer to newer equipment as weaving machines rather than looms. Weaving machines vary from older, shuttle looms to modern shuttleless machines with sophisticated electronic controls.

A. Shuttle Weaving Machines:

For centuries, the basic loom operated with a shuttle to lay the weft yarn. By the middle of the twentieth century, shuttle looms had developed to a high level of efficiency, allowing them to make fabric rapidly with reduced numbers of flaws. These shuttle weaving machines depend on a shuttle, a boat-shaped, metal-tipped carrier, to supply a continuous length of weft yarn for the weaving operation. The yarn is actually wound on a small spindle or bobbin known as a pirn or quill, which is placed in an opening in the shuttle. The shuttle enters the shed and moves across the width of the fabric to lay the pick; it stops at the opposite side of the fabric; and, after that pick is beaten into place, a new shed is formed and the shuttle returns across the loom, releasing yarn from the pirn to produce another pick. As this operation is repeated, the weft yarn is alternately woven over and under the warp yarns at the sides of the fabric to form the selvedge.

The width of the fabric is controlled by the number and spacing of the warp yarns across the loom. The yarn supply on each pirn is fairly small; it is enough to produce several inches of fabric length. Pirn in the shuttle must be replaced when the yarn supply is exhausted. The frequency with which a pirn has to be replaced depends on the fineness of the weft yarn. Coarse yarns require more frequent replacement; finer yarns need to be replaced less often.

In the mechanical changer, full pirns are kept ready in a revolving case. The macgine rams them into the shuttle when the shuttle comes to rest briefly after crossing the yarn. The pressure of the full pirn crowds the empty quill out of the shuttle. It falls through a slot into a container under the loom. The new pirn is pushed mechanically into place in the shuttle, which has a self-threading device that automatically picks up the yarn when the new pirn is inserted. This allows the weaving to continue without a stop.

A specialized process has been developed that allows winding of pirns to take place at the loom. In the Unifil system, empty pirns are carried on a conveyer belt to a point where yarn from a large package is wound onto an empty pirn that is then returned to a position where it can be placed in the shuttle. This system requires that fewer wound pirns be supplied, but it has several limitations. It is useful only for single-colour picks, and because the cost of the system is high, it is most economical for coarse yarns that would require especially frequent pirn replacement. Picking when two or more different colours or types of weft yarn are used requires two or more shuttles and a more complex and costly type of loom arrangement. A conventional shuttle loom has one shuttle box on each side of the machine.

To insert yarns of different colours or types, a number of shuttle boxes must be moved up and down to bring shuttles into position to create the pattern. Such looms are often called pick-and-pick looms. Among the advantages of most shuttleless looms is that they draw yarn for each pick directly from yarn packages, making it easier and less costly to insert a number of different colours or types of yarn.

The length of fabric produced by a single weaving machine is determined by the length of the individual warp yarns wound on the warp beams. If a 500-yards length of fabric is needed, each end on the warp beam will be longer than 500 yards to provide enough yarn for the fabric length, plus an additional amount for certain allowances. The amount of fabric produced in a given time period is governed by the speed at which the picks are inserted.

The speed with which weaving machines operate has traditionally been expressed in picks per minute, or ppm. It operates at speeds ranging from about 110 to 225 picks per minute (ppm). As shuttle equipment was operated at higher speeds to increase mill productivity, the noise level in weave rooms became intense. Shuttle looms are extremely noisy because the picker stick, or bar that hits the shuttle across the shed, and the bar that catches it on the other side make loud clacking noises each time they make contact with the shuttle. The shuttle loom is the oldest kind of loom. It is effective and versatile, but it has other disadvantages. The shuttle sometimes causes abrasion on the warp yarns as it passes over them and sometimes causes thread breaks. This, in turn, results in machine stoppage in order to tie the broken yarns. Shuttle looms operate more slowly than some new types of looms.

B. Shuttleless Weaving Machines:

Shuttleless weaving machines were invented to increase the speed of weaving, reduce the literally deafening noise and overcome the other disadvantages of the shuttle loom. The modern loom with a shuttle, although much faster in operation than the earliest automatic looms, is not susceptible to further increases in speed because of the variety of operations that the machine must perform. Time is required for stopping the shuttle and accelerating it in the other direction and the weight of yarn on the pirn that must be carried across the shed limits the speed. For this reason, future loom developments are likely to be in the area of shuttleless weaving.

Shuttleless weaving machines wove 17 percent more fabric in 1987 than they did in 1982, and Textile World predicts that shuttle looms will be outnumbered by shuttleless weaving machines in the early 1990s.

Shuttleless machines may be classified as to the method used in inserting the weft yarns. Four basic types have been developed:

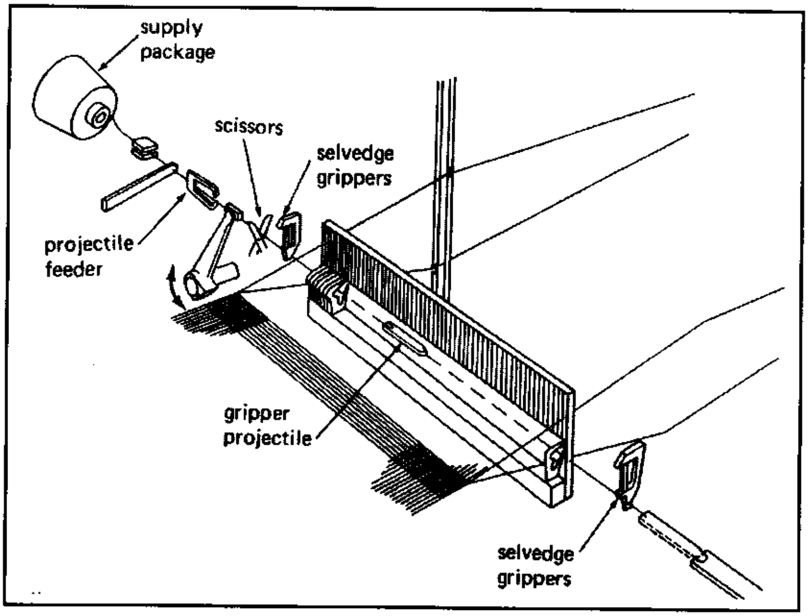
- Machines with grippers or projectiles (throw across)
- Machines with mechanically operated gripper arms or rapiers (reach across)
- Machines employing air or water jets to carry the weft (spit or blow across)
- Machines that form multiple sheds (multiphase)

In hand weaving and automatic shuttle weaving, the weft yarn is continuous and runs back and forth across the fabric, but in most shuttleless weaving, the weft yarn extends only from selvedge to selvedge, as it is cut off before it passes across the shed. In all shuttleless weaving, the yarn for the pick is unwound from large, stationary packages of yarn that are sometimes set on one side and at other times set on both sides of the loom. Since weaving speed depends on fabric width, there is every incentive to build wider machines for more efficient weft insertion.

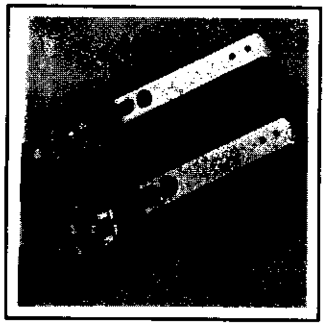
Projectile, Missile, or Gripper Weaving Machine:

These weaving machines were developed in the 1950s in Switzerland and represent the first proven shuttleless weaving machine. In the gripper or projectile type of weaving machine, a small bullet-shaped or hooklike device grips the end of the weft yarn, which is shown in the following figure. As the gripper is projected across the warp shed, it tows the weft behind it. The projectile can move more quickly than a conventional shuttle because of its decreased size; it can travel farther more easily, thereby making possible the weaving of wider fabrics, and it does not require the step of weft the shuttle; it pulls the yarn directly from a prepared yarn package.

Projectile looms with one or more projectiles are available; the multiple-projectile type is more common. Two types of projectile looms are used. In one, the projectile travels only in one directiis returned to the starting point by a conveyor belt. To maintain the weaving speed, each machin must have several projectiles, although only one is in use at any one time. It is called multiple-prtile systems. They can be used in machines with a wide weaving bed so the projectile grippers can transfer the pick across the fabric in a relay fashion. In other multiple-projectile systems, the gripper from the first projectile picks up yarn from the supply source and moves across the shed to lay that length of yarn; then, as beat-up occurs, the projectile drops into a conveyor system that returns it to the supply side to pick up new yarn. In the meantime, the second gripper has pulled a pick to repeat the process.



Operation principles for a projectile weaving machine



Steel gripper projectiles as small as 4 inches

In the other type of gripper machine, a single gripper inserts one weft yarn alternately from the right- and left- hand sides of the loom. It is called single-projectile system. This system picks up yarn on the supply side and carries it the entire width of the shed. After beat-up has occurred, the projectile picks up yarn from a second supply source on the other side and returns across the shed to place the next pick. The gripper serves the same function as a conventional shuttle, but instead of holding a pirn, it carries the yarn behind it. Packages of yarn must, therefore, be placed on both sides of the machine.

Each pick is individually cut, so there is not a continuously woven selvage like that produced by a shuttle machine. Instead, the edges are fringed. To finish them, a tucking device is used on both sides to interlace the fringe with the last few warp yarns along each edge.

Such machines may be wide or narrow; they are available in weaving widths up to approximately 508cm (200 inch). In addition to being quiet, machines are popular because they can deliver weft yarns from larger packages, which increases productivity reduces some faults in weaving.

The projectile machine not only weaves fabric more quickly than does the shuttle loom, but it runs with less noise, making it possible for manufacturers to comply more easily with government regulations that restrict noise levels.

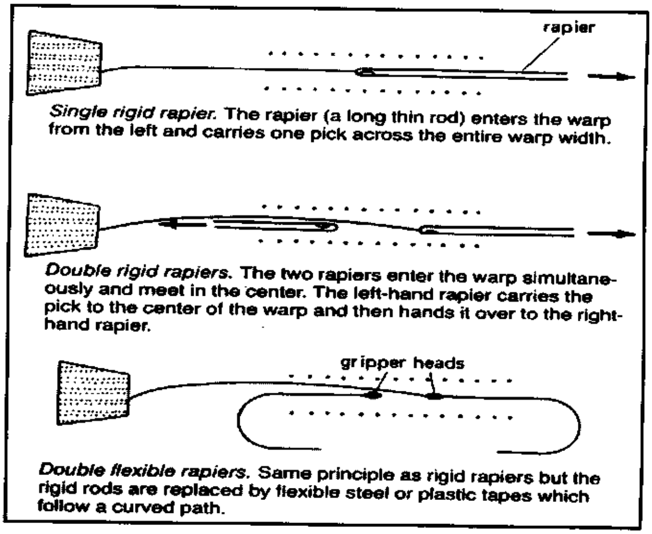
There is also a saving in power costs for wide-width fabrics. Narrow fabrics are not economically woven on this loom since too much time is spent in periods of acceleration of the gripper. Wide fabric widths are quite productive, as the power consumed is less than that for a conventional shuttle loom of the same size. Sheets are woven side by side on some of these machines to take advantage of these savings. According to data from producers of these machines, the looms can reach speeds slightly over 1,200 meters of weft yarn per minute.

The projectile loom has good versatility and is used for a wide variety of basic fabrics ranging from cotton-type goods such as percale and printcloth to worsted-type material. It does require a smooth, uniform yarn that is properly sized to reduce friction. The projectile loom has speeds of up to 300 ppm.

Rapier weaving machine:

As in the projectile loom, a stationary package of yarn is used to supply the weft yarns in the rapier machine. One end of a rapier, a rod or steel tape, carries the weft yarn. The other end of the rapier is connected to the control system. The rapier moves across the width of the fabric, carrying the weft yarn across through the shed to the opposite side. The rapier is then retracted, leaving the new filling in place.

In some versions of the machine, two rapiers are used, each half the width of the fabric in size. One rapier carries the yarn to the center of the shed, where the opposing rapier picks up the yarn and carries it the remainder of the way across the shed. A disadvantage of both these techniques is the space required for the machine if a rigid rapier is used. The housing for the rapiers must take up as much space as the width of the machine. To overcome this problem, looms with flexible rapiers have been devised. The flexible rapier can be coiled as it is withdrawn and will therefore require less space. However, if the rapier is too stiff, it will not coil; if it is too flexible, it will buckle. The double rapier is used more frequently than the single rapier. Rigid and flexible rapier machines operate at speeds of up to 1,300 meters of weft per minute. These rapier looms are efficient. They operate at speeds ranging from about 200 to 260 ppm at about the noise level of projectile looms. They can produce a wide variety of fabrics ranging from muslin to drapery and upholstery materials.



The operation principle of three rapier systems

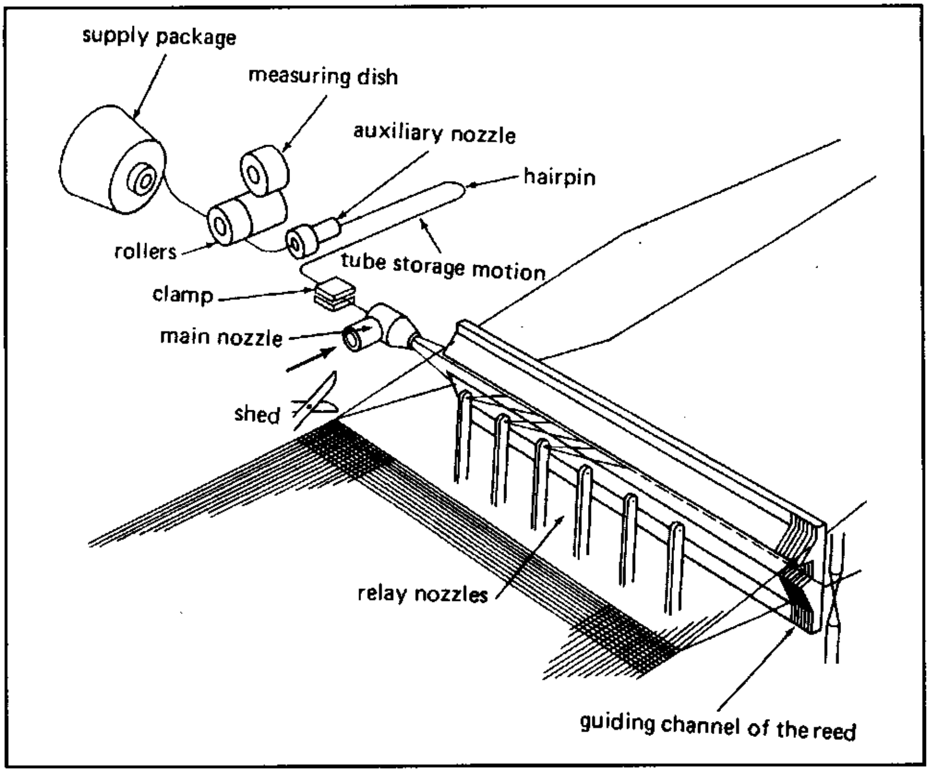
Newer rapier machines are built with two distinct weaving areas for two separate fabrics. On such machines, one rapier picks up the yarn from the center, between the two fabrics, and carries it across one weaving area; as it finishes laying that pick, the opposite end of the rapier picks up another yarn from the center, and the rapier moves in the other direction to lay a pick for the second weaving area, on the other half of the machine. The above figure shows the action on a single width of fabric for a single rigid rapier system, a double rigid rapier system, and a double flexible rapier system.

Rapier machines weave more rapidly than most shuttle machines but more slowly than most projectile machines. An important advantage of rapier machines is their flexibility, which permits the laying of picks of different colours. They also weave yarns of any type of fibre and can weave fabrics up to 110 inches in width without modification.

Air-jet Weaving Machine:

These weaving machines, invented in Czechoslovakia and later refined by the Swiss, Dutch, and Japanese were designed to retain the tensionless aspect of the picking action of the water jet while eliminating the problems caused by the use of water.

The above figure depicts the basic steps in air-jet weaving. The yarn is pulled from the supply package at a constant speed, which is regulated by the rollers, located with the measuring disk just in front of the yarn package. The measuring disk removes a length of yarn appropriate to the width of the fabric being woven. A clamp holds the yarn in an insertion storage area, where an auxiliary air nozzle forms it into the shape of a hairpin.



Operation principle of the Air-jet loom

The main nozzle begins blowing air so that the yarn is set in motion as soon as the clamp opens. The hairpin shape is stretched out as the yarn is blown into the guiding channel of the reed with the shed open. The yarn is carried through the shed by the air currents emitted by the relay nozzles along the channel. The initial propulsive force is provided by a main nozzle. Electronically controlled relay nozzles provide additional booster jets to carry the yarn across the shed. The maximum effective width for air-jet weaving machines is about 355 cm (140 inch). At the end of each insertion cycle the clamp closes; the yarn is beaten in, and then cut, after the shed is closed. Again, some selvage-forming device is required to provide stability to the edges of the fabric.

These weaving machines use a jet of air to propel the weft yarn through the shed at rates of up to 600 ppm. Data from manufacturers indicate that air-jet looms operate at speeds up to 2,200 meters of pick inserted per minute. They can weave multicoloured yarns to make plaids and are available with both dobby and jacquard patterning mechanisms.

Air-jet looms require uniform weft yarns. They are more suitable for use with heavier than lighret yarns because the lighter weight yarns are more difficult to control through the shed. Yet, if the yarn is too heavy, the air jet may not be able to carry the weft across the loom. Within these restraints, the air-jet loom is effective and can produce a wide variety of fabrics. Also, the air-jet loom operates at a lower noise level than the shuttle, projectile, or rapier looms. Air-jet weaving is more popular because the machines cost less to purchase, install, operate, and maintain than rapier or projectile weaving machines, and the air-jet can be used on a broader variety of yarns than a water jet.

Today automated flaw detectors installed on air-jet machines can inspect fabric. The unit on the batcher is programmed to stop the machine when defects that fall outside preset tolerances are detected. The batcher operator then cuts out the defect, seams the fabric, and restarts the fabric take-up. These flaw detectors are capable of inspecting fabric at 400 ppm.

Water-jet weaving machine:

These weaving machines were first developed in Czechoslovakia in the 1950s and subsequently refined by the Japanese in the 1960s. Water-jet weaving machines are not used as frequently as air jets, but they are preferred for some types of fabrics. The process is unsuitable for yarns of hydrophilic fibres because the fabric picks up too much moisture. Water-soluble warp sizings are used on most staple warp yarns. Therefore, the use of water-jet looms is restricted to filament yarns of acetate, nylon, polyester, and glass; yarns that are nonabsorbent, and those that do not lose strength when wet. Furthermore, these fabrics come off the loom wet and must be dried. In this technique a water jet is shot under force and, with it, a weft yarn. The force of the water as it is propelled across the shed carries the yarn to the opposite side. This machine is economical in its operation. A water jet of only 0.1 centimeter is sufficient to carry a yarn across a 48 inch shed. The amount of water required for each weft yarn is less than 2.0 cubic centimeters. Water-jet machines can reach speeds of 2,000 meters of picks per minute. The water-jet looms can produce superior high quality fabrics that have good appearance and feel.

Both air and water jet weaving machines weave rapidly, provide for laying different colours in the weft direction, and produce uniform, high quality fabrics. They are less noisy and require less space than most other types of weaving machines. They cause minimal damage to warp yarns during the weaving operation, because the air or water jets are less abrasive than moving metal parts.

The speeds of shuttleless weaving machines can be compared by measuring the picks per minute (ppm) or the yards laid per minute (ypm) in weft insertion. In 1990, the top speed for a projectile weaving machine was 420 ppm with between 1000 and 1203 ypm weft insertion. Flexible rapier machines operated at 524 ppm and rigid rapiers at 475 ppm, laying weft at up to 1404 and 930 ypm, respectively. Air jets could lay as many as 1200 ppm and water jets up to 1500 ppm, laying 2145 and 2360 ypm, respectively.

If a fabric 60 inches wide is woven on each machine at a density of 50 picks per inch, approximately 84 yards of weft yarn would be needed to produce an inch of fabric. In theory, the projectile would produce approximately 8.4 inches of fabric per minute; the flexible rapier, 10.5 inches; the rigid rapier, 9.5 inches; the air jet, 24 inches; and the water jet, 30 inches. The slowest of the new machines could produce a yard of fabric in 4.3 minutes, and the fastest would take just 1.2 minutes. Seldom do weaving machines operate at full capacity, but even at 50 percent efficiency such machines could produce a yard of fabric every 2.5 minutes.

Multiphase or multished weaving machine:

All the weaving techniques discussed thus far require that the shed be open all the way across the machine for the device carrying the filling yarns to pass through the shed. This imposes a limit on loom speed. The multiphase weaving machine overcomes this limitation by forming many different sheds at different places across the machine and forming these only as the weft yarn inserted. In this way, a number of weft yarns can be inserted, one behind the other. As a section of the shed opens, the weft passes, and the shed closes, opening again in the new pattern as the next weft yarn arrives. Speed is increased because of the number of yarns that can be inserted almost simultaneously one right after the other, but the actual speed of movement of the weft yarns is lower than in other types of machines. For this reason, weft yarns that are weaker can be used. Sultzer Ruti, the manufacturer of a multiphase machine, states that its loom will insert up to 5,400 meters of pick per minute.

The process transforms weaving into a continuous process rather than a cycle of shedding, picking, and beating up. Multiphase loom continually inserts weft yärns from yarn carriers. Rotary beat-up devices press inserted yarn firmly against previously formed cloth. If the pattern changes, small groups of yarns are changed into a new shedding position after each new yarn carrier has passed.

The operation of multished weaving machines is based on a series of wavelike motions across the weaving surface. In general, fabrics woven on these looms do not have a true 90- degree angle between warp and weft; the weft yarns are slightly slanted, or skewed. Multished weaving is limited to special types of fabrics, but it can be expected to gain acceptance in the years ahead.

As many as 16 to 20 weft carriers insert the precut weft in a continuous process instead of the intermittent process of single-shed weaving. Beating up and shedding arrangements are different. In this continuous weaving process, the number of picks per minute is doubled. However, multiphase looms have never been extensively used in the industry.

Fabric selvages or selvedges:

In yard goods, the outer edges are constructed so they will not ravel. These finished edges are called the selvages (self-edges) and are often made with heavier and more closely spaced warp yarns than are used in the rest of the fabric by using more or stronger warp yarns or by using a stronger weave. Selvages (also called selvedges) provide strength to fabric for safe handling of the fabric. Selvage should not curl. The warp yarns always run parallel to the selvedges. Proper use of the selvages can also prevent the bowing and bias conditions that occur in some fabrics. The weaving machines need mechanisms which through the formation of sufficiently strong selvages bind the wefts together, thus imparting to the fabric a proper appearance and solidity and preventing the breaking up of the threads on the fabric edges during the subsequent operations.

In shuttle looms, there is no need for special selvedge; since the yarn is not cut after each weft insertion, the edges of the fabric are smooth and strong. On conventional shuttle looms, it is formed when the weft yarns turns to go back across the fabric. The conventional loom makes the same kind of selvedge on both sides of the fabric. At the present time this is the only advantage of shuttle loom over shuttleless loom. In shuttleless weaving, since the weft yarn is cut after every insertion, there is fringe selvedge on both sides of the fabric. In this case, special selvedges are needed to prevent slipping of outside warp yarns out of the fabric. There are several types of selvedge designs that are used for this purpose with shuttleless looms. The kind of selvedge used depends upon economy of production and the expected use of the fabric.

- **Plain selvages:**

  These selvages are constructed of the simple plain weave with the same size yarn as the rest of the fabric, but with the threads packed more closely together. Such selvages are fairly durable and firm. Plain selvages are similar to the structure of the rest of the fabric. They do not shrink and can be used for seam edges.

- **Tape Selvages:**

  The tape selvages are sometimes constructed with the plain weave but often are made of the basket or twill weaves, which makes a flatter edge. Tape selvages are made of heavier yarns or ply yarns, which provide greater strength. They are firmer and wider than plain selvages. For towels, bed sheets, drapery and curtain fabrics, tape selvages give added strength to the edges. Selvages vary in width from one-quarter to three-eights of an inch.

- **Split selvages:**

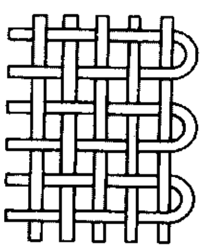
Split selvages are made by weaving a narrow width fabric twice its ordinary width with two selvages in the center. The fabric is then cut between the selvages, and the cut edges are finished with a chain stitch or hemming. Split selvedges are used when items such as towels are woven side by side and cut apart after weaving.

- **Fused selvages:**

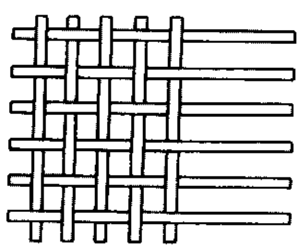
These selvages are made on fabrics of thermoplastic fibres, such as polypropylene, nylon, etc., by pressing a hot mechanical element on the edges of the fabric. The fibres melt and fuse together, sealing the edges. Electronically controlled thermal cutters are used to cut and fuse selvedges of synthetic fabrics on weaving machines. The temperature of the cutters is reduced when the machine is stopped. This technique is sometimes used to split wide fabrics into narrower widths.

- **Leno selvages:**

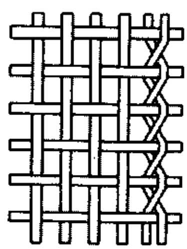
The leno selvages are obtained by binding the wefts with strong additional threads working in leno or gauze weave and by eliminating through cutting the protruding weft ends. Half cross leno weave fabrics have excellent shear resistance. They are made with special leno weaving harnesses. The leno selvage is used on some shuttleless looms. The construction utilizes a narrow leno weave, which locks the cut ends along the fabric edge. A loose weave generally requires a tight leno selvage, whereas a light weave may have a leno selvage with less tension. The leno gauze system is optimally suited for heavy fabrics, blankets, wall coverings.



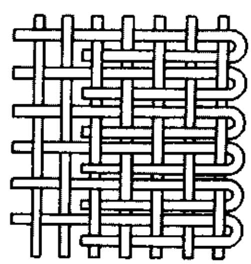
normal bound selvage as produced by a shuttle loom



fringe selvage



leno selvage (not twist)



tucked selvage

- **Tucked-in selvages:**

The tucked selvedge is a technique used on some shuttleless looms. A device is used to tuck and hold the cut ends into the fabric edge. In tucked-in selvage, the fringed edges of the weft yarns are woven back into the body of the fabric using a special tuck-in mechanism. As a result, the weft density is doubled in the selvage area. Tucked-in selvedge was being only used for projectile weaving machines in the past, however, it is now also applied to other shuttleless weaving machines. This system is generally used for light to middleweight fabrics, when weave and fabric density permits. There are also available tucked-in selvage motions, which are entirely controlled by pneumatic or mixed pneumatic and mechanical devices.

The construction of the selvage is dependent upon the particular weave and a number of other factors. A formula for weaving the tucked-in selvage considers fibre density, the diameter of the yarns (which is also affected by twist, ply, and count variation), as well as the yarn diameter balance, or ratio of the diameter of the weft yarn to that of the warp yarn – in effect, if the diameter of the weft yarn is finer than the diameter of the warp yarn, fewer wefts can be inserted in the fabric selvage, because the warp intersection requires more space between the wefts than one diameter of the weft.

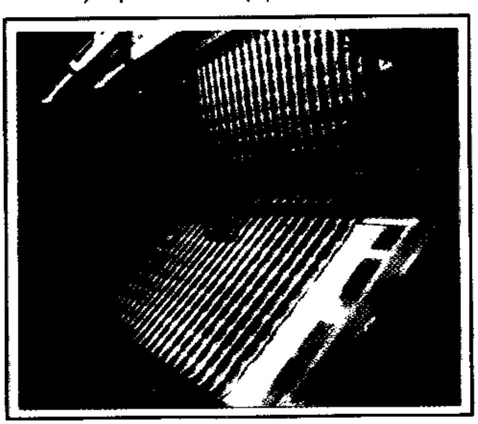
When setting up for the selvages on a projectile weaving machine, the following points must be noted.

- The selvage must be drawn into the reed 15 mm wide.
- The selvage must not be thinned too much.
- The reed must be filled with yarns up to the last dent.

If possible, the selvages are always drawn-in on separate harnesses. The selvage harnesses are always behind the ground harnesses, so that the front shed is shorter. This arrangement enables the shed to be adjusted smaller.

Grey Fabric Inspection Lines:

After weaving, some fabrics are inspected on the weaving machine for quality purposes. Inspection speed can be varied between 0 to 100 linear meters per minute. Inspection machines have a lighted diffusion screen. Fabric alignment is controlled by a mobile trolley operated by photocells to sense the cloth.



FABRIC STRUCTURE AND DESIGN