4

WINDING, WARPING, AND SIZING

4.1 INTRODUCTION

A plain woven fabric is produced by interlacing two sets of threads, commonly known as warp and weft (or filling). Warp usually runs along the length of the fabric and the weft or filling essentially at a right angle to warp across the width of the fabric, as shown in Fig. 4.1a. The process of interlacement (Fig. 4.1b), commonly known as weaving, transforms the individual yarns into a woven fabric. Although there is a large variety of different ways to interlace two sets of threads to produce different types of fabric structures, a plain weave is the most widely used.

A fabric usually consists of several thousand warp yarns across the whole width. It is in no way practically feasible to weave a fabric by placing several thousand warp yarn packages side by side at the back of a weaving machine, i.e., the loom, for numerous reasons. The weaving process, therefore, requires the preparation of a weaver's beam which is placed at the back of the loom. The weaver's beam contains the exact number of warp yarns (ends) required to produce a fabric of the given specifications. To assemble the weaver's beam containing several thousand warp yarns and to make it sufficiently strong to withstand mechanical stresses and abrasion during weaving, the warp yarns generally need to be sized with chemicals by the process known as sizing or slashing. It is also not practically feasible to place several thousand warp yarns at the back of the sizing machine. So a number of flange beams, called warper's beams, containing several hundred warp yarns are placed at the back of the

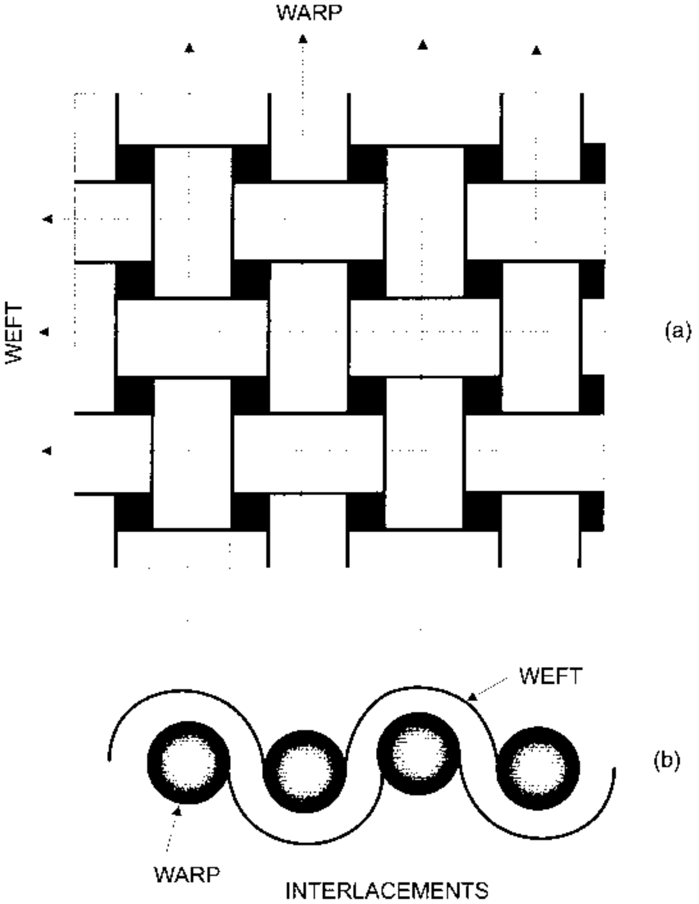


Fig. 4.1 Interlacements in plain-weave fabric.

sizing machine. A single warper's beam is assembled by placing in the creel as many packages as required by the number of yarns in it. The packages placed in the creel of the warping machine are large wound packages in the case of ring-spun yarn or direct packages from modern spinning systems such as open end, friction, and air jet. Therefore, in a nutshell the process of weaving requires certain preparatory steps to transfer the spun yarns from the spinner's package to a weaver's beam ready for weaving [1]. The processes involved are

1. Winding
2. Warping
3. Sizing
4. Drawing-in and tying

The success of the weaving operation is considerably influenced by the quality of yarn and the care taken during the preparatory weaving processes, such as winding, warping, and sizing. Also, careful consideration of the sizing ingredients, size add-on levels, process of slashing, and slasher-related parameters are a few of the several variables that must be controlled precisely for the success of an efficient weaving operation. The yarn supplied from the spinning machines should be sufficiently strong, uniform, smooth, knot-free, and slub-free to withstand the cyclic stresses and abrasion the yarns are subjected to during the process of weaving. Table 4.1 summarizes the characteristics of a good warp yarn for efficient weaving. A poor quality yarn will cause excessive breakages during weaving no matter how carefully the warp has been assembled during the preparatory weaving processes.

The warp yarn supplied to the warping machine should be uniform, free of all objectionable faults, and wound on a reasonably large package of a suitable build that unwinds trouble-free in the warping creel. Also, the knots or splices, introduced for removing faults and tying-in yarn from a number of bobbins during the winding operation, should be reasonably small and sufficiently strong so as to allow them to freely pass through the heddle eyes and dents of reed and withstand the weaving operation. The warp beams prepared during the warping operation should have a large length of yarn with all the warp yarns laid parallel with sufficient space between them. The density of

Table 4.1 Characteristics of a Good Warp for Efficient Weaving

Strong
Uniform
Smooth
Knot-free
Slub-free
Withstands abrasion of moving loom parts
Withstands cyclic strains and stresses of loom

the warp beam should be uniform from the start to finish to ensure trouble-free unwinding in the creel of the sizing machine. A carefully prepared warping beam with a uniform density and no broken ends or cross-ends contributes toward the success of slashing and weaving. The following sections give a brief discussion of the winding, warping and sizing processes.

4.2 WINDING

Unevenness in traditionally spun staple yarns is a natural phenomenon usually induced by the process of manufacturing (spinning). Although with modern process controls and machines many imperfections in the spun yarns can be controlled, some still remain in the final yarns. Most common of all imperfections are thin or weak places, thick places, slubs, neps, and wild fibers, as shown schematically in Fig. 4.2. During the subsequent processes of winding, warping, and slashing, not all but some of these imperfections create obstacles to steady and smooth working. Therefore, it is important to classify, quantify, and remove those imperfections which may cause the interruption of the operation. In other words, only ''objectionable'' faults need to be removed for trouble-free processing of the yarns.

The ring-spinning operation produces a ring bobbin containing just a few grams of yarn which is unsuitable for the efficiency of further processing, such as warping, twisting, and quilling. This necessitates the preparation of a dense and uniform yarn package of sufficiently large size which can unwind in the subsequent operations without interruptions. The packages prepared for warping are normally cross-wound, containing several kilograms of yarns. This implies that a number of knots or splices are introduced within each final package. Bear in mind, each knot or splice itself is an artificially introduced imperfection; therefore, the size of this knot or splice must be precisely controlled to avoid an unacceptable fault in the final fabric. In modern winding machines, knots and splices are tested photoelectrically for size, and only acceptable knots and splices are allowed to pass on to the winding package. In modern spinning processes, such as open end, friction and air jet, the spinning process itself produces a large cross-wound package, thus eliminating the winding operation. Nowadays splices are used on all the spinning systems including ring, open end, and air jet for repairing ends down during spinning. In the absence of winding, it is pertinent to note that the yarn spun on such modern spinning systems must have no or only a small number of objectionable imperfections. In most modern spinning machines, the manufacturers have incorporated devices that continuously monitor the quality of the yarn being spun, thus assuring fault-free spun yarns.

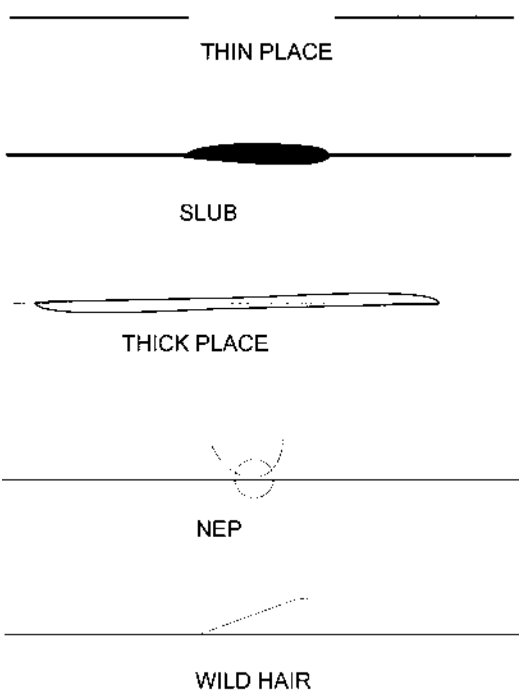


Fig. 4.2 Schematics showing typical yarn faults.

4.2.1 Functions of the Winding Operation

Important functions of the winding operation are

1. Clearing of yarn faults
2. Making larger wound packages
3. Preparing soft packages for dyeing

Clearing

Clearing is a process of removing imperfections from the spun yarn. The clearing operation must be carried out during the winding process only because the cost of the winding/clearing operation is usually far lower than that of the subsequent operations, such as warping, slashing, and weaving [1]. Moreover, attempting to clear faults at a later stage (e.g., in warping) will be inefficient as a number of good warp yarns will become inoperative. For example, a break of a single warp yarn on the loom brings the entire loom to a stop, thus reducing the efficiency of the loom.

The imperfections or faults which occur in spun yarns include slubs or thick places, weak or thin places, neps, and wild fibers, as shown in Fig. 4.2. Thin places in the yarn are usually weak spots, making the yarn susceptible to breakage during subsequent preparatory and weaving operations. Therefore, such thin places which are weak should be replaced with a strong knot or splice. Some of these thin places which are not unacceptably weak can be covered by the application of size during the slashing operation. The thin places are usually removed by applying tension to the yarn during the winding process. The level of tension applied determines the number of thin places (weak spots) removed. Thin places having a breaking strength lower than the tension applied are usually broken during the winding operation. Thick places and slubs are the places in the yarn having a diameter significantly greater than the normal diameter of the yarn. Such faults are removed either electronically (using optical or capacitance sensors) or mechanically. In the latter case, the yarn is passed through a small slit, usually twice or more the size of the diameter of the yarn during its travel from the ring tubes to the winding package, as shown in Fig. 4.3. Those slubs and thick places larger than the opening of the slit are cut and replaced by a knot or an end-to-end splice. Otherwise, in modern winding machines thick places and slubs are measured by a photoelectrical device which continuously senses the diameter of the yarn being wound and compares the cross section of the yarn with that of such faults.

Making Larger Packages

Making larger packages is an essential function of winding, especially for staple yarn spun on a ring-spinning system. Smaller ring bobbins containing relatively short lengths of yarn are cross-wound onto a larger wound package, usually a cone or parallel wound or flanged cylindrical package. These wound packages, as shown in Fig. 4.4, are made up of several ring bobbins by joining the ends. Such increased lengths of yarns will ensure continuous operation in subsequent mass production processes such as warping, twisting, quilling, and weaving.

The type and quality of package prepared during winding depend upon the winding systems employed. There are three principal types of winding that are commonly used on modern winding machines, namely,

1. Random or open winding
2. Precision winding
3. Digicone winding

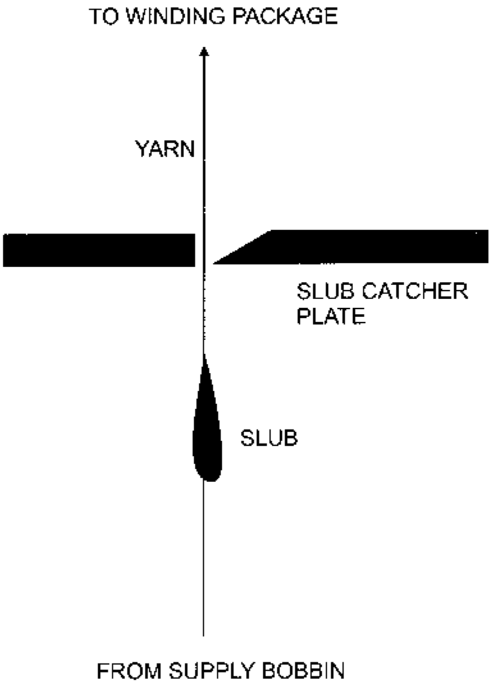
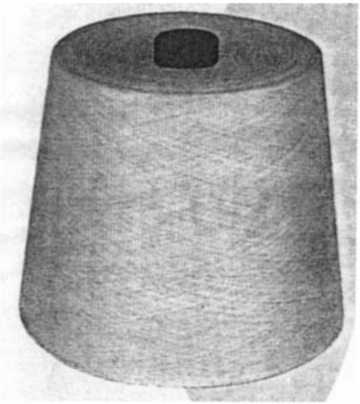


Fig. 4.3 Schematic showing the principle of mechanical slub and thick place removal during winding.

In random or open winding the package is surface driven by its frictional contact with the driving cylinder or drum, as shown in Fig. 4.5. In the case where a plain driving cylinder is used for driving the package, the yarn guide is driven by belts or gears to impart one full traverse along the length of the package. However, in most modern winders the driving drum is grooved so as to guide the yarn for a full traverse across the length of the package. More often, the drum is driven by a shaft, running at a constant speed, across the whole length of the winder or by an individual motor attached to each drum. In this type of winding, the ratio between the package revolutions per minute and the double traverse, known as winding ratio, changes constantly during the entire process of winding. For a bigger package, this winding ratio is small and vice versa. The helix angle—half of the crossing angle—does not change throughout the build of the package. As the double traverse remains constant,



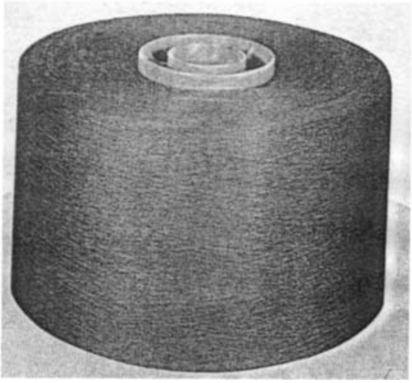


Fig. 4.4 Cross-wound packages.

the increase in the package diameter has to be compensated with a constant decrease of revolutions per double traverse, this results in gradually decreasing winding ratios. When this winding ratio becomes a whole number, such as 1:1, 2:1, 3:1, and so on, the yarn is laid over the yarn wound in the previous traverse, resulting in the formation of a ‘‘ribbon’’. This ribbon zone has a higher winding density and poor unwinding behavior caused by ‘‘sluff-off’’ of the yarn. Prevention of ribbon formation is achieved by several methods, namely, (1) modulating the yarn guide frequency, (2) creating slippage between the package and grooved drum, and (3) lifting the package away from the driving drum at fixed time intervals. All these methods momentarily alter the winding ratio, thereby avoiding ribbon formation [2–4].

In precision winding, the package itself is driven by a train of gears, and the yarn guide is directly connected as shown in Fig. 4.6. The ratio between the package revolutions and the double traverse—the winding ratio—remains constant, whereas the helix angle changes constantly throughout the package build, higher (open) at the smaller package diameter and lower (close) at the higher package diameter. Because the package itself is driven, the rotational speed (rpm) of the package has to be decreased constantly with the increase in the package diameter so as to maintain constant winding speed. The major

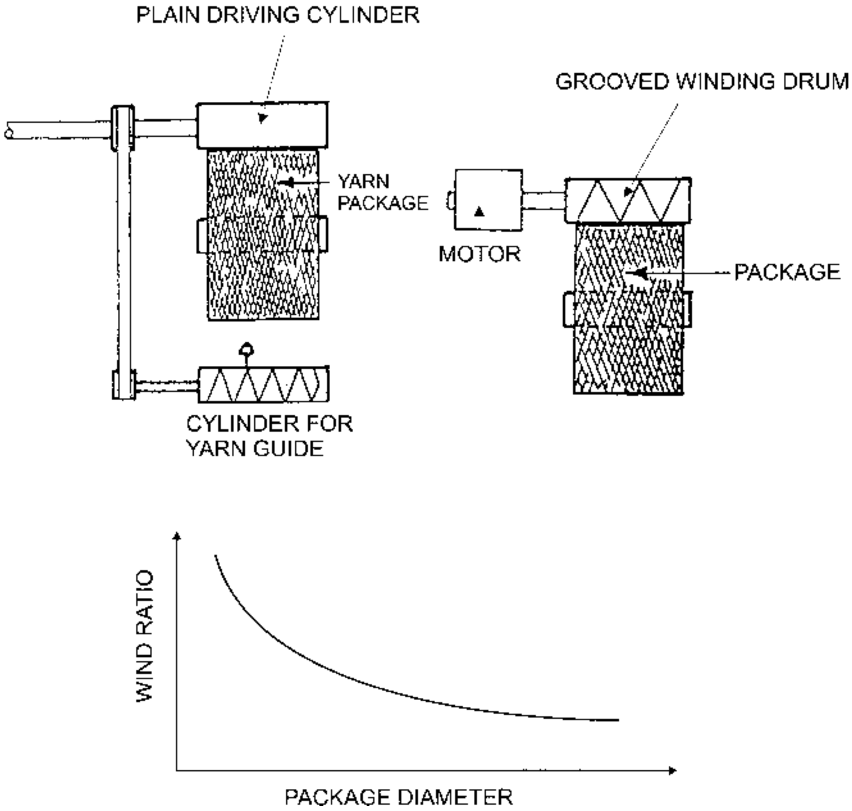


Fig. 4.5 Random winding. (From Refs. 4 and 5.)

advantage of this type of winding is that there is no ribbon formation because the winding ratio remains constant throughout the package. However, the major drawback of this type of winding is constantly increasing density of the package as the package grows larger because of the constantly decreasing helix angle [2–4].

A more recent development of winding type is ‘‘Digicone’’ winding, where the control systems, consisting of digital microprocessor, produce well-built packages of uniform density. A schematic of Digicone winding is shown in Fig. 4.7 The control system consists of two sensors, n_1 and n_2, to register the revolutions of the package and variable drive, P. The microprocessor calculates and analyzes the signals provided by the sensors, placed near the package holder and the traverse mechanism. These values are in turn compared with the programmed values (in EPROM), and the drive system is activated as

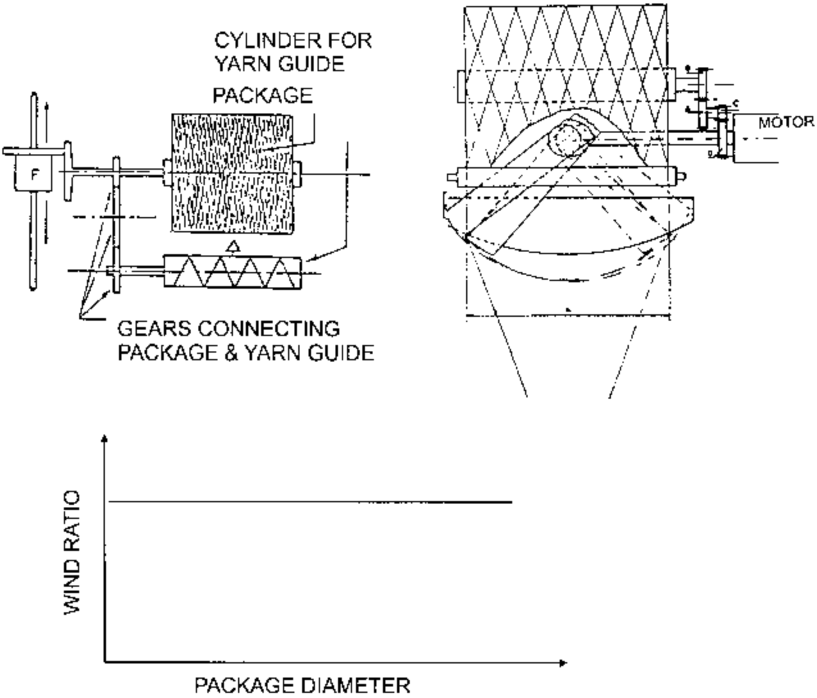


Fig. 4.6 Precision winding. (From Refs. 4 and 5.)

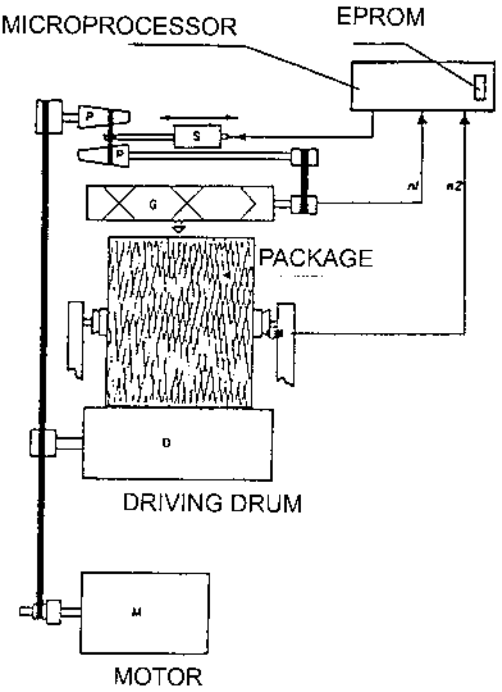


Fig. 4.7 Digicone winding. (From Ref. 6.)

necessary. On the Digicone winder the most appropriate helix angle for a particular end-use application can be ascertained. For difficult-to-dye yarn, a crossing angle of 18° is proved to be best. On the other hand for accommodating longer lengths of yarn on the package the crossing angle may be decreased to as low as 10°. On the Digicone system, any crossing angle between these two extreme limits (10 to 18°) can be easily set by changing the appropriate pulley on the shaft of the driving drum, D. The crossing angle remains constant because the drive to drum and the yarn guide are connected through the variable drive and belts, as shown in Fig. 4.7. The mechanism allows the process to achieve correct winding speed and traverse of the yarn guide to maintain constant crossing angle [2–4].

In Digicone winding, the mechanism begins with a precision winding operation such that a crossing angle of α_1 is set initially. As the winding progresses (the package diameter increases), the crossing angle decreases until a programmed crossing angle of α_2 is reached. At this stage, the microprocessor will reset the drive to change the crossing angle back to the same level as in the beginning, i.e., α_1. Again the precision winding is continued until a preprogrammed crossing angle of α_2 is reached, and so on until the final package diameter is reached. Figure 4.8 graphically displays this process of package building. The difference between α_1 and α_2 is set to such a small value that no appreciable density difference occurs. This results in stable, uniform, and well-built packages, leading to optimal performance during weaving, knitting, and dyeing operations [5,6].

Soft Packages for Dyeing

For cloth produced from dyed yarn, the preparation of the yarn packages ready for dyeing is usually carried out at the winding stage. The packages to be dyed should have a low but uniform winding density from start to finish, uniform package build, and identical packages and tube dimensions. These factors influence the level and uniformity of dyeing within and between the packages and also between batches. The soft wound packages allow the dye liquor to freely circulate between the layers of yarn so as to yield uniform and level dyeing of the yarns. The density profile of the package is shown in Fig. 4.9. The density varies gradually from the inside to the outside of the package as shown. Any loss in the density of the package in the inner layers is compensated for by the increased density in the outer layers.

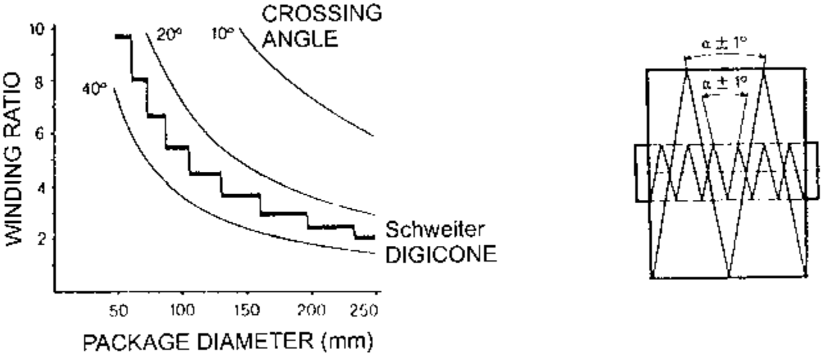


Fig. 4.8 Relationship between winding ratio and package diameter for digicone and precision winding. (From Ref. 6.)

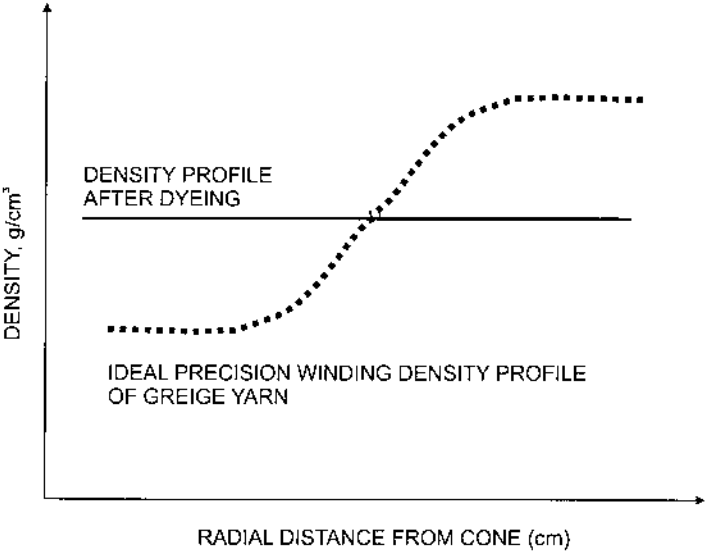


Fig. 4.9 A typical winding density profile.

For producing low density packages the most important parameter to control is the winding tension and the pressure between the package and the winding drum. Usually dyeing packages are wound with a minimum of winding tension; there is, certainly, a danger of allowing some weak places to be wound on the packages. A reasonable trade-off between the minimization of the winding tension and passing-on of the weak places to the packages should be maintained. On modern winding machines, as the diameter of the wound package increases, the pressure of the package to the winding drum is automatically reduced. This prevents the outer layers of the dyeing packages from having more compact winding than the layers beneath them.

For ensuring uniform dyeing of the yarns closer to the bare package, it is customary to use perforated tubes or cones, as well as coiled spring tubes covered with a paper or knitted material. Such packages allow dye liquor to freely circulate from the inside to the outside of the package, thus ensuring uniform and level dyeing. Before dyeing, the packages are usually subjected to a prewetting and scouring treatment. Due to the wetting, the yarn swells and shrinks, thus resulting in an increase in packing density resulting in higher resistance to flow of dye liquor. Therefore, sufficient allowance should be made for the yarn to shrink due to swelling, without adversely affecting the dyeability of the wound packages.

In a nutshell, the purpose of the winding operation is to supply adequate length of yarn to the warping operation which requires yarn that is uniform, is free of all objectionable imperfections, and has as few knots or splices as practically feasible. The wound packages should have a satisfactory build so as to allow uniform unwinding in the creel of the warping machine. Also, the knots or splices introduced during the winding operation should be small enough, thus enabling them to freely pass through the heddle eyes and the reed dents of the loom, as well as be strong enough to withstand the weaving operation.

4.2.2 Knotting/Splicing

The process of piecing (joining) two yarn ends—resulting from yarn breaks, removal of a yarn defect, or due to the end of the supply package—has received considerable attention in the past two decades. An ideal yarn piecing would be one which can withstand the subsequent processes without interruption and which does not lead to any deterioration in the quality of the finished product [7]. The yarn joining or piecing technique should be suitable for all fiber types irrespective of yarn structure and linear density. Earlier attempts in this area were directed to tying two ends by a weaver's knot or fisherman's knot such that the ends do not slip apart. However, the size of the knot, which depends on the type of knotter and the linear density of the yarns, would normally be two to three times the diameter of the single yarn, leading to a characteristic objectionable fault in the finished product. Knots have a detrimental effect on quality; they are obstructive because of their prominence and so frequently cause breaks due to catching in thread guides or even being sheared off. This leads to time-wasting stoppages of the machinery during warping, sizing, and weaving. Due to the above-mentioned drawbacks of knotted yarns, knotless yarn joining methods have received considerable attention by researchers [7–9].

Methods for Producing Knot-Free Yarns

The development of methods for producing knotless yarns began during the early 1970s. Various methods have been used for producing knot-free yarn piecing, including [8]

1. Wrapping
2. Gluing

3. Welding or fusing
4. Splicing
    a. Mechanical splicing
    b. Electrostatic splicing
    c. Pneumatic splicing

In the wrapping method, two yarn ends are overlapped, and an auxiliary yarn is wrapped around them to produce a joint of high strength, as shown in Fig. 4.10a. This method produces a thick and rigid joint, and the mechanism involved is very complicated. The auxiliary thread often causes problems during subsequent processing. In the gluing method, two overlapped ends of yarns are glued by a special adhesive, as shown in Fig. 4.10b. This technique produces a thick joint and rigid structure because of the rigidity of the glue (adhesive) used. Also, drying of the adhesive takes a long time, resulting in lower productivity of the process. In the welding technique two yarn ends are welded together by a melting process, as shown in Fig. 4.10c. Although this technique produces a short but high strength joint, it can be applied only for thermoplastic fibers (e.g., nylon), and the welded portion has a different structure due to the melting process [8]. The first three methods listed above are no longer used in practice because the pieced portion (joint) is thicker and more rigid and also in one case contains an extraneous material, namely, the adhesive.

Splicing

In splicing, the joint is more or less like the yarn itself and produces sufficiently strong piecing without adversely affecting the appearance of the final fabric, and consequently it is more widely used in modern winders. The concept of splicing is similar to the method of joining rope (or cable) ends together. For the purpose of joining, the two ends of a rope are untwisted and then intermingled by some mechanical means. The methods of yarn splicing involve mechanical, electrostatic, and pneumatic systems [7].

Mechanical Splicing. In mechanical splicing the yarn ends are untwisted to open the fibers. Two ends are overlapped and then twisted together again to essentially the same twist level as in the basic yarn, as shown in Fig. 4.10d. The fibers at the end of the yarn are used to bind the splice joint resulting in a corkscrew-like appearance. The disadvantages of this system are (1) it is difficult to open up the yarn ends consistently due to irregular twist distribution; (2) it is possible to achieve proper separation of fibers at yarn ends only for short staple fibers—for long staple yarn it is somewhat difficult to separate fibers at the yarn ends, which has a negative effect on binding of fibers; (3) different twisting wheels are required for opening and twisting of yarns of

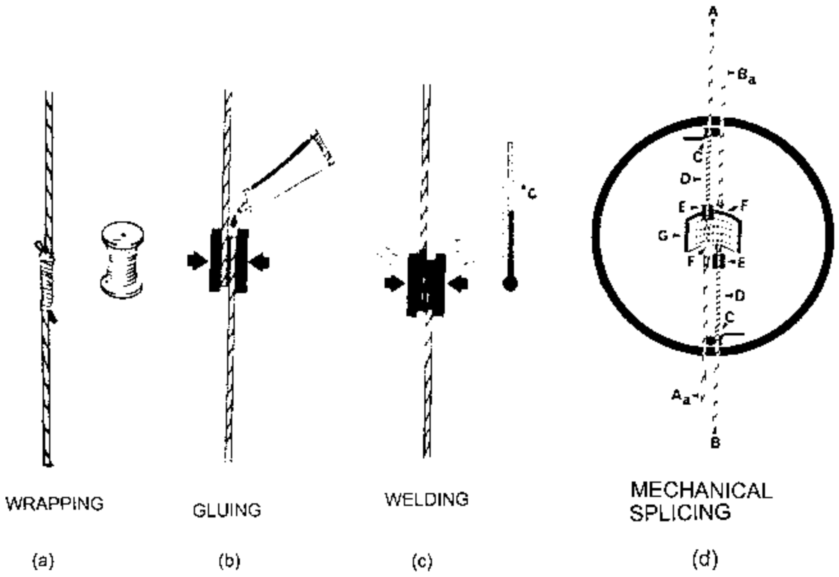
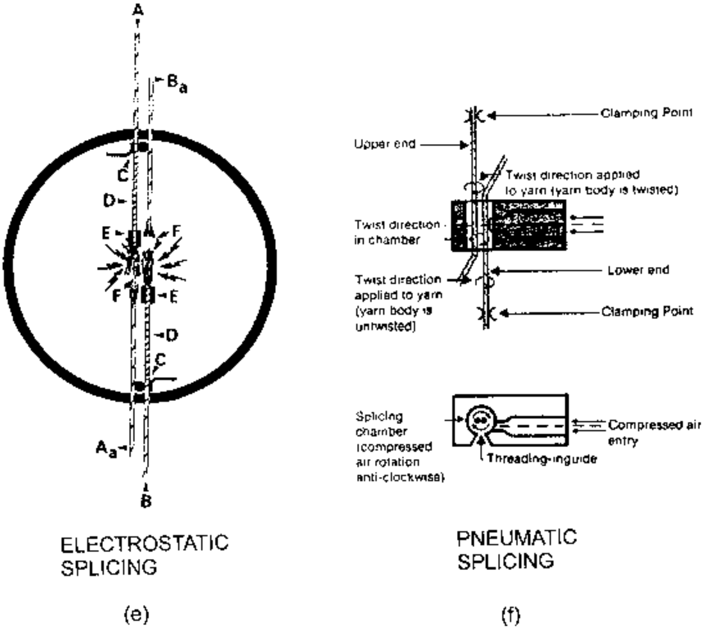


Fig. 4.10 Different methods for producing knot-free yarn. (From Refs. 7 and 8.)

different twist levels and made from different staple length fibers, involving costly adjustments; (4) in this splicing technique it is not possible to splice plied yarns as opening by untwisting is not possible; and (5) mechanical splicers require more frequent maintenance and servicing due to the entry of dust and fly [8].

Electrostatic Splicing. The yarn ends are separated and untwisted in the opening zone. The opened-up yarn ends are then spread out evenly in an electrostatic field, after which they are intermingled and bound again by a pole change, while simultaneously twist is inserted corresponding to the twist in the basic yarn, as shown in Fig. 4.10e. Theoretically, this method of splicing is very suitable as it provides ideal blending of fibers in the splice zone, but it suffers from some practical drawbacks; these include

1. Required opening and separation of fiber ends for effective spread-out in the electronic field is not always achieved satisfactorily. This is due to irregular twist distribution in the base yarn.
2. For a yarn containing a large number of fibers in the cross section



(e) (f)

Fig. 4.10 Continued.

the intermingling of prepared fibers at the yarn ends is a problem as fibers obstruct one another.

3. Plied yarns cannot be spliced due to difficulty in opening fibers at the yarn ends by mechanically untwisting.
4. The time taken to splice the yarn is quite long, thus decreasing the efficiency of the winding process. Also, high voltage is required to achieve the desired charge. The climatic condition of the winding room has an obvious effect on the electrostatic field [8].

Pneumatic Splicing. In this method, the yarn ends are inserted into a splicing chamber and then overlapped to join them together by means of a strong current of compressed air, as shown in Fig. 4.10f. The splicing time and air pressure are determined according to fiber type and yarn characteristics [8]. The splicing operation consists of the vertical application of air to the fibers and a simultaneous rotational movement of the air to twist/untwist the yarn. This type of air movement is achieved by the position of the blower apertures and the design of the shape of the splicing chamber. Pneumatically spliced yarn produces a joint that can meet all the requirements in subsequent processing, both in terms of strength and appearance. The time taken to carry out efficient pneumatic splicing is relatively short, thus winding efficiency is not severely limited. Moreover, pneumatic splicing can be applied to a wide range of fiber and yarn types without requiring precise adjustments or settings, thus facilitating efficient winding [8].

Double Splicing. This splicing technique has attained considerable importance in the synthetic fiber manufacturing industry because knots have a detrimental effect on quality. A new splicing technique called ‘‘double splice’’, based on the principle of pneumatic splicing, is normally used in joining continuous filament yarns and tire cords. In this technique, yarn filaments are intermingled by using an air splicer, leaving virtually no protruding ends [9].

4.3 WARPING

Warping is a process of transferring yarn from a predetermined number of single-end packages, such as cones or cheeses, into a sheet of parallel yarns of a specified length and width. The individual warp yarns are uniformly spaced across the whole width of the beam. In warping, the sheet of parallel yarns is wound onto a flanged beam called a warper’s beam [10]. The function of warping is primarily to transfer large lengths of yarns from a number of large wound packages to a warper’s beam containing a predetermined number of yarn ends (threads), so that it runs without interruption at a high speed. Removing faults from yarns during warping is not recommended because it affects the efficiency of the process. A single break makes several hundred other good warp yarns inoperative, thus affecting productivity.

4.3.1 Warping Systems

There are two basic systems of warping, namely, the direct system and the indirect system, as shown in Fig. 4.11. In the direct system the warp yarns from a creel are wound directly onto a flanged warper’s beam. This system is most widely used for mass production of warper’s beams containing only one type of warp yarns. Because of the difficulties involved in setting up a pattern of different types and colors of warp yarns, the direct system is not normally used for the preparation of a patterned warper’s beam [1]. Any pattern that is required to be produced is adjusted by combining beams of different colors during the slashing operation. The cumbersome work of setting the pattern at the slashing stage is time intensive and inefficient. In the indirect

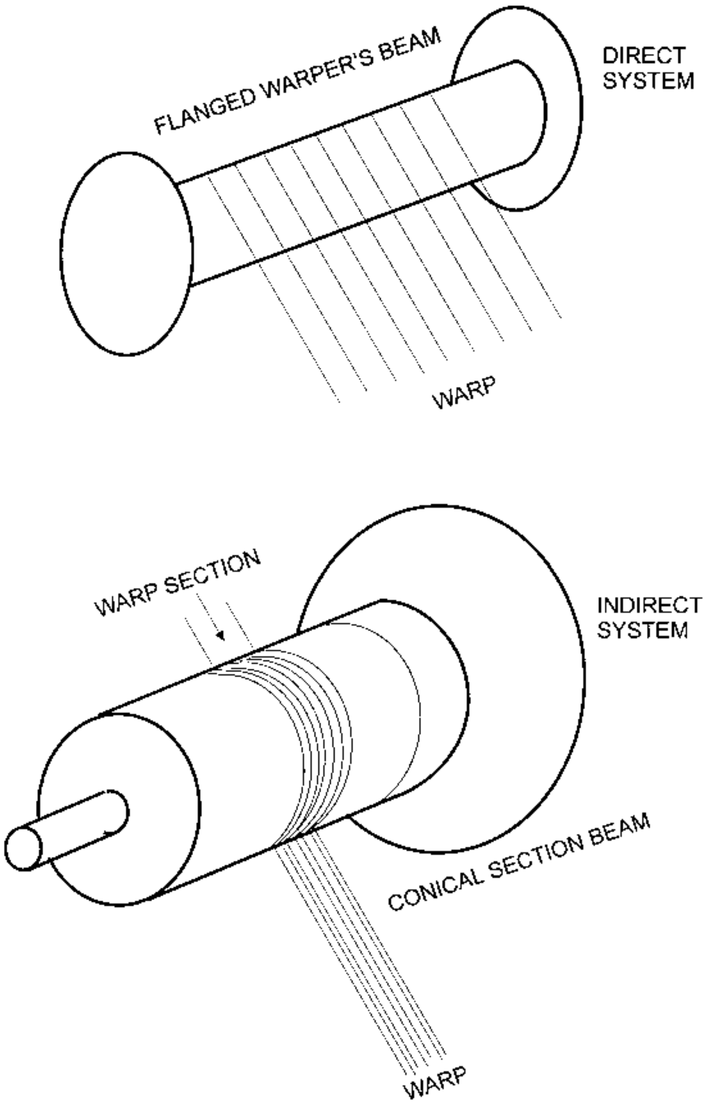


Fig. 4.11 Warping systems.

system, a number of sections of patterned warp, containing different colors, are wound sequentially on a section beam, as shown in Fig. 4.11. Once a desired number of sections (desired number of total ends) are wound on a section beam, the warp is transferred onto a weaver's beam.

Direct System

In the direct system of warping, a predetermined number of yarn packages are placed in a large creel, as shown in Fig. 4.12. Each yarn package is firmly inserted on a package holder, as shown in Fig. 4.13. The yarn from each package is then threaded through its own stop motion and a tensioner at the front of the creel, as shown in Fig. 4.14. Yarns from all packages are brought together to form a warp sheet, which is taken to the head stock where it is uniformly spaced by passing through dents of a comb and where the actual winding of the yarn sheet on a beam takes place. The beams thus prepared are known as section beams, warper's beams, or back beams. The required

Fig. 4.12 Direct warping system. (Courtesy of West Point Foundry and Machine Company.)

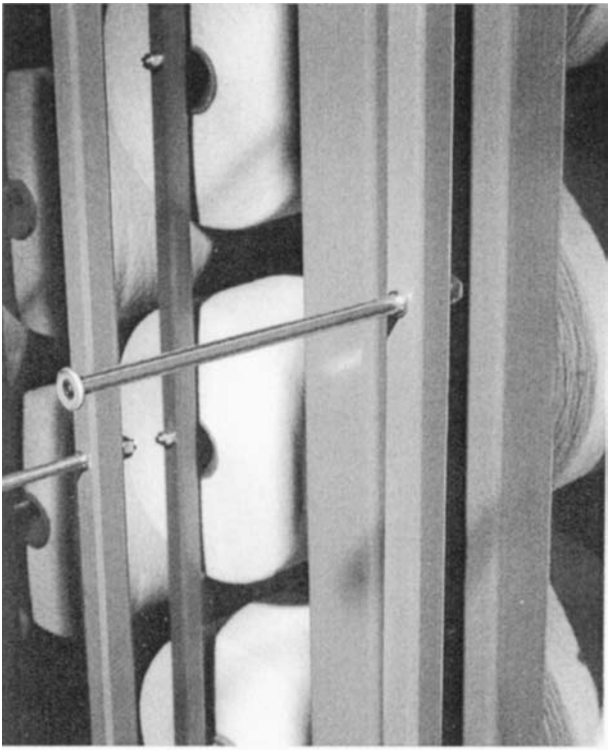


Fig. 4.13 Yarn package holders. (Courtesy of West Point Foundry and Machine Company.)

number of these beams is placed at the back of the sizing machine. The type of creel, tensioner, warp stop motion, head stock, and control devices on warping machines may vary depending on the manufacturer; however, their basic functions remain the same.

Indirect System

Unlike the direct system, warping and the preparation of a weaver's beam takes place on the same machine but in two consecutive steps. In the first step, the warp is prepared in sections on a large drum with one conical end, as shown in Fig. 4.15. Then the rewinding of the entire warp sheet from this

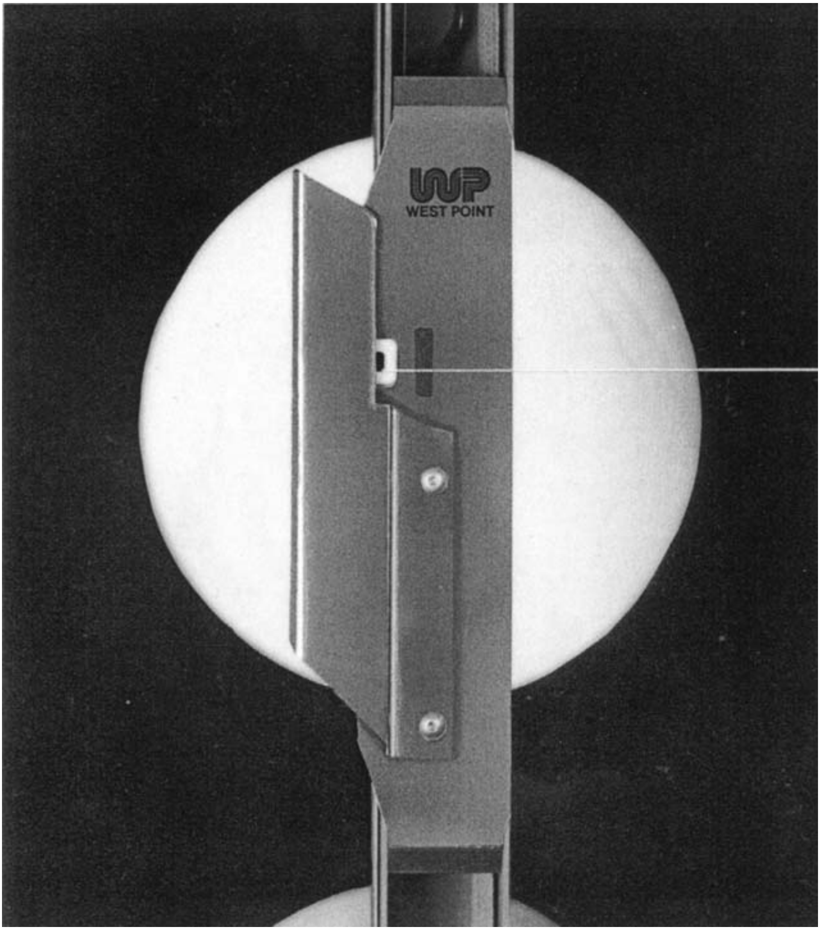


Fig. 4.14 Stop motion. (Courtesy of West Point Foundry and Machine Company.)

drum to a weaver's beam is done in the second step. The operations in the first and the second step are commonly known as warping and beaming, respectively.

For preparing the sections on a drum, the warp yarn is withdrawn from the creel through a tension device and stop motion (similar to the one described in the previous section) and is in turn passed through a leasing reed. Then all

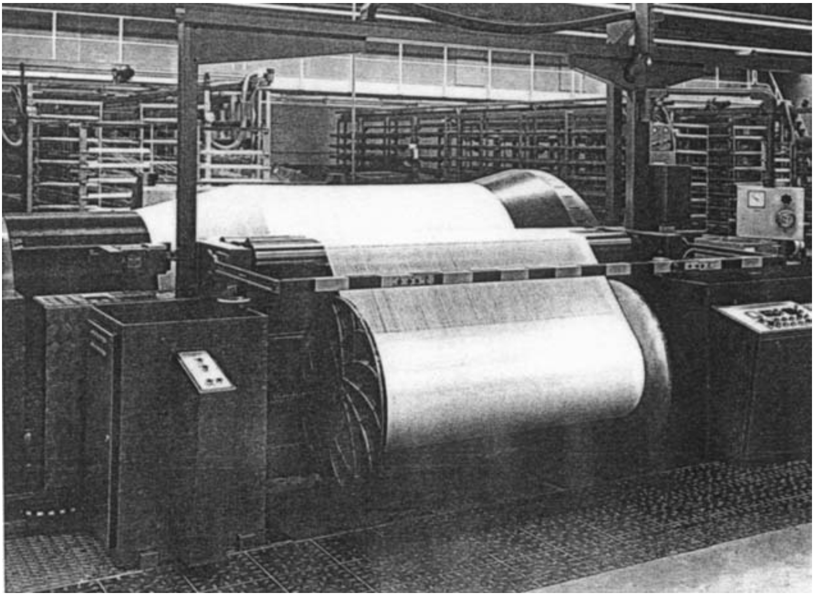


Fig. 4.15 Sectional warping and beaming machine. (Courtesy of Sucker-Muller-Hacoba GmbH & Co., Germany.)

the sectional warps are condensed into a section of the desired width by passing them through a V-shaped reed guide and over a measuring roller to the drum. The density of the warp in a given section is the same as the number of ends per unit width required in the weaver's beam for producing a fabric with a given color pattern and specification. The length of each section is generally equal to the length of the warp required in a weaver's beam plus due allowance for the waste in the process. One end of the warping drum is conical shaped, as shown in Fig. 4.15. This is necessary for providing support to the outside ends of the first section to prevent the yarns from sloughing off at the end of the drum.

The leading end of each section is attached to the drum such that the edge of the section is placed exactly on the nose of the conical portion of the drum or by the nose formed due to winding of the previous section, as shown in Fig. 4.16. During the process of winding a section on the drum, a slow continuous traverse is imparted to the section of warp being wound. After the initial few turns of the warping drum, a lease thread is inserted in each section

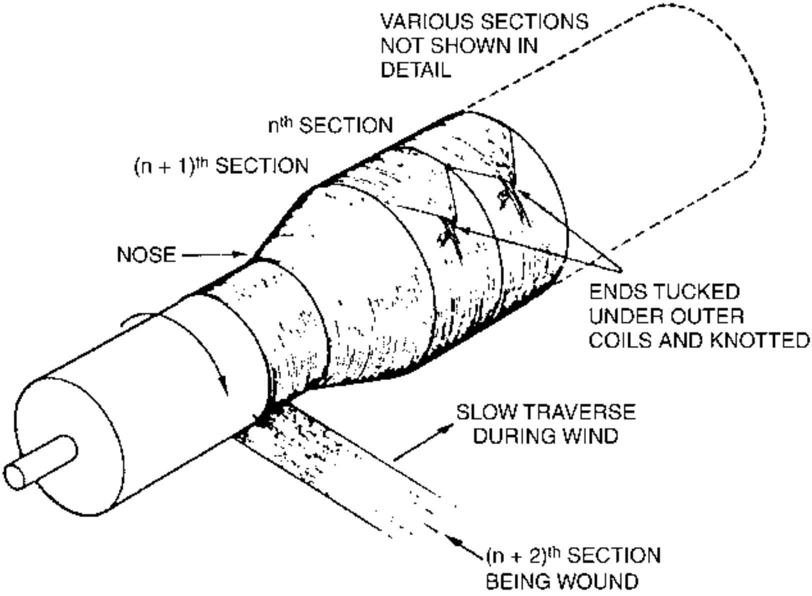


Fig. 4.16 Schematics of section warping. (From Ref. 1.)

with the help of a leasing device. This is necessary for maintaining the correct order of the warp ends as required by the multicolored pattern. These one-and-one leases inserted during warping are helpful during drawing-in of warp ends in the harnesses of the loom.

After completing the warping operation, the full sheet of warp built on a warping drum contains the exact number of ends and width of warp required on the weaver's beam. This warp sheet is then rewound on a weaver's beam ready for weaving if the yarns do not require sizing. The yarns that require sizing are also processed exactly in a similar manner, but additional split strings are inserted during one-and-one leasing. These split strings are later replaced during slashing by split rods [10]. The beam prepared on such sectional warpers can be conveniently sized on a slasher without much loss in time because the introduction of one-and-one leases ensures perfect arrangement of all warp threads according to the pattern set during warping, and the counting and arrangement of threads in the expansion comb of the slasher are no longer required [10].

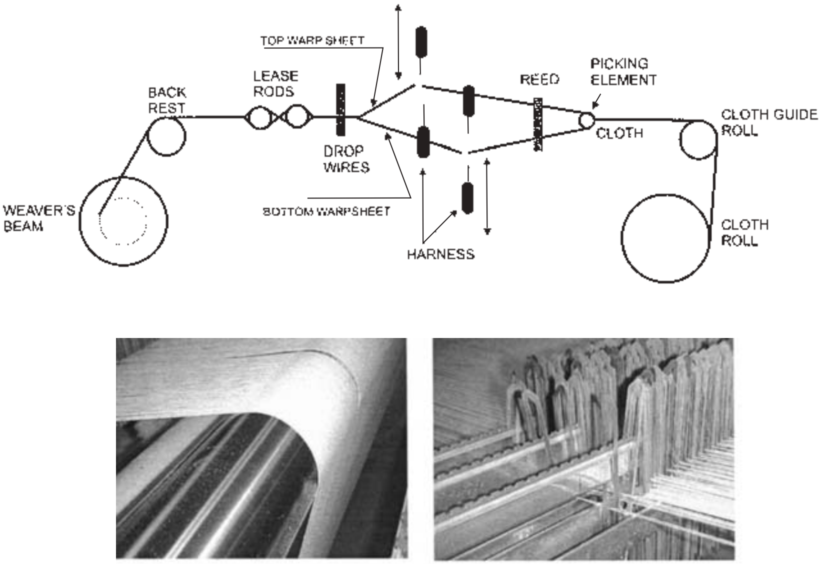
The productivity of the indirect system may turn out to be much lower in comparison to the direct warping system; however, the overall production costs from winding to the gaiting-up of a beam on the loom for the indirect warping system can be lower depending on the complexity of the pattern and length of the fabric being produced [10]. In the direct system of warping, the cost is directly in proportion to the length of the fabric being produced. As the amount of production needed increases, in terms of the length of fabric, the cost of the direct warping system decreases, and it tends to level off when the optimal operating conditions are reached. Nevertheless, in the indirect system the costs are reasonably constant irrespective of the warping length being produced [10].

4.4 SIZING

The primary purpose of sizing is to produce warp yarns that will weave satisfactorily without suffering any consequential damage due to abrasion with the moving parts of the loom. The other objective, though not very common in modern practice, is to impart special properties to the fabric, such as weight, feel, softness, and handle. However, the aforementioned primary objective is of paramount technical significance and is discussed in detail herein.

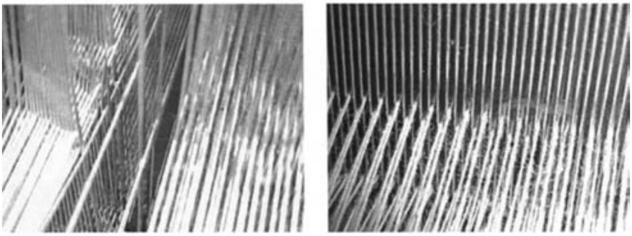
During the process of weaving, warp yarns are subjected to considerable tension together with an abrasive action. A warp yarn, during its passage from the weaver's beam to the fell of the cloth, is subjected to intensive abrasion against the whip roll, drop wires, heddle eyes, adjacent heddles, reed wires, and the picking element [12], as shown in Fig. 4.17. The intensity of the abrasive action is especially high for heavy sett fabrics. The warp yarns may break during the process of weaving due to the complex mechanical actions consisting of cyclic extension, abrasion, and bending. To prevent warp yarns from excessive breakage under such weaving conditions, the threads are sized to impart better abrasion resistance and to improve yarn strength. The purpose of sizing is to increase the strength and abrasion resistance of the yarn by encapsulating the yarn with a smooth but tough size film. The coating of the size film around the yarn improves the abrasion resistance and protects the weak places in the yarns from the rigorous actions of the moving loom parts. The functions of the sizing operation are

1. To lay in the protruding fibers in the body of the yarn and to cover weak places by encapsulating the yarn by a protective coating of the size film. The thickness of the size film coating should be optimized. Too thick a coating will be susceptible to easy size shed-off on the loom.



BACK REST (WHIP ROLL)

DROP WIRES



HEDDLE EYES

REED WIRES

Fig. 4.17 Parts of the loom and major abrasion points.

2. To increase the strength of the spun warp yarn without affecting its extensibility. This is achieved by allowing the penetration of the size into the yarn. The size in the yarn matrix will tend to bind all the fibers together, as shown in Fig. 4.18. The increase in strength due to sizing is normally expected to be about 10 to 15% with respect to the strength of the unsized yarn. Excessive penetration

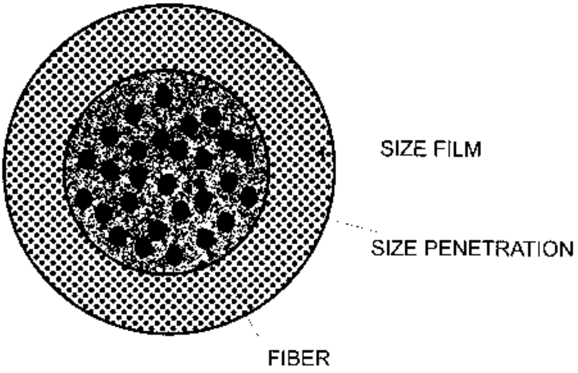


Fig. 4.18 Fiber–size binding in a yarn (not to scale). (From Ref. 13.)

of the size liquid into the core of the yarn is not desirable because it affects the flexibility of the yarn.

3. To make a weaver's beam with the exact number of warp threads ready for weaving.

Figure 4.19 illustrates various possible conditions that may occur in practice depending upon the properties of the size employed. This emphasizes the importance of an optimal balance between the penetration of the size into the yarn and providing a protective coating around the yarn, as shown in Fig. 4.19d. The flow properties of the size liquid and the application temperature have important effects on the distribution of the size within the yarn structure. More size at the periphery of the yarn will tend to shed off on the loom under the applied forces because the size is not well anchored on the fibers. Too much penetration, as shown in Fig. 4.19a, may leave too little size around the yarn surface to protect it against the abrasive action. To rectify such a condition, a higher size add-on is required to provide the required protective surface coating [13].

4.4.1 Sizing–Weaving Curve

A typical sizing–weaving curve is as shown in Fig. 4.20. Initially the warp breaks decrease with the increase in size add-on level. This is due to the associated increase in yarn strength and reduction in yarn hairiness. The coating of the protective size film around the yarn provides improved resistance

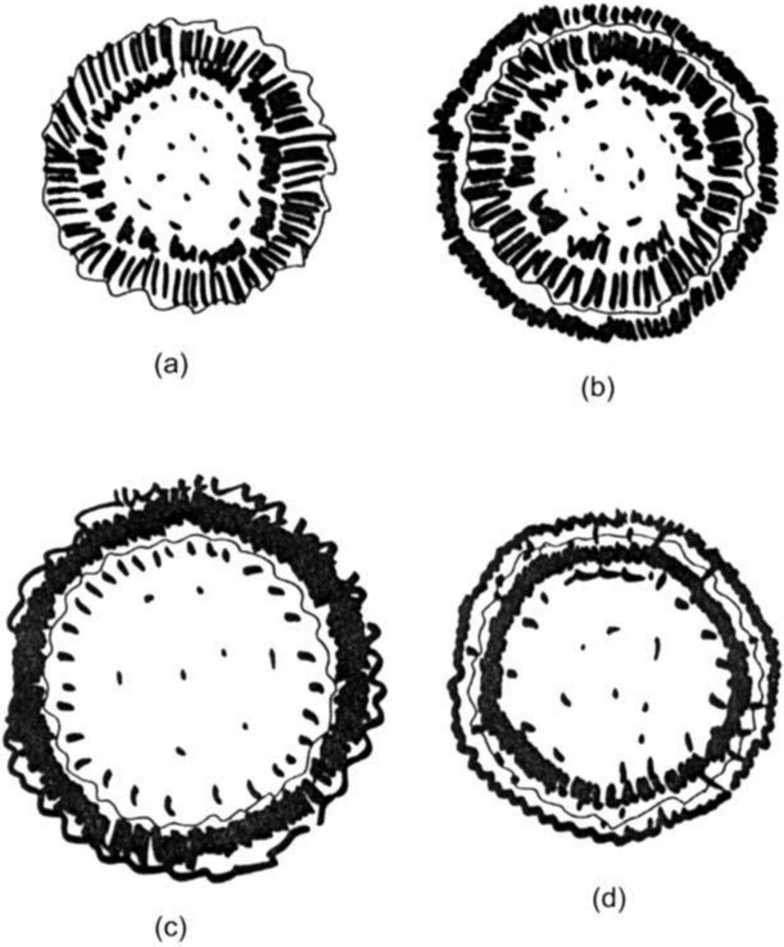


Fig. 4.19 Schematics showing size distribution; (a) too much penetration, no surface coating; (b) too much penetration, more size added to provide surface coating; (c) too little penetration, no anchoring of yarn structure; (d) optimal distribution. (From Ref. 13.)

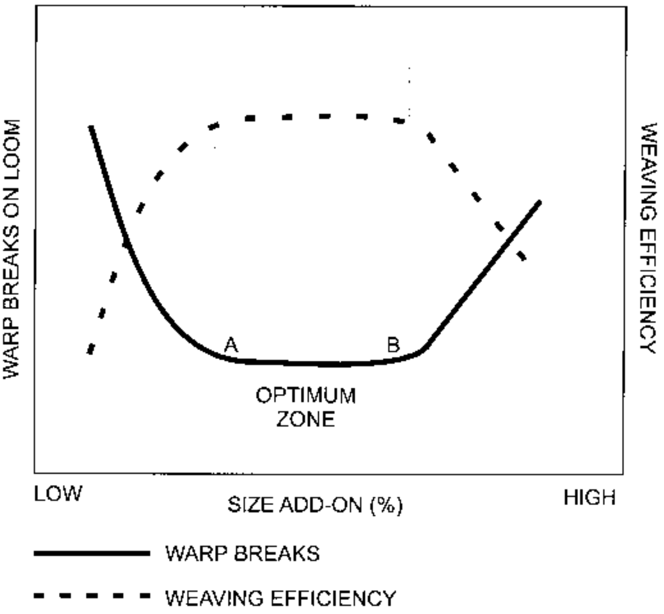


Fig. 4.20 A typical sizing–weaving curve. (From Ref. 20.)

to abrasion and also affords adequate protection to the weak places in the yarn. The reduction in warp breakage rate with an increase in size add-on reaches a point beyond which further size add-on will not show any significant improvement in yarn performance on the loom. The weaving efficiency, which is inversely proportional to warp yarn end breakage rate, reaches its peak when the warp breakage rate is at its minimum. The optimal range of size add-on is usually between points A and B as shown in the typical curve in Fig. 4.20. Increasing the size add-on beyond the optimum, in fact, has a detrimental effect on weaving performance since the warp breaks increase. Excessive size add-on leads to an increased penetration of the size, which makes the yarn inflexible. Also, higher size add-on may tend to coat the yarn with a very thick film of size which is not sufficiently anchored to the fibers. Such a thick coating of size film may have a lower extensibility compared to the extensibility of the warp yarn itself. Inflexibility of the yarn and a size film not bound securely have a net effect of size film shedding due to its easy rupturing, thus making the yarn vulnerable to intensive abrasion action and leading to a higher warp breakage rate. The best weaving efficiency region consistent with optimal size add-on is usually achieved in practice by trial and error. In the next chapter the different methods used for correlating laboratory evaluation and its relationship to actual weaving performance are discussed.

4.4.2 Sizing Machines

The essential components of a sizing machine to slash spun warp yarns may be categorized as follows:

1. Creels—unwinding zone
2. Size boxes—sizing zone
3. Drying cylinders—drying zone
4. Bust rods—splitting zone
5. Head stock—weaver's beam preparation zone
6. Controls and instrumentations

Figure 4.21 shows a schematic diagram of a typical sizing machine and its essential components.

Warp yarns from warping beam placed in a creel are withdrawn and fed to the size box by a feed roll. The yarns are then impregnated in a size liquor preheated to a desired application temperature. Then the yarns are passed through a pair of rolls, commonly known as squeeze rolls, to squeeze out excessive size before they are subjected to the drying cylinders of the drying zone. This is necessary to minimize the drying energy required to dry the warp yarns. The yarns wet with size solution are passed over and under the heated drying cylinders to dry the sheet of warp yarns to a desired level. The dried yarn sheet is then passed through a series of bust rods in the splitting zone to

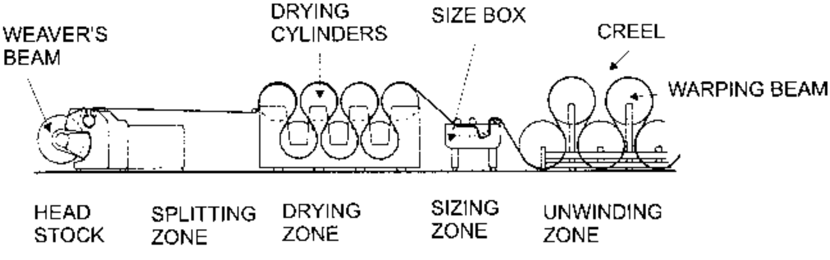


Fig. 4.21 Schematic of sizing operation. (Courtesy of West Point Foundry and Machine Company.)

separate the yarns. In the final phase, the separated yarns are passed through a guide comb and wound onto a weaver's beam. The following sections will deal with each function and component of the sizing machine separately.

Creels—Unwinding Zone

The creel on a modern slasher is available in several different forms. Basically it must be well built and of robust construction, capable of carrying heavy warper's beams. The primary function of the creel is to allow smooth and steady unwinding of the warp yarn sheet without a side to side swinging of the warper's beam and without entangling two adjacent warp sheets being unwound. Also, the ends from either side of the warper's beam should not touch the beam flanges. To prevent the sideways swinging of the beams and allow a smooth unwinding of the warp sheet, modern creels are equipped with ball bearings to support the end shafts of the warper's beams. This also helps in eliminating unwinding tension variations in the warp sheet [14].

Both fixed and movable (on wheels) types of creels are available. The advantage of the movable creel is that while slashing is in progress from one set of beams, the loading of another set can be done on another stand-by creel, which can be attached to the back of the sizing machine later without loss of much time. Consequently, the next set on the sizing machine can be started with much less down time, thus increasing the slashing efficiency.

The major creel types housing multiple beams are [14]

Over/under
Equitension
Inclined
Vertical stack

Over/Under Creel. In the over/under creel, as the name implies, the warp yarn passes over one beam, under the next beam, again over the next beam, and so on, as shown in Fig. 4.22. This type of creel is most commonly used for slashing spun warp yarns of cotton and synthetic fibers. The threading pattern of warp from the beams in this type of creel varies depending upon the number of size boxes used. For heavy to medium construction fabrics, where two size boxes are used in industrial practice, all top beams in the creel may be threaded over and under and then straight to the first size box, as shown schematically in Fig. 4.23. All bottom beams are threaded over and under and then straight to the second size box [11], as shown in Fig. 4.23.

Equitension Creel. In this type of creel, the warp sheet is withdrawn from the individual beam and is passed over a guide roll mounted on the creel

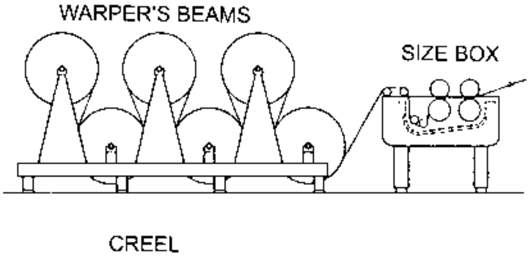


Fig. 4.22 Over/under creel. (From Ref. 11.)

framework. Thus the yarn sheet from each warper's beam is drawn individually and passed over a guide roll; it then joins the yarn coming from other beams of the top or bottom tier, respectively, and then passes forward directly to the size box [11], as shown in Fig. 4.24. This type of creel is more useful for lightweight fabrics of open constructions.

Inclined Creel. The inclined creel may be either double tier or single tier. Obviously, the single tier creel requires much greater floor space, and two tier creels are therefore more commonly used in the industry. The double tier inclined creel is commonly used for filament warps. As shown in Fig. 4.25, the inclined creel allows a direct path of the yarn from each beam through the hook reed to the size box.

Vertical Creel. This type of creel is most suitable where a large number of warper's beams are used. This creel allows the operator easy access to all the warper's beams. The beams are supported on vertical stands in three decks in several modules, as shown in Fig. 4.26. The passage between each pair of

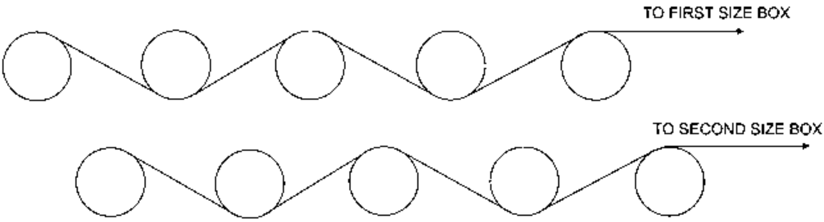


Fig. 4.23 Over/under creel for two size boxes. (From Ref. 11.)

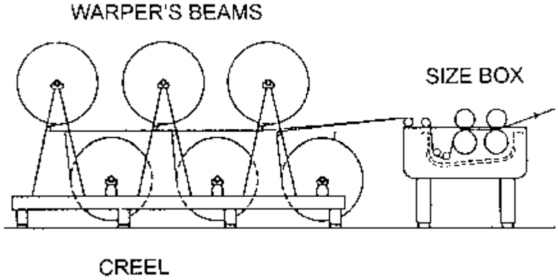


Fig. 4.24 Equitension creel. (From Ref. 11.)

modules allows the operator to easily mend a break or correct a problem in a warp yarn leaving the warper's beam [11].

Warping Beam Braking Systems. These systems are required for preventing the over-running of the beams, especially during the reduction in speed of the slasher at the time of a break or during the doffing of the weaver's beam. Also, the braking device allows control of yarn tension between the size box and the creel during the normal constant speed operation. The most commonly used braking system is the ''rope and belt'' device in which the braking force is applied by means of a rope wrapped around the warper's beam head or by a belt wrapped around a drum or a grooved pulley attached to the beam [11], as shown in Fig. 4.27. Usually the drum or grooved pulley containing ball bearings is attached to both ends of the warping beam shaft so as to ensure free rotation during the normal working of the slasher. The braking force is applied by hanging deadweights that must be decreased man-

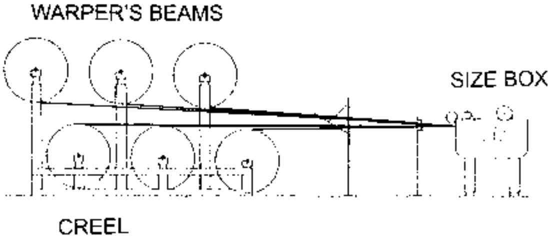


Fig. 4.25 Inclined creel. (From Ref. 11.)

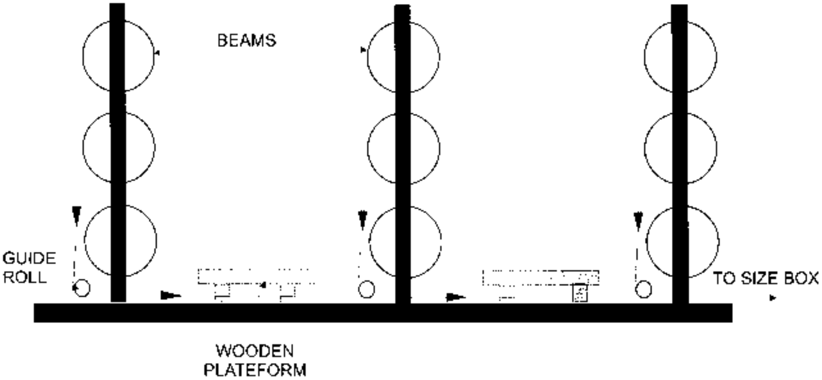


Fig. 4.26 Vertical creel. (From Ref. 11.)

ually as the beam diameter decreases to maintain a uniform yarn tension from start to finish of the warping beams. The deadweight system is substituted by pneumatic cylinders in the pneumatic braking system. The pneumatic pressure in such cylinders on the individual warping beam can be integrated into a central regulator accessible to the operator. The centralized pneumatic braking system, integrated with the sizing machine drive controller, is very efficient because it applies a higher braking force only when the slasher is decelerated. This prevents the application of excessive tension during the normal working of the slasher [14]. A more precise system is the automatic pneumatic braking system in which a sensor is placed between the creel and the size box for measuring the tension in the whole warp sheet. The desired tension in the warp sheet is preadjusted by the operator depending upon the yarn type, yarn count, and style of the fabric being produced. The air pressure in the pneumatic cylinders is automatically adjusted in proportion to the tension fluctuations registered during acceleration or deceleration, and also from start to finish of the warper's beams. This system assures a constant unwinding tension of the warp yarns from the warp beams for the entire sizing process, with minimal operator intervention [15].

Size Boxes—Sizing Zone

The size box and all parts that remain in contact with the size solution are made of stainless steel to prevent corrosion. The shape of the size box from the bottom is contoured with no sharp ends. The size liquor in the size box

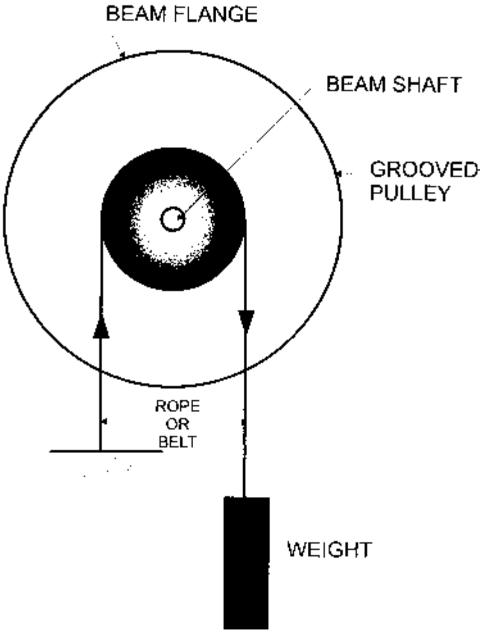


Fig. 4.27 Rope or belt braking system. (From Ref. 11.)

is normally heated by steam supplied through a steam coil placed at the bottom of the size box. The steaming coils placed in the size box should ensure uniform heating of the size liquor in the entire size box. The type and the design of the coil vary depending upon the size box manufacturer. The entry of the high pressure steam in the size box also creates a turbulence which results in the agitation of the size liquor. This is favorable in the case of a starch-based size used for sizing spun yarns because the agitation prevents gelling and scumming of the size near the corners. For filament slashing, a size box with direct heating coils is not desirable as the agitation of the size liquor may disturb the filaments. Also, the bottom of the size box should have an outlet to the effluent disposal system so that the size box can be completely drained when cleaning is required [16].

The configuration of size boxes is quite diverse and they are available in a variety of different forms depending upon the sizing machine manufacturer. However, the basic function of all size boxes is to impregnate the warp sheet in the size liquor at a predetermined application temperature and to squeeze out the excess size liquor before the yarn sheet reaches the drying zone. Most slashers are equipped with a single sizing box having two pairs of squeezing rolls and an immersion roll. Figure 4.28 shows a typical size box. A sheet of warp yarn is drawn from the warper's beams and fed to the size box over a pair of guide rolls with a slack rod or tension roll riding on the warp between the two guide rolls. The sheet of yarn is immersed in a size solution by one or two immersion roll(s). The immersion roll is normally movable. It is mounted on the size box with a rack and pinion mechanism so that it can be freely lowered and raised. The amount of size that will be picked up by the yarns will depend upon the depth of the immersion roll and the level of size liquor in the size box. At a given constant size level in the box, the lower the position of the immersion roll, the greater the pick-up of the size by the yarns, as it allows a longer time for the yarns to remain in the size liquor and vice versa. The yarn sheet with wet size on it then passes through one or two pairs of squeezing rolls, as shown in Fig. 4.28.

The purpose of the squeeze rolls is to remove the excess size liquid from the yarns. For filament yarn sizing a single squeeze size box is usually used; however, in case of spun cotton and synthetic yarns where higher size add-on is required, double squeeze size boxes are normally preferred [10]. The bottom roll in a pair of squeeze rolls is made up of stainless steel and the top roll is made from cast iron material covered with rubber. The top roll is usually

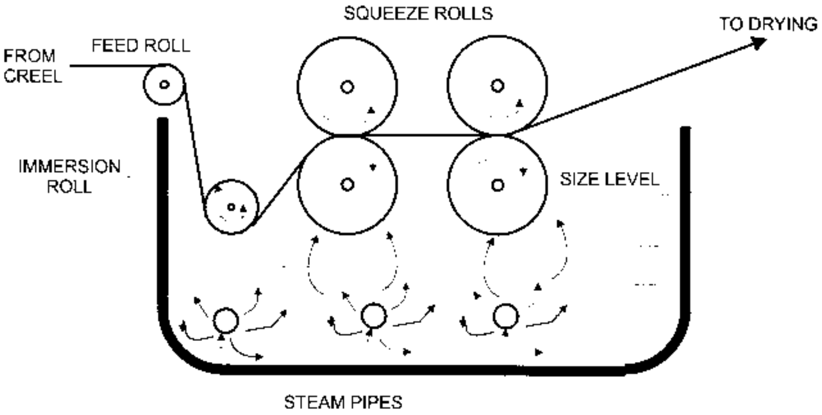


Fig. 4.28 Schematics of size box. (From Ref. 16.)

under pressure in addition to its own weight of around 180 to 250 kg. The pressure is usually applied by compressed air operating on pneumatic cylinders or pneumatic diaphragms [10]. In modern slashers, the trend is to use a high squeezing pressure to save energy in drying and to make it possible to use higher concentrations of the size liquor to obtain the predetermined size add-on. In high pressure squeezing, the squeeze roll loading is up to approximately 9000 kg (20,000 lb), which is about 15 times the loading used in a conventional size box [18]. In high pressure squeezing, the quantity of water evaporating during the drying process will be lower, thereby allowing not only savings in drying energy, but also an increase in sizing machine productivity [17]. The drawback of the high pressure squeezing is that the top squeeze rolls deflect or bend when loaded at such high pressure. This results in a nip size variation across the width of the roll, as shown in Fig. 4.29. An uneven nip zone width causes a variation of squeezing pressure across the roll width, resulting in variation in size add-on from the selvedge to the center of the warp sheet [18]. For narrow size boxes (< 1.4-m width of yarn sheet) West Point Co. research [18] has found that the variation in size add-on due to top roll bending is not significant. Nevertheless, in the case of wider size boxes corrective action

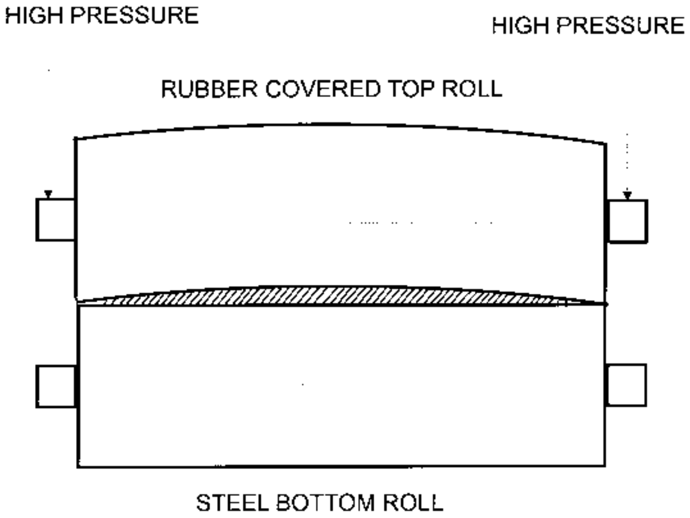


Fig. 4.29 Schematics showing nip deformation in high pressure squeezing. (From Ref. 18.)

incorporating ‘‘crowned’’ squeeze rolls should be used to obtain a uniform nip width. A crowned squeeze roll is produced by grinding the rubber cover top roll to a slightly larger diameter in the center than at the ends. This compensates for the possible bending of the top roll while under high pressure and provides a reasonably uniform nip width and squeezing pressure across the entire width of the roll [18].

A double squeeze size box with twin rolls is also used for slashing light and heavy warp sett spun yarns. The twin immersion rolls allow both sides of the yarns to be exposed to the size mixture, thus ensuring uniform coating and penetration of the size liquor. Both squeeze rolls are equipped with independent loading and lifting controls. This provides flexibility to the slashing operator in using either one or both rolls depending upon the requirement [14]. A size box having double roller, double immersion with high pressure squeezing, as shown in Fig. 4.30, is also used [19]. In such a size box, one set of immersion and squeeze rolls is followed by another set of immersion and squeeze rolls. A recent development is the Equi-Squeeze Size Box, shown in Fig. 4.31. In this system the top squeeze roll position is adjustable. A unique bracket and loading system allows the positioning of the roll to the rear 15 or 30 degrees off the top center position, as shown in Fig. 4.31. By moving the roll to the rear, the adherence of yarns to the roll as they leave the squeezing nip is minimized.

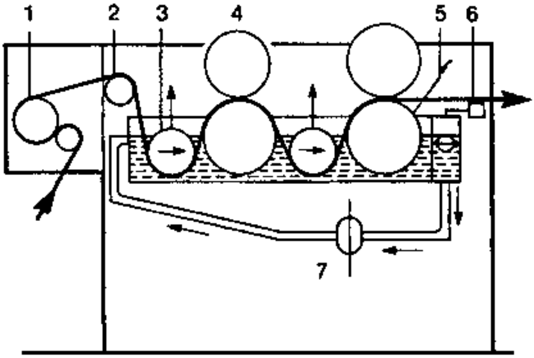


Fig. 4.30 Schematic of double squeeze rollers, double immersion with high pressure squeezing. (1) Driven dry feed rollers; (2) guide roller; (3) immersion roller; (4) rubber-covered squeeze roller; (5) finishing roller; (6) size level float switch; (7) size circulating pump. (Courtesy of Platt Sizing.)

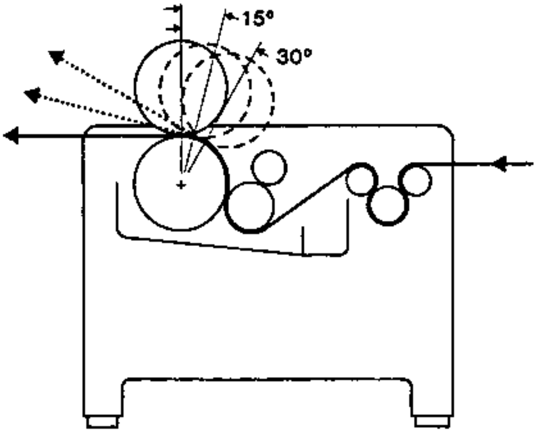


Fig. 4.31 Equisqueeze size box. (From Ref. 11.)

Drying Cylinders—Drying Zone

There are two principal types of drying methods used, namely,

1. Cylinder, or can, dryers
2. Hot air, or convection, dryers

Cylinder Dryers. These are most widely used as they are the most energy efficient. The cans or cylinders are about 75 cm in diameter and are used in a multiple unit containing a series of five, seven, nine, or eleven cylinders, usually arranged in two tiers to save floor space. The maximal working pressure of steam in these cylinders is about 4.92 kg/cm^2 (70 psi). The cylinders are made of stainless steel. These cylinders are mounted on ball bearings and driven positively by a chain and sprocket. This eliminates undue tensioning of the yarns while they are dried. The cylinders are also coated with nonstick coating, e.g. Teflon®, for preventing the size and yarns from sticking while the warp is partially dried. Usually the first three cylinders from the front are coated with Teflon in any sizing machine containing five, seven, and nine cylinder systems. For an eleven-cylinder drying system, usually the first four cylinders are coated with Teflon. In the case of filament sizing, usually all cylinders are coated with Teflon.

The cylinders in a drying section are usually arranged either horizontally or vertically. The horizontal system (Fig. 4.21) is generally used because it allows easy access to the cylinders for threading and mending a break, whereas the vertical system is useful in cases where floor space is limited and when more cylinders are required because a greater number of size boxes are used [14]. The horizontal system of drying cylinders usually consists of seven, nine, or eleven cylinders, depending upon whether one or two size boxes are used. The number of drying cylinders required in a typical slasher will be decided by the density of the warp and the slashing speed that is used. For a higher number of warps and faster slashing speeds, a greater number of drying cylinders will be required. With faster slashing operation, the time available for the warp yarns to be dried will be less, and therefore a high heat transfer rate is required. On a multicylinder machine, in practice, it is desirable to increase the drying temperature during the first phases of drying and to decrease it during the final phases. However, too high of a drying temperature is detrimental to the quality of the sized warp and also too much penetration of size will take place. Typically the temperature range from 80 to 105°C is used in practice [1].

Convection Drying. In this system, hot air is used as a drying medium instead of the steam used in cylinder drying. The heated air is passed through the drying chamber. The warp yarn through its passage in the drying chamber comes into contact with the heated air circulation, as shown in Fig. 4.32. The air is heated either by electric coil or steam [14]. The advantage of the hot air convection drying system is that the whole yarn surface is subjected to a uniform drying temperature in contrast to cylinder drying where only a part of the yarn surface is in contact with a hot cylinder. The surface of the yarn in contact with the hot cylinder is likely to be overdried. Cylinder drying is therefore expected to result in uneven drying, with a resultant uneven distribution and migration of size in the yarn [20]. Modern multiple-cylinder drying systems overcome this drawback by subjecting both the top and bottom sides of the yarns to drying by allowing the yarns to pass over and below the hot cylinders, resulting in progressive and uniform drying.

Infrared and Microwave Drying. Other forms of drying methods, though not yet widely used in practice for sizing, are infrared drying and microwave drying systems. These systems aim to conserve energy through the efficient and cost-effective use of drying energy to replace conventional steam-based conductive drying. Infrared drying energy can be sourced either electrically or from gas. In an electric system, a series of infrared lamps with reflectors are mounted above and/or below the warp yarn sheet to be dried. The cost of electricity-based infrared drying is usually higher than that of conventional steam-based conductive drying. Gas-based infrared energy can

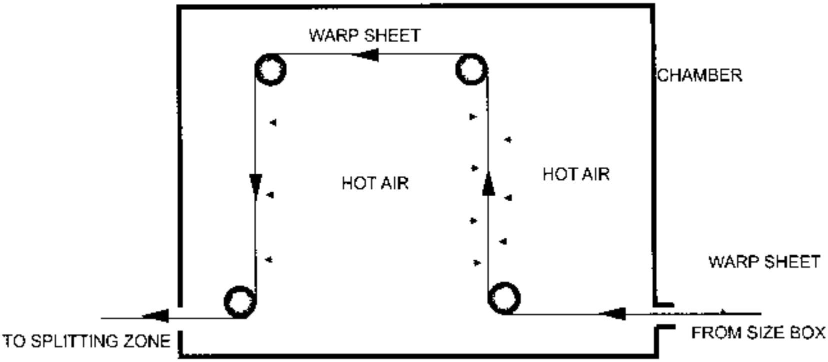


Fig. 4.32 Schematic of convection dryer.

be achieved by heating refractory materials to incandescence. This drying energy is similar to hot air drying based on the convection principle. The heat produced due to the combustion of gases is also circulated. The yarn can be passed through a number of infrared-radiating gas burners for drying.

Microwave radiation is an inexpensive form of energy generation widely used in many industrial practices. Microwave energy can be obtained easily without causing pollution and therefore receives attention for the drying of textiles where large amounts of energy are consumed. The major problem of the conventional form of microwave energy radiation is the lack of uniform heating, resulting in randomly occurring hotspots which cause overheating in some areas and underheating in others. This problem has been corrected recently by the introduction of appropriately designed ''waveguides'' systems where microwave energy is transmitted back and forth across the material. This improvement in uniformity of distribution in microwave radiation has opened up new opportunities for its use in textile drying applications. Industrial microwave systems designed for specific purposes are now available which can be retrofitted to the existing conventional fossil fuel burning ovens or drying chambers that can be used as pre- or post-dryers. The use of microwave drying in sizing is in an early stage of development and has yet to replace the conventional drying methods based on conduction and convection.

Lease Rods—Splitting Zone

The function of the lease rods in the splitting zone is to separate the individual yarns which are stuck together because of the drying of the size film in the drying section. To achieve this, a series of lease or bust rods, with one large diameter busting rod, are used, as shown in Fig. 4.33. The lease rods are generally chromium-plated hollow cylindrical bars flattened at both ends to be placed firmly in the brackets. The number of lease rods used is determined by the number of warper's beams being used in the creel. The yarn sheet emerging from the drying section is divided into two sections by one large lease rod, as shown in Fig. 4.33, and each section is further subdivided into two subsections by successive lease rods. The pattern of dividing by lease

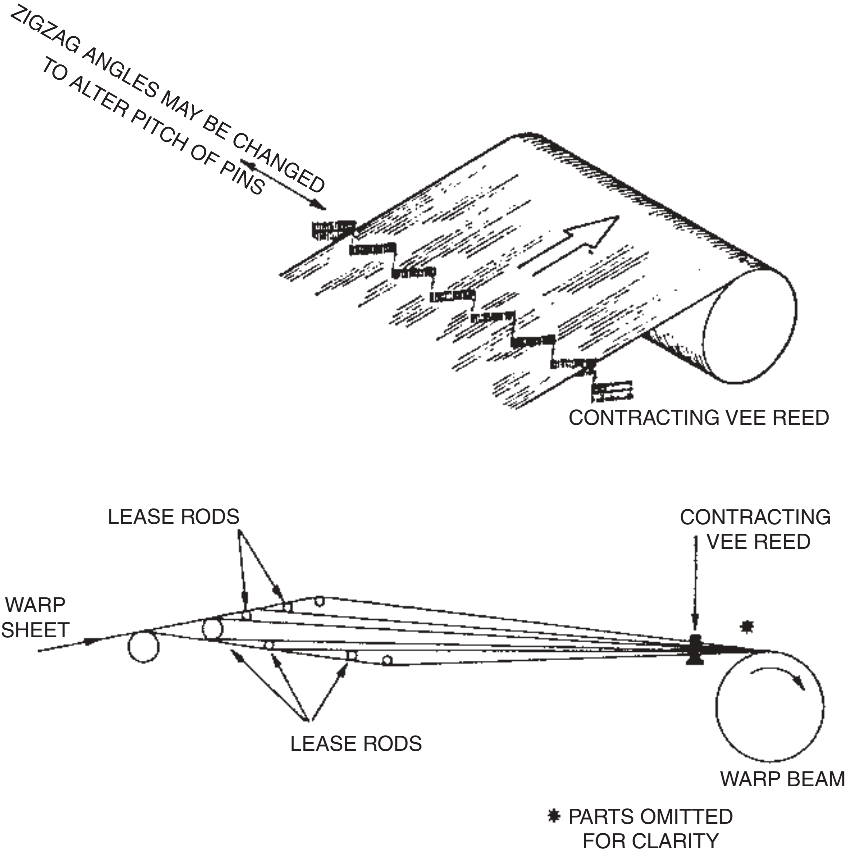


Fig. 4.33 Schematics of splitting zone. (From Ref. 1.)

rods in the splitting section is usually kept similar to the pattern of combining the sheet in the unwinding section, which helps in maintaining the order of the warp sheet, thus facilitating the subsequent drawing-in operation [1]. Also, the leasing-in of the sized yarns to the weaver's beam is facilitated by inserting leases in the top few layers of the warp. Even under normal operating conditions, the splitting zone imposes tension in the warp by offering resistance to the forward movement of the dried warp sheet. However, under stable running conditions, the tension imposed on the warp sheet is not affected significantly [21].

Head Stock

The head stock is a take-up unit supporting the weaver's beam and necessary drive gears. The drive equipment imparts necessary beaming tension for compact and straight winding of the warp yarn on the weaver's beam. The configuration of the head stock is available in a variety of widths and styles. The width of the head stock is determined by the width of the weaver's beam and the number of weaver's beams being wound side by side. Usually head stocks are available which allow winding on a single beam, two beams side by side, and two beams positioned vertically or half beams run in center [14]. Double beam head ends with vertical arrangement are primarily used for towel, gauze, and leno warps, which contain so few warps that winding on only one beam may either lead to the warp being overdried or else the full drying efficiency of the cylinder surfaces not being used [10].

A typical head stock is shown in Fig. 4.34. Irrespective of the configuration, the head stock is equipped with a positively driven roll, commonly known as the delivery roll or draw roll. The cork and rubber covered draw roll is placed between two heavy chrome-plated nip rolls, as shown in Fig. 4.35, to assure that the yarn sheet being drawn is wrapped well around the draw roll [14]. The delivery roll moves at a constant speed for any sizing machine, and the speed of the weaver's beam is adjusted to impart the necessary winding tension. This poses a problem of driving the weaver's beam at a constant tension from start to finish of the beam, because the surface speed of the beam keeps increasing as the diameter of the beam increases, and consequently the winding tension also increases. This requires that the driving arrangement of the weaver's beam must incorporate a proportional reduction in the rotational speed of the weaver's beam to assure winding at a constant surface speed. On most modern sizing machines this is automatically controlled. Depending upon the type of arrangement used, the head stock driving system may be grouped as controlled tension beam drive, DC multimotor drive, or digital drive [14].

Fig. 4.34 Head end of a sizing machine. (Courtesy of West Point Foundry and Machine Company.)

The arrangement and the principle used vary from machine to machine and the techniques employed by various manufacturers differ considerably, although the objectives remain the same.

Controlled Tension Beam Drive. This system is the most accurate; is reliable, easy, and inexpensive to maintain; and is used widely. The drive is purely mechanical and utilizes a pneumatically loaded clutch to transfer the input torque to a positive infinitely variable (PIV) speed variator. In this system, the position of the pulleys in transmission is adjusted by comparing the revolutions of the clutch input shaft to the output shaft. With the increasing beam diameter the torque required to drive the beam also increases; however, the revolution of the beam should decrease to keep the surface speed constant, so the slippage across the clutch should be increased. This will lead to a reduction in the clutch output speed at the constant input speed. The automatic adjustment of speed and torque thus continues until the beam is full. While placing the new empty beam, the operator is required to reset the system to the proper ratio of barrel to full beam diameter [14]. In this type of system, normally a single DC motor drive is used for the whole sizing machine.

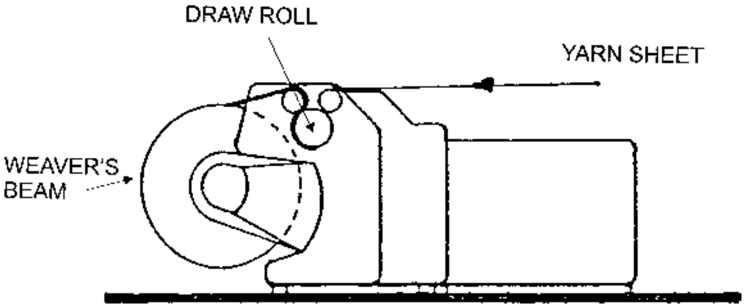


Fig. 4.35 Side view of a typical head stock. (From Ref. 11.)

Multimotor Drive. This system uses two DC motors, one for driving all components of the sizing machine, except the beam, and the other exclusively for driving the beam. The motor driving the beam provides constant winding tension as the beam diameter increases. This system is very simple mechanically but very complicated electrically. This system does not require resetting before beginning the new beam [14].

Digital Drive. This system comprises an electrical analog to the mechanical line shaft drive. The components of the sizing machine such as head end, dryer section and size box, etc., are driven by an individual motor. The digital system used for regulating the speed is most accurate [14].

Controls and Instrumentation

There are a variety of controls available on modern sizing machines. The essential functions of all these controls are to provide optimal quality of warp at a minimal cost. The controls usually act on the basis of information provided by the particular sensors placed on the machine. Figure 4.36 is a sketch of a typical two–size box slasher with locations of various sensors and controls. The most important of these are summarized here [22]:

1. Automatic tension control. In the direction of the yarn path, from the creel to the weaver's beam at the head stock, controls are placed to monitor tension and effectively regulate the speed of the sizing machine. The controls are placed in the creel to maintain uniform unwinding of the warp beams in the creel, in the size box for a smooth drive of the dry feed rolls, in the drying section to drive cylinders, and in the head stock to drive the weaver's beam.

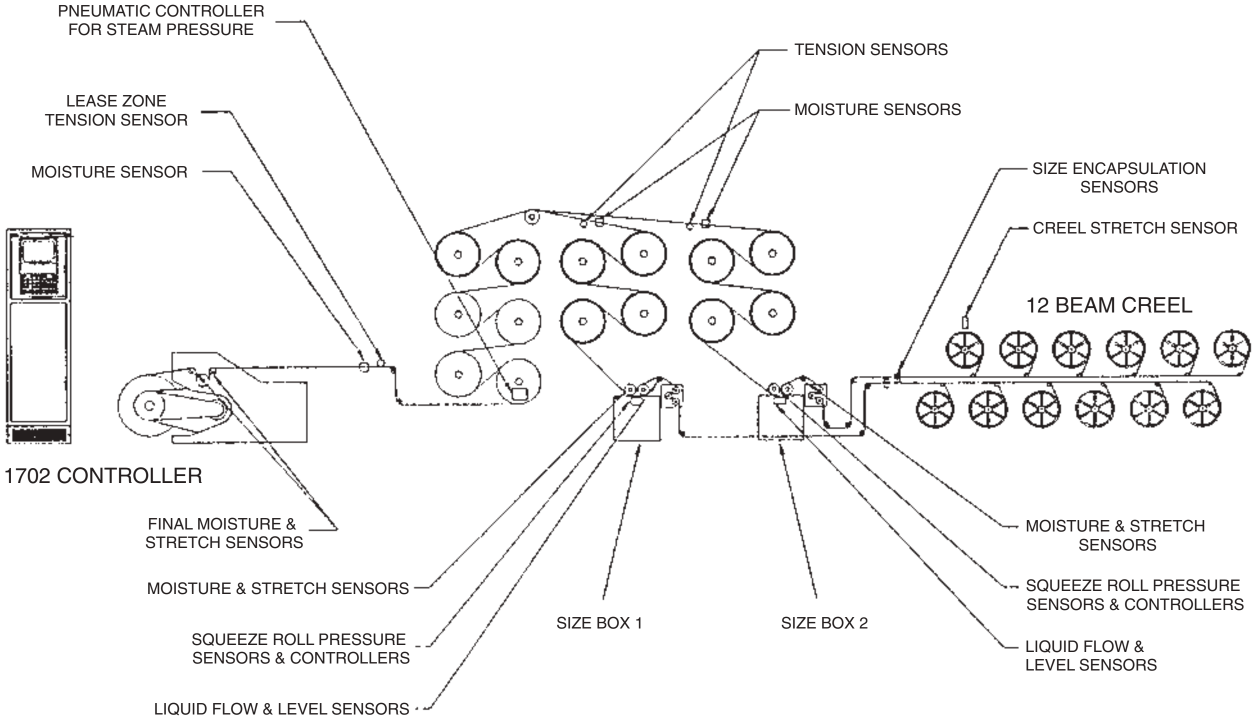


Fig. 4.36 Sensors and controls on a typical two–size box slasher. (From Ref. 22.)

2. Automatic size box level regulator, with a warning indicator for low size level or overflow.
3. Electronic stretch indicators and controllers with digital display for yarn elongation. Excessive yarn elongation (stretch) resulting from the applied tension is detrimental to the quality performance of the warp during weaving. The loss in elongation results in an increase in warp breaks on the loom. Surface speed sensors, mechanical or electronic, in direct contact with the warp sheet are placed from the creel to the front roll in each zone. The automatic controls adjust the size box roll speeds to maintain a constant stretch.
4. Electronic moisture detectors, used to regulate the slashing speed automatically or steam pressure in the drying cylinders.
5. Steam pressure controllers in the cylinders which may be interfaced to drive the controller to reduce the steam pressure during the slow or creep speed operation.
6. Temperature controls for the drying cylinders which can be used for maintaining accurate temperature and effective condensate removal.
7. Squeeze roll pressure release system designed to decrease the squeezing pressure when operating the machine at creep speed or maintaining proportional pressure with respect to the operating speed of the sizing machine.
8. Size liquor filtration and circulation system designed to filter out yarn waste and fibers (wild yarns and short fibers) found in the sizing system.
9. Creel braking systems to decelerate the warper's beams effectively, thereby preventing over-run and maintaining the unwinding tension at a constant speed operation.
10. Microprocessor controls interfaced to a computer for effective management of the operating variables of the sizing machine.
11. Wet pick-up measurement and size add-on control. In this device, microwave energy which is absorbed by water is used to continuously measure the wet pick-up immediately after the yarn sheet leaves the size box. The on-line refractometer monitors the size solids in the size mix. The size add-on, which is the product of the wet pick-up and size solids in the size mixture, is automatically calculated by the microprocessor. The correction in the size add-on is made by automatically adjusting the squeeze roll pressure to keep the add-on practically constant throughout the sizing operation [22].

12. On-line size encapsulation measurement. Size encapsulation is the measure that defines the degree of reduction of the yarn hairiness due to sizing. One on-line yarn hairiness sensor is placed on the unsized and the other on the sized yarn sheet. The difference between the two, expressed as percentage, is the measure of size encapsulation [22].

Effect of Sizing Machine Parameters

The different zones of sizing machines—namely, creel, size box, drying, and head end—have to be controlled effectively for producing a good loom or size beam. Although the design and configuration of the sizing machine have some influence, the effect of different sizing parameters on the quality of size beam in general will be considered in this section. The quality of sizing will have a profound effect on the weaving efficiency and the quality of the woven fabric. Since modern shuttleless looms are running at four to ten times faster than the speed of the conventional shuttle loom, effective sizing—by exercising all the necessary controls on the sizing parameters from creel to head end—is important.

Creel Zone. The warping beams are the heart of the creel zone for ensuring effective unwinding of the warp. Therefore, the physical quality of the beams must be good. The edges should be smooth and free of burrs so that the warp ends do not cling to the edges during the process of unwinding. This may cause the warp yarn to break or be damaged due to abrasion. The mill should ensure that the warp beams are cleaned and polished at regular intervals. Also, the distance between the flanges of the beams should be constant and these flanges must be at right angles to the barrel. This must be measured before warping so that it does not create a problem when beams are delivered to the sizing section. The quality of warping on the beams should be good, with no cross-ends nor buried or embossed ends at the edges near the flanges. The density of the warping beam should be as uniform as possible to ensure uniform unwinding during sizing. The warping tension must be controlled and beam density (hardness) must be measured with a suitable pressure gauge (e.g., durometer). Warping beam preparation data such as slack selvedges, broken ends, laps, and cross-ends must be recorded and supplied to the sizing machine operator to enable effective control and correction of various problems.

On the sizing machine, the warping beams must be aligned properly in the creel. The distance between the front end of the creel to the back of the size box must be fixed on both sides to avoid slack or tight ends on the selvedges. The beam journals should be adequately tight, and bearings should work freely to ensure proper tension is maintained. The effect of the braking system has been described previously in this section. The control of yarn stretch between the back of the creel and the size box is critical. It should be as low as possible but should not exceed 0.4 to 0.8%, and it should be checked frequently.

Size Box. The major features of modern size boxes were discussed previously in this section. Positive feeding of yarns from the creel to the size box is necessary for ensuring a minimal stretch in the creel zone. The purpose of the size box is to allow the immersion of the yarns in the size box for a uniform and thorough penetration of the size and coating of the surface of the yarn. The following sizing variables should be checked and controlled where necessary:

Viscosity of the size solution
Sizing machine speed
Size add-on levels
Concentration of the size mixture
Volume of the size box (both quantity and size level)
Threading arrangements
Condition of squeeze rolls
Squeezing pressure
Hardness of squeeze rolls
Diameter of squeeze rolls
Number of size boxes
Yarn count and size box warp density per unit space

Size viscosity is dependent on the concentration of the size and the application temperature in the size box. Viscosity influences the size pick-up and consequently the size add-on of the yarn being sized. The continuous heat losses in the size box are caused by the incoming warp sheet, which is at a lower temperature; convection and radiation losses from the surface of the size to the atmosphere; and conduction losses of the size box itself. Unless the heat is uniformly applied to replenish the loss, the size solution will be cooled and a resultant increase in the viscosity is unavoidable. Heating of the size in the box is usually done by injecting steam into the size mixture. The quality of steam, therefore, is important. Excessive moisture in the steam will dilute the size due to condensation, thereby reducing the effective solid content of the size mixture. This, in turn, lowers the viscosity and affects the size pick-up and size add-on of the yarn being sized.

Squeeze roll configuration, thickness and hardness of covering, surface finishes, roll diameter, speed of the sizing machine, and squeezing pressure are a few important parameters which affect the sizing quality. A wide variety of size box configurations is available to fulfill the specific needs of various constructions and styles of fabrics for a particular mill.

Roll hardness of the rubber-covered squeeze roll influences the level of size add-on of the yarn. The suitability of the squeeze roll is dependent upon the particular sizing application (style and construction of fabric, spun or filament yarns, blend of spun yarn, yarn counts, etc.) and the sizing chemical being used (e.g., starch, PVA, acrylics, auxiliaries etc.). Harder rolls enable a sharper nip and lower pressure than softer rolls, thereby squeezing more size from the yarn and resulting in a lower pick-up. A soft roll makes a flatter nip at the same squeeze pressure so resultant size pick-ups are higher. As the thickness of the rubber covering the squeeze roll decreases, the nip becomes sharper causing the size pick-up to decrease. The prolonged exposure to high heat and constant use tend to harden the rolls and can cause permanent deformation of the coverings of the squeeze roll, which affects sizing due to uneven squeezing, lapping on rolls due to broken ends, and build-up of size on rolls. Periodic buffing of the squeeze rolls should take place, and the rolls should be re-covered when necessary. An impression of the nip should be made periodically and the record should be maintained. All settings, such as temperature, pressure, switches, and monitors, should function well at all times to ensure good quality of sizing.

The size box level determines the contact time between the yarn and size mixture. If the size level in the box is low, the yarn contact time will be shorter and vice versa. With shorter contact time, the size may not penetrate into the yarn, and the coating of the yarn may not be adequate. Ultimately, a low size level in the size box influences the size add-on, size coating, film characteristics, and control of yarn hairiness, besides affecting other properties. Devices to monitor and control the size level should be installed to eliminate the adverse effect of differences in size level on sizing.

The control of the yarn stretch between size box and drying zone is also important. Yarns being wet in the size box tend to elongate depending upon the fiber and yarn characteristics. Appropriate devices should be utilized to monitor the stretch. Space between yarns in the size box is an important criterion to ensure sufficient penetration by and adequate encapsulation of the size. This cannot occur if the yarns are too close together (i.e., crowded). This crowding of yarns in the size box creates a problem, particularly with spun yarns where the protruding fibers of adjacent yarns become entangled and cemented together. Consequently, higher energy may be required during splitting after drying. This will also increase yarn breakage during sizing, increase yarn hairiness and clinging on the loom, increase yarn breakage during weaving, and increase size shedding on loom. Too small spacing between yarns will also result in matting and entanglement, and this is especially acute in hairy yarns having long protruding fiber ends. To reduce this problem, the spreading of yarns further apart must be done to increase spacing between them. The distribution of the yarns in the size box may be expressed as percent yarn occupation:

$$\text{percent occupation} = \frac{\text{number of ends in the sizing sett}}{\begin{array}{c}\text{number of threads per cm at 100\% occupation}\\ \times\,\text{distance between flanges of warp beam in cm}\end{array}} \times 100$$

The number of threads at 100% occupancy can be calculated from Table 4.2. The distance between the flanges of the warping beam provides the information on the total working space in the size box since it represents the width of the warp sheet. The actual number of ends is the total number of yarns in the fabric style being sized. The normal percent occupancy is about 50% for yarns sized for shuttle looms and about 60 to 80% for yarns sized for air-jet weaving. Another parameter used for expressing the yarn spacing in the size box is equivalent yarn diameter (EYD). If the space between adjacent yarns in the size box is equal to 1 yarn diameter, the EYD is 1, which corresponds to a size box occupation of 50%. Similarly, yarn spaced 2, 3, and 4 diameters apart would have EYD of 2, 3, and 4, respectively, which correspond to percent yarn occupations of 33, 25, and 20%, respectively. Spun yarns normally require an EYD of 1.1 to 1.5.

Drying. About 75 to 80% of the total energy used in sizing is for drying the warp sheet. The water in the warp sheet is evaporated by converting it into steam that can be readily removed. Out of the three methods of heat transfer, namely, conduction, convection, and radiation, the conduction method is most commonly used, where multicylinder drying is employed. The mechanism of cylinder drying is explained in Fig. 4.37. The heat of vaporization of the superheated steam transfers to the wet yarn through the walls of the drying cylinder. The amount of water to be evaporated from the wet yarn depends upon the size add-on levels and the solid content of the size. This relationship is graphically presented in Fig. 4.38. For example, a yarn sized at 12% add-on with 8% solid content in the size box requires 1.38 kg of water to be removed through evaporation for each kilogram of yarn being sized.

Table 4.2 Diameters and Number of Threads for Different Counts of Yarns

Cotton yarn count (Ne)	Yarn Count (tex)	Yarn diameter (in.)	Yarn diameter in (mm)	Threads per in.	Threads per cm
200	2.95	0.00270	0.06858	370.38	145.82
199	2.97	0.00271	0.06875	369.46	145.45
198	2.98	0.00271	0.06892	368.53	145.09
197	3.00	0.00272	0.06910	367.59	144.72
196	3.01	0.00273	0.06927	366.66	144.35
195	3.03	0.00273	0.06945	365.72	143.99
194	3.04	0.00274	0.06963	364.78	143.62
193	3.06	0.00275	0.06981	363.84	143.25
192	3.08	0.00276	0.06999	362.90	142.87
191	3.09	0.00276	0.07017	361.95	142.50
190	3.11	0.00277	0.07036	361.00	142.13
189	3.12	0.00278	0.07055	360.05	141.75
188	3.14	0.00278	0.07073	359.10	141.38
187	3.16	0.00279	0.07092	358.14	141.00
186	3.17	0.00280	0.07111	357.18	140.62
185	3.19	0.00281	0.07130	356.22	140.25
184	3.21	0.00281	0.07150	355.26	139.87
183	3.23	0.00282	0.07169	354.29	139.48
182	3.24	0.00283	0.07189	353.32	139.10
181	3.26	0.00284	0.07209	352.35	138.72
180	3.28	0.00285	0.07229	351.38	138.34
179	3.30	0.00285	0.07249	350.40	137.95
178	3.32	0.00286	0.07269	349.42	137.57
177	3.34	0.00287	0.07290	348.44	137.18
176	3.36	0.00288	0.07310	347.45	136.79
175	3.37	0.00289	0.07331	346.46	136.40
174	3.39	0.00289	0.07352	345.47	136.01
173	3.41	0.00290	0.07374	344.48	135.62
172	3.43	0.00291	0.07395	343.48	135.23
171	3.45	0.00292	0.07417	342.48	134.83
170	3.47	0.00293	0.07438	341.48	134.44
169	3.49	0.00294	0.07460	340.47	134.04
168	3.51	0.00295	0.07482	339.46	133.65
167	3.54	0.00295	0.07505	338.45	133.25
166	3.56	0.00296	0.07527	337.43	132.85
165	3.58	0.00297	0.07550	336.42	132.45
164	3.60	0.00298	0.07573	335.40	132.05

Table 4.2 Continued

Cotton yarn count (Ne)	Yarn Count (tex)	Yarn diameter (in.)	Yarn diameter in (mm)	Threads per in.	Threads per cm
163	3.62	0.00299	0.07596	334.37	131.64
162	3.65	0.00300	0.07620	333.34	131.24
161	3.67	0.00301	0.07643	332.31	130.83
160	3.69	0.00302	0.07667	331.28	130.43
159	3.71	0.00303	0.07691	330.24	130.02
158	3.74	0.00304	0.07716	329.20	129.61
157	3.76	0.00305	0.07740	328.16	129.20
156	3.79	0.00306	0.07765	327.11	128.78
155	3.81	0.00307	0.07790	326.06	128.37
154	3.83	0.00308	0.07815	325.01	127.96
153	3.86	0.00309	0.07841	323.95	127.54
152	3.88	0.00310	0.07866	322.89	127.12
151	3.91	0.00311	0.07892	321.83	126.70
150	3.94	0.00312	0.07919	320.76	126.28
149	3.96	0.00313	0.07945	319.69	125.86
148	3.99	0.00314	0.07972	318.62	125.44
147	4.02	0.00315	0.07999	317.54	125.01
146	4.04	0.00316	0.08026	316.45	124.59
145	4.07	0.00317	0.08054	315.37	124.16
144	4.10	0.00318	0.08082	314.28	123.73
143	4.13	0.00319	0.08110	313.19	123.30
142	4.16	0.00320	0.08139	312.09	122.87
141	4.19	0.00322	0.08167	310.99	122.44
140	4.22	0.00323	0.08197	309.88	122.00
139	4.25	0.00324	0.08226	308.78	121.57
138	4.28	0.00325	0.08256	307.66	121.13
137	4.31	0.00326	0.08286	306.55	120.69
136	4.34	0.00327	0.08316	305.43	120.25
135	4.37	0.00329	0.08347	304.30	119.80
134	4.41	0.00330	0.08378	303.17	119.36
133	4.44	0.00331	0.08410	302.04	118.91
132	4.47	0.00332	0.08441	300.90	118.46
131	4.51	0.00334	0.08473	299.76	118.02
130	4.54	0.00335	0.08506	298.61	117.56
129	4.58	0.00336	0.08539	297.46	117.11
128	4.61	0.00337	0.08572	296.31	116.66
127	4.65	0.00339	0.08606	295.15	116.20

(*Continued*)

Table 4.2 Continued

Cotton yarn count (Ne)	Yarn Count (tex)	Yarn diameter (in.)	Yarn diameter in (mm)	Threads per in.	Threads per cm
126	4.69	0.00340	0.08640	293.98	115.74
125	4.72	0.00342	0.08674	292.81	115.28
124	4.76	0.00343	0.08709	291.64	114.82
123	4.80	0.00344	0.08745	290.46	114.35
122	4.84	0.00346	0.08780	289.28	113.89
121	4.88	0.00347	0.08817	288.09	113.42
120	4.92	0.00349	0.08853	286.90	112.95
119	4.96	0.00350	0.08890	285.70	112.48
118	5.00	0.00351	0.08928	284.50	112.01
117	5.05	0.00353	0.08966	283.29	111.53
116	5.09	0.00355	0.09005	282.07	111.05
115	5.13	0.00356	0.09044	280.86	110.57
114	5.18	0.00358	0.09083	279.63	110.09
113	5.23	0.00359	0.09123	278.40	109.61
112	5.27	0.00361	0.09164	277.17	109.12
111	5.32	0.00362	0.09205	275.93	108.63
110	5.37	0.00364	0.09247	274.68	108.14
109	5.42	0.00366	0.09289	273.43	107.65
108	5.47	0.00367	0.09332	272.17	107.16
107	5.52	0.00369	0.09376	270.91	106.66
106	5.57	0.00371	0.09420	269.64	106.16
105	5.62	0.00373	0.09465	268.37	105.66
104	5.68	0.00374	0.09510	267.09	105.15
103	5.73	0.00376	0.09556	265.80	104.65
102	5.79	0.00378	0.09603	264.51	104.14
101	5.85	0.00380	0.09650	263.21	103.62
100	5.91	0.00382	0.09698	261.90	103.11
99	5.96	0.00384	0.09747	260.59	102.59
98	6.03	0.00386	0.09797	259.27	102.07
97	6.09	0.00388	0.09847	257.94	101.55
96	6.15	0.00390	0.09898	256.61	101.03
95	6.22	0.00392	0.09950	255.27	100.50
94	6.28	0.00394	0.10003	253.92	99.97
93	6.35	0.00396	0.10057	252.57	99.44
92	6.42	0.00398	0.10111	251.21	98.90
91	6.49	0.00400	0.10167	249.84	98.36
90	6.56	0.00402	0.10223	248.46	97.82

Table 4.2 Continued

Cotton yarn count (Ne)	Yarn Count (tex)	Yarn diameter (in.)	Yarn diameter in (mm)	Threads per in.	Threads per cm
89	6.63	0.00405	0.10280	247.08	97.27
88	6.71	0.00407	0.10338	245.68	96.73
87	6.79	0.00409	0.10398	244.28	96.17
86	6.87	0.00412	0.10458	242.88	95.62
85	6.95	0.00414	0.10519	241.46	95.06
84	7.03	0.00417	0.10582	240.04	94.50
83	7.11	0.00419	0.10645	238.60	93.94
82	7.20	0.00422	0.10710	237.16	93.37
81	7.29	0.00424	0.10776	235.71	92.80
80	7.38	0.00427	0.10843	234.25	92.22
79	7.47	0.00430	0.10912	232.78	91.65
78	7.57	0.00432	0.10981	231.30	91.06
77	7.67	0.00435	0.11052	229.82	90.48
76	7.77	0.00438	0.11125	228.32	89.89
75	7.87	0.00441	0.11199	226.81	89.30
74	7.98	0.00444	0.11274	225.29	88.70
73	8.09	0.00447	0.11351	223.77	88.10
72	8.20	0.00450	0.11430	222.23	87.49
71	8.32	0.00453	0.11510	220.68	86.88
70	8.44	0.00456	0.11592	219.12	86.27
69	8.56	0.00460	0.11675	217.55	85.65
68	8.68	0.00463	0.11761	215.97	85.03
67	8.81	0.00466	0.11848	214.37	84.40
66	8.95	0.00470	0.11938	212.77	83.77
65	9.08	0.00474	0.12029	211.15	83.13
64	9.23	0.00477	0.12123	209.52	82.49
63	9.37	0.00481	0.12219	207.88	81.84
62	9.52	0.00485	0.12317	206.22	81.19
61	9.68	0.00489	0.12417	204.55	80.53
60	9.84	0.00493	0.12521	202.87	79.87
59	10.01	0.00497	0.12626	201.17	79.20
58	10.18	0.00501	0.12735	199.46	78.53
57	10.36	0.00506	0.12846	197.73	77.85
56	10.54	0.00510	0.12960	195.99	77.16
55	10.74	0.00515	0.13077	194.23	76.47
54	10.94	0.00520	0.13198	192.46	75.77
53	11.14	0.00524	0.13322	190.67	75.07

(*Continued*)

Table 4.2 Continued

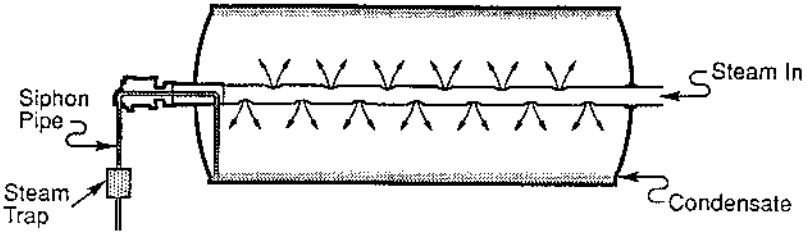
Cotton yarn count (Ne)	Yarn Count (tex)	Yarn diameter (in.)	Yarn diameter in (mm)	Threads per in.	Threads per cm
52	11.36	0.00529	0.13449	188.86	74.35
51	11.58	0.00535	0.13580	187.03	73.64
50	11.81	0.00540	0.13716	185.19	72.91
49	12.05	0.00545	0.13855	183.33	72.18
48	12.30	0.00551	0.13998	181.45	71.44
47	12.56	0.00557	0.14147	179.55	70.69
46	12.84	0.00563	0.14299	177.63	69.93
45	13.12	0.00569	0.14457	175.69	69.17
44	13.42	0.00576	0.14621	173.72	68.40
43	13.73	0.00582	0.14790	171.74	67.61
42	14.06	0.00589	0.14965	169.73	66.82
41	14.40	0.00596	0.15146	167.70	66.02
40	14.76	0.00604	0.15334	165.64	65.21
39	15.14	0.00611	0.15530	163.56	64.39
38	15.54	0.00619	0.15733	161.45	63.56
37	15.96	0.00628	0.15944	159.31	62.72
36	16.40	0.00636	0.16164	157.14	61.87
35	16.87	0.00645	0.16393	154.94	61.00
34	17.37	0.00655	0.16633	152.71	60.12
33	17.89	0.00665	0.16883	150.45	59.23
32	18.45	0.00675	0.17144	148.15	58.33
31	19.05	0.00686	0.17419	145.82	57.41
30	19.68	0.00697	0.17707	143.45	56.48
29	20.36	0.00709	0.18009	141.04	55.53
28	21.09	0.00722	0.18328	138.58	54.56
27	21.87	0.00735	0.18664	136.09	53.58
26	22.71	0.00749	0.19020	133.54	52.58
25	23.62	0.00764	0.19397	130.95	51.56
24	24.60	0.00779	0.19797	128.30	50.51
23	25.67	0.00796	0.20222	125.60	49.45
22	26.84	0.00814	0.20677	122.84	48.36
21	28.12	0.00833	0.21164	120.02	47.25
20	29.53	0.00854	0.21686	117.13	46.11
19	31.08	0.00876	0.22250	114.16	44.94
18	32.81	0.00900	0.22859	111.11	43.75
17	34.74	0.00926	0.23522	107.98	42.51
16	36.91	0.00955	0.24246	104.76	41.24

Table 4.2 Continued

Cotton yarn count (Ne)	Yarn Count (tex)	Yarn diameter (in.)	Yarn diameter in (mm)	Threads per in.	Threads per cm
15	39.37	0.00986	0.25041	101.43	39.93
14	42.18	0.01020	0.25920	97.99	38.58
13	45.42	0.01059	0.26898	94.43	37.18
12	49.21	0.01102	0.27997	90.72	35.72
11	53.68	0.01151	0.29242	86.86	34.20
10	59.05	0.01207	0.30669	82.82	32.61
9	65.61	0.01273	0.32328	78.57	30.93
8	73.81	0.01350	0.34289	74.08	29.16
7	84.36	0.01443	0.36656	69.29	27.28
6	98.42	0.01559	0.39593	64.15	25.26
5	118.10	0.01708	0.43372	58.56	23.06
4	147.63	0.01909	0.48492	52.38	20.62
3	196.83	0.02204	0.55993	45.36	17.86
2	295.25	0.02700	0.68578	37.04	14.58
1	590.50	0.03818	0.96984	26.19	10.31

The drying configuration employed depends upon the number of size boxes used, number of yarns in the sett, wet splitting, percent yarn spacing or EYD employed, number of drying cylinders available, size add-on level, solid content of the size mixture, etc. If only one size box is used, the yarn sheet is generally split in two and each sheet is dried on a separate set of drying cylinders and then combined again for final drying. By increasing the spacing between the yarns, the cylinders are not overloaded and the yarns actually dry faster, and this allows increase in sizing speed. If two size boxes are employed, there will be four sheets of wet warp, each dried separately before combining them for the final drying. Yarns sized using the high pressure squeezing technique require much less drying energy (fewer cylinders); additionally higher sizing speeds can be employed because they contain less water.

The rate of evaporation (drying rate) and the threading of yarns through the cylinders are critical for uniform drying. The temperature of the first drying cylinder is normally set at the lowest possible temperature so that sticking of yarns on the cylinder is avoided. Such sticking causes a rough yarn surface which tends to increase shedding of size both on the sizing machine and on the loom during weaving. Moreover, sticking of yarns to the cylinder increases



1. Steam enters the dry cans and strikes cylinder wall.
2. Steam condenses to water giving up its latent heat of vaporization (980 BTU/lb.).
3. The latent heat transfers to the cylinder wall.
4. The cylinder wall transfers the heat to the wet yarn.
5. The water in the yarn vaporizes.
6. The steam trap lets the condensed water inside the cylinder out through the siphon pipe for return to boiler.
7. More steam enters. Back to Step 1.

Fig. 4.37 Mechanism of cylinder drying in sizing. (Courtesy of D. Hall, Auburn University, Auburn AL.)

hairiness of yarns as the fibers are pulled from the yarn bundle during transfer to the next cylinder. After the first cylinder, the temperature is gradually increased to ensure thorough drying. If possible, the last drying cylinder should be set relatively cool to prevent false moisture regains and to control tension variations. Most sizing machines are fitted with Teflon-coated drying cylinders to minimize the sticking of the yarns. These coatings must be safeguarded and should be free of scratches or worn surfaces. Too high temperature of the drying cylinders should be avoided as it tends to cause the size to migrate due to sudden conversion of water into steam. The size is blown away from the yarn when in contact with very hot cylinders, causing an inadequate coverage of the yarn due to a lack of encapsulation or else excessive size on some yarns.

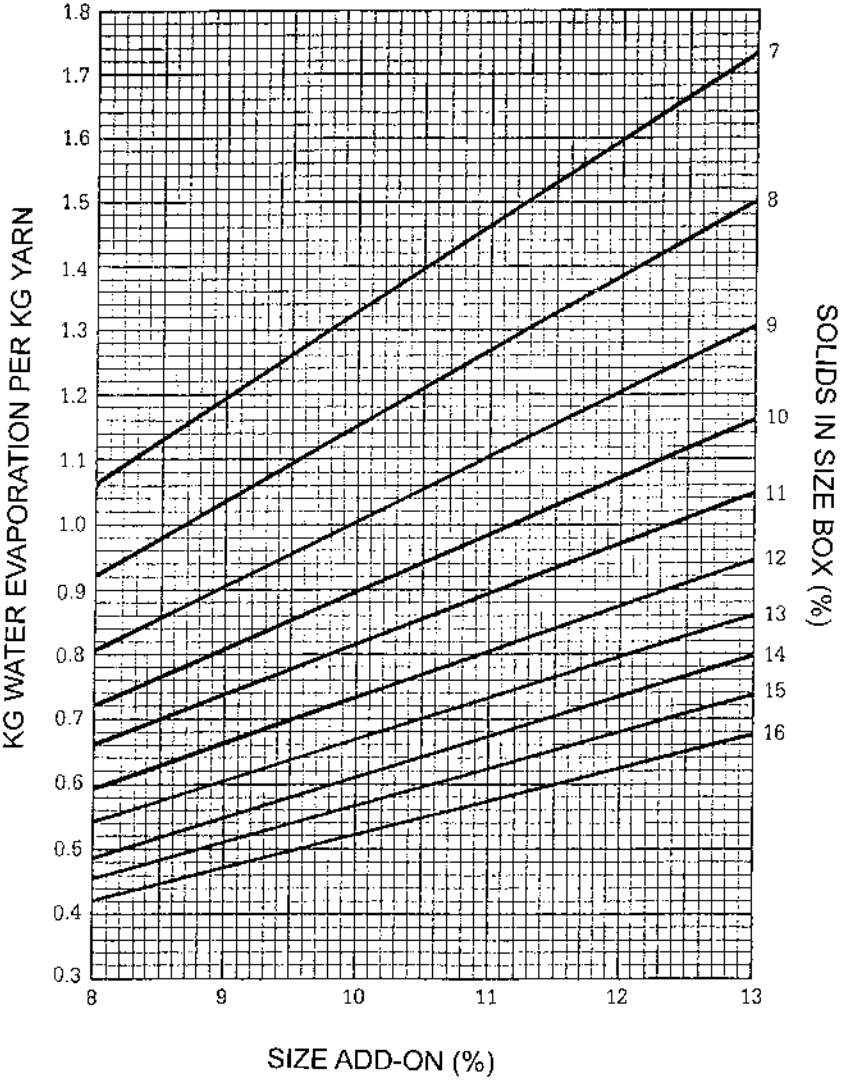


Fig. 4.38 Water evaporation requirements versus percent size add-on and percent size solids in size box. (Courtesy of DuPont Co.)

The yarn with an inadequate size coating will break during weaving while the yarn with excessive size will cause shed-off on loom.

Yarn Stretch. The most critical issue in sizing is to control the yarn stretch. As yarns pass through the long path from creel to head stock, the tension applied in the process will tend to elongate it. If this elongation is not controlled, the deformation so introduced will be permanently set in the yarn. The control of yarn elongation (stretch) between the squeezing rolls of the size box and the first drying cylinder is critical, since the wet yarns under high heat undergo stretching even at low tensions. This must be controlled by proper selection of the drive system, such as digital or variable speed differential transmission, between the size box and the drying unit.

The tension develops when the yarn is passed through the drying cylinders for ensuring proper drying. The surface speeds of all drying cylinders should be controlled, and if they are uniform, no stretch will develop in the drying zone. Despite good control, the variable speed transmission employed is susceptible to some output variation resulting from the variation in input speeds and loads. This results in a variation in tension, particularly in the wet warp sheet and during periods of acceleration and deceleration of sizing speeds. The newer sizing machines are fitted with better controls and mechanisms to control stretch more precisely.

The number of drying cylinders required to dry the yarns—based on the drying loads—can be determined from the data of wet pick-up (WPU), solid content of the size, speed of the sizing machine, number of ends in the sett, and yarn count. The following calculations represent a typical example:

$$\text{wet pick-up} = \frac{\text{weight of sizing solution (kg)}}{\text{weight of unsized yarn (kg)}}$$

$$= \frac{\text{size add-on to yarn (\%)}}{\text{solids in sizing solution (\%)}}$$

$$\text{drying load} = \frac{\begin{array}{c}\text{sizing speed (m / min)} \times \text{total ends}\\ \times\, \text{WPU} \times (100 - \%\ \text{solids in solution})\end{array}}{1000 \times 1000 \times 100} \times \text{yarn count (tex)}$$

The drying load is expressed in kilograms of water evaporated per minute. For example, a sizing machine is operated at a speed of 73.2 m/min, there are 6000 ends in the sett, 8% is the solid content in the solution, 10% is the size add-on, and the yarn count is 22.7 tex. Then the calculation is

$$\text{WPU} = \frac{10}{8} = 1.25 \text{ kg of solution per kg of yarn}$$

$$\begin{aligned}\text{drying load} &= \frac{73.2 \times 6000 \times 1.25 \times (100-8)}{1000 \times 1000 \times 100} \times 22.7 \\ &= 11.46 \text{ kg of water evaporated per minute}\end{aligned}$$

Thus it will require six drying cylinders for two-shed drying.

The above example provides an idea of the minimum number of drying cylinders for predrying; spreading of warp yarns over as many drying cylinders as available will result in the best drying of the warp, with adequate encapsulation, control of hairiness, and size penetration.

Head Stock. The properly dried warp ends coming out from the drying zone must be handled well by separating individual ends and be wound on the weaver's beam at uniform tension. If the ends are not separated well, the size film is damaged when the yarns pass through the lease rods. The size coating on the yarn surface is damaged and the yarns become vulnerable to breaks on the loom during weaving. If the spacing between the yarns is adequately set, there is no entanglement of the fibers of two adjacent yarns, which prevents damage to the size films. The proper splitting of yarns at the first leasing rod is an indication of proper sizing. A low splitting force indicates that the yarn hairiness will not be increased due to splitting.

The bust rods (lease rods) should be of large diameter and well polished to prevent the damage to the warp sheet. The yarn sheets should be evenly split between the lease rods such that the individual sheets represent the warping beam from which they came. This minimizes the yarn tension and size shedding in the splitting zone. The lease rods should be adjusted to ensure uniform spacing and leveled warp sheets to ensure that they do not touch each other while entering the front comb.

The density and height of the comb wires should be sufficient to ensure uniform winding of the warp on the weaver's beam. Uneven spacing between the dents and the crossed ends should be avoided to ensure a uniform distribution of the warp sheet. A traversing V or slant comb reed is used to help in providing an even distribution of the warp yarns and for avoiding abrasion between the yarns, which causes size shedding. To avoid abrasion and size shedding the yarns should never touch the bottom of the comb. It is recommended that the spread of the warp sheet exiting the drying cylinders should be the same as the distance between the flanges of the weaver's beam on which the warp is wound. If the distance between the flanges of the weaver's beam is higher, then the yarns are drawn at an angle which produces undue stresses and strains, which may result in size shedding, yarn breaks, and attendant problems during weaving.

The winding of the warp on the weaver's beam is done at a constant speed by means of a precision mechanism. The winding tension and uniformity of the ends should be controlled. The yarn should be drawn by the delivery roller and presented straight to the weaver's beam. The press rolls on the beam should be clean and smooth to ensure correct pressure and beaming tension. If too high a pressure is used, then the beam density will be too high and yarn slackening may occur during winding; while too soft a pressure will result in a very soft weaver's beam, which will cause problems during weaving. As the beam diameter increases, the surface speed also increases if the rotational speed is not decreased proportionately. This will exert high winding tension, which is detrimental. In modern precision winding mechanisms, the revolutions of the beam are reduced to keep the surface speed constant.

4.5 SINGLE-END SIZING SYSTEMS

Single-end sizing systems are widely used for sizing a wide variety of multifilament yarns, such as zero twist flat, textured, and low twisted fine denier yarns. Modern single-end sizing machines operate at extremely high speeds of up to 500 m/min. The sizing system is very versatile and it has simplified the yarn passage to produce high quality sizing beams. The single-end sizing systems consist of a creel and a warper, beam-to-beam sizing of the warper beams, and a beamer to assemble sized section beams into a weaver's beam. Figure 4.39 illustrates the single-end sizing system.

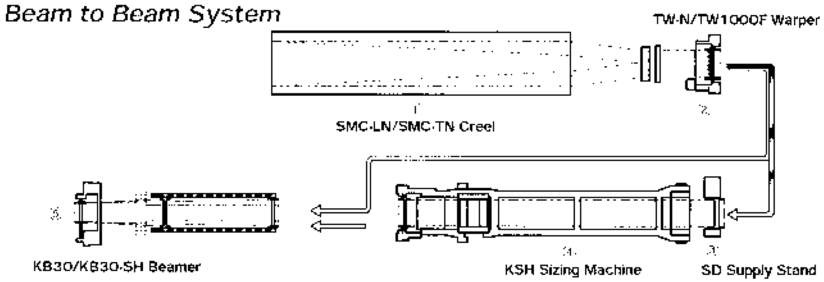


Fig. 4.39 Single-end sizing systems. (Courtesy of Tsudakoma Corporation, Japan.)

About 800 to 1500 supply packages can be placed in the creel, and the ends delivered from these packages are wound onto a large warper's beam on a warping machine at uniform tension. The broken ends or filaments in a supply package can be repaired or removed during this process to ensure a defect-free warper's beam. The warper's beam is placed on the supply stand at the back of the sizing machine. The yarns are sized by impregnating them in the sizing solution and then dried and wound onto a sectional beam on the beam-to-beam sizing machine. Figure 4.40 shows a schematic of the beam-to-beam sizing machine. The yarn is fed to the sizing section by a positively driven feed roller and the squeezing roller. A high pressure squeezing of 15 kN is used to ensure adequate squeeze and reduction in subsequent drying load. The squeezing pressure is automatically controlled in accordance with the sizing speed. The sizing machine comprises both cylinder drying and hot air chamber drying. The cylinder drying acts as a predrying step, with the number of drying cylinders varying from three to seven depending upon the yarn type and sizing speed. The hot air drying chambers enable the contactless drying of the sized yarn to ensure undisturbed size coating and smooth yarn surfaces without adversely affecting the yarn or its properties. The drying temperatures in the chambers can be adjusted to between 150 and 160°C for high-speed operations and to between 120 and 130°C for low-speed operations. Since the warper's beam thus prepared is free of yarn defects, the sizing machine generally runs without interruptions, therefore making it feasible to operate at a high production speed and efficiency with very little downtime. The yarns are sized, dried, and wound onto a sectional warper's beam at a distance of almost 1 mm apart, thus eliminating crowding during sizing and intermingling during subsequent unwinding. The required number of section beams are placed on the beam creel of the beamer so as to assemble a weaver's beam. The versatility of this system allows it to be used as a nonsizing system by skipping the sizing process, making it particularly suitable for high-twisted filament yarns. Warper's beams are prepared on a warper, and waxing or oiling, if required, is applied during the process. Such unsized section beams can then be assembled on a beamer into a weaver's beam. Alternatively, the system can also be used as a creel to the beam sizing system, where the yarns delivered from the packages mounted in the creel can be directly sized, dried, and wound straight onto a section beam. The sized section beams are then placed on the beam creel of a beamer to wind onto a weaver's beam. This system is suitable for high quality filament yarn packages containing a minimum number of yarn defects, and in such cases the system ensures a high level of performance and quality preparation of beams.

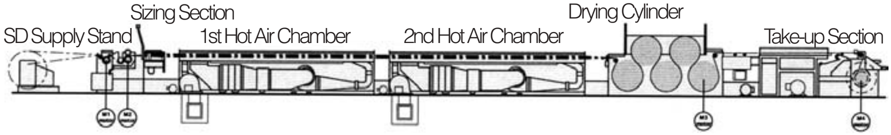


Fig. 4.40 Beam-to-beam sizing machine. (Courtesy of Tsudakoma Corporation, Japan.)

4.6 DRAW-WARPING AND SIZING

It is necessary that thermoplastic yarns (fibers) should be drawn to provide the necessary molecular orientation to achieve desired physical and mechanical properties. The production of drawn thermoplastic yarns and fibers can be accomplished in several ways. However, requirements of the subsequent fabric-forming process normally dictate the type of yarn production method which is best suited for a particular yarn and package performance [23]. The use of partially oriented yarn (POY) is increasing because of the relatively long shelf-life, ease of transportation and handling, and the fact that it can be produced in relatively large quantities at low cost. Fabrics made from such POY yarns will have a poor dye uptake and strength; therefore, it is necessary that they are fully drawn before the fabric formation stage. In conventional production methods the spun POY yarns are drawn and heat set on texturizing machines or produced in a flat (untwisted and untextured) filament state before subjecting to warping operation. This method is known as spinning–drawing–warping. In this method of processing POY yarns, it is necessary to handle each feeder package individually, and therefore uniform tension and temperature control for each end become critically important. Even slight differences in tension and temperature from end to end will result in different yarn properties such as tenacity and elongation [24]. Moreover, uneven drawing between two packages will cause differences in dye uptake when the fabric is formed. In order to alleviate some of the drawbacks of processing POY yarns by this conventional method and to improve the conversion process for efficiency and quality, new methods have been recently reported [25,26]. The new processes of draw-warping or draw-beaming and draw-sizing now enable producers to use POY feedstock to produce a fully drawn warping beam and sizing beam in a single step, yielding better quality preparation at higher production speeds and lower operating costs [25].

4.6.1 Draw-Warping or Draw-Beaming

This process produces sectional or warp beams from undrawn or partially oriented filament yarn by combining drawing and warping in a single process step, thus eliminating the separate step of draw-twisting altogether. This single step process is cost effective and also produces excellent quality by rendering a very uniform dye uptake, attributed to simultaneous drawing and heat setting of the entire yarn sheet. Moreover, since the feeder packages are very large, several sets are produced under identical processing conditions.

The combined unit for simultaneous draw-warping, as shown in Fig 4.41, consists of the following [27]:

1. *Creel*. It has a capacity to hold up to 1500 packages. It can be either a buggy type, rotary, or magazine type consisting of all package sizes and different types of yarns. It also contains oil-dampened yarn tension compensators to ensure uniform unwinding tensions on all individual ends in the yarn sheet.
2. *Drawing unit*. This unit consists of seven cantilevered godets with a hot plate for processing polyester yarns, as shown in Fig. 4.42. The unit provides the required force for uniform drawing of the sheet of yarn ends. The housing of the draw unit is designed as a rugged construction of welded heavy grade sheet metal. The seven godets are also welded and are supported on cantilevered shafts in

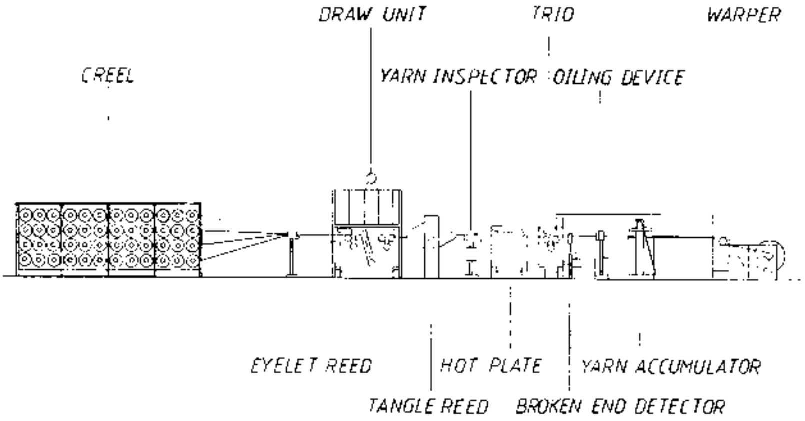


Fig. 4.41 Draw-warping line. (Courtesy of Liba Maschinenfabrik GmBH, Germany.)

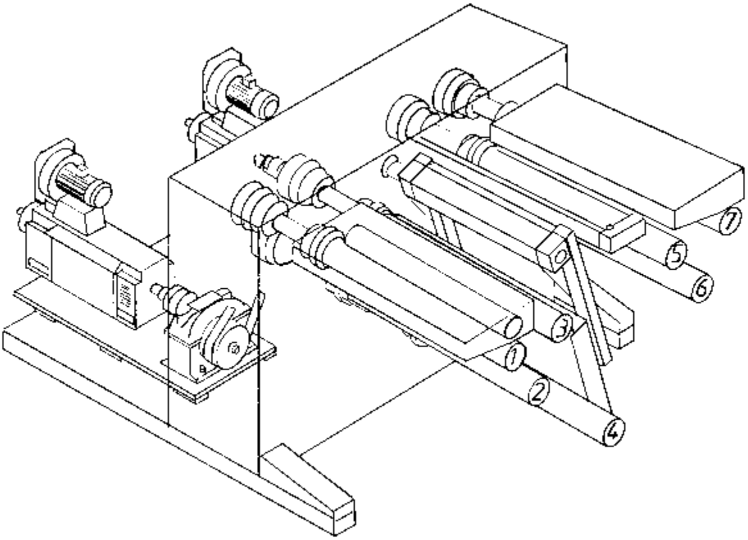


Fig. 4.42 Drawing unit. (Courtesy of Liba Maschinenfabrik GmBH, Germany.)

self-aligning roller bearings [24]. All godets are chromium plated to prevent abrasive damage. The drive to the unit consists of two thyristor-controlled DC motors for the godet groups 1–3 and 4–7, reducing gears, and flat belts for the two godet groups through a common electric supply. Drawing is accomplished between godets 3 and 4 by the different speeds of the two godet groups. The ratio is preset at a predetermined level and maintained with high precision by a digital controller under all operating conditions. Because of their helical inner structure, the heated/cooled godets work according to the counterflow principle and therefore have a high degree of surface temperature uniformity [24]. For processing, godets 2 and 3 are heated and godet 4 is cooled. A hot plate is used between these godets to heat set the yarn sheet. The hot plate swivels away from the yarn sheet when the line stops so as to prevent overheating of the yarn ends. Processing of nylon is generally done with unheated godets and without the hot plate in the draw zone. For processing delicate yarns, godet 3 can be equipped with shock heating/cooling for a quick temperature change. Rubber-coated nip rolls are used at the entry and exit points of the draw unit.

3. *Tangle reed*. In the tangle reed, each yarn end is individually entangled by means of compressed air to produce sufficient cohesion for subsequent processes. The integrated groups of tangle jets are located in two swivel-mounted manifolds. One group of jets accommodates numerous single jets. Each group can be removed separately. These groups of jets can be operated selectively for entangling only the required number of yarn ends.
4. *Yarn inspector*. An optoelectric yarn inspector, either in a single or dual channel design, is used for detecting broken ends. These are equipped with infinitely adjustable sensitivity.
5. *Relaxation zone or godet trio*. When processing nylon, it is important that controlled shrinkage reduction takes place at a low yarn tension. To achieve this, a hot plate with high heat flow density similar to that in the draw unit is used. Controlled shrinkage is achieved through differences in speed between the draw unit and the godet trio. The underfeed of the trio in relation to the draw unit is adjusted according to the process requirements. The center godet of the trio can be cooled by water in order to reduce the heat absorbed by the yarn sheet from the hot plate.
6. *Oiling device*. It contains an oiling roll, with its speed infinitely adjustable for a wide range of applications. The application of oil improves the running properties of the yarn in subsequent processes, such as warp knitting, sizing, and weaving. When the warper is stopped, a special mechanism to lift the yarn sheet away from the oiling roll can also be equipped to prevent excessive application of oil.
7. *Warper*. The warper, similar to the warper for spun and filament yarns, can handle the section beams having flange diameters that are commercially used. Optionally, it can also handle dual beams simultaneously. The warper is driven by a DC motor electronically connected with the entire line. The expansion reed is equipped with a motor drive to laterally position the yarn sheet and adjust the yarn sheet width, as well as with interchangeable chromium needle reeds. All monitoring devices and switches for the entire line for setting, operating, and controlling the electric and hydraulic components are located in one operating panel at the warper and are easily accessible and convenient to handle. Temperatures, speeds, and speed ratios are preset and monitored. The monitoring devices indicate the working order of the entire line as well as any malfunctioning in individual components. The hydraulic system in the warper head stock

facilitates mounting and doffing of the beams, engaging the drive coupling, and operating the press roll to enable quick beam doffing [27].

4.6.2 Draw-Sizing

The process of draw-sizing combines the steps of drawing, warping, and sizing in a single step. The sectional beams with individually sized yarn ends can be produced from partially oriented yarns. The sized section beams are in turn combined into weaving beams on an assembling machine. The processes are very cost effective and produce an outstanding product quality [26]. The draw-sizing line consists of a combination of a draw-warping unit with the single-end sizing machine and a creel and a separate beam assembler. With this combination, filament yarns can be quickly and efficiently draw-sized at speeds up to 500 m/min. [25]. In a single-end sizing machine, up to 1100 ends can be sized and wound on a section beam and then subsequently assembled to make a weaver's beam on an assembling line, as shown in Fig. 4.43. The essential components of creel and draw units of a draw-sizing line are similar to those described for a draw-warping line. After wet intermingling in the drawing zone, the oil-free wet warp sheet enters the sizing bath under optimal tension for size pick-up. Size enters between the intermingling nodes and thus cements all monofilaments together. A conditioning reed leads the wet sized warp sheet to the drying zone, consisting of a series of steam heated cylinders (rolls) or containing radiofrequency dryers which conserve energy. The moisture content of the yarns is reduced from close to 60% down to 10% at exit from the dryers. An enclosed steam-heated Teflon-coated hot roll dryer performs the final drying to 1% moisture content, relaxation and heat setting, bringing the boiling water shrinkage down to a 1% level. Finally, the warp sheet is wound onto beams of 200-cm maximum width and 100-cm flange diameter. Sizing can either be incorporated in the warp-drawing process as in the warping–drawing–sizing line, or warp-drawing can be performed on a warping-drawing machine at a relatively high speed, followed by off-line beam-to-beam sizing. The off-line process produces inferior quality preparation because the crowding of warp threads in a relatively narrow pitch results in more filament damage, more yarn breaks, and less uniform size pick-up [25]. Also, the integrated on-line process requires one less step and therefore reduced material handling, resulting in better process economics. The advantages of WDS systems are

1. Improved dye uptake and levelness because of the drawing of the entire warp sheet under isothermal conditions.

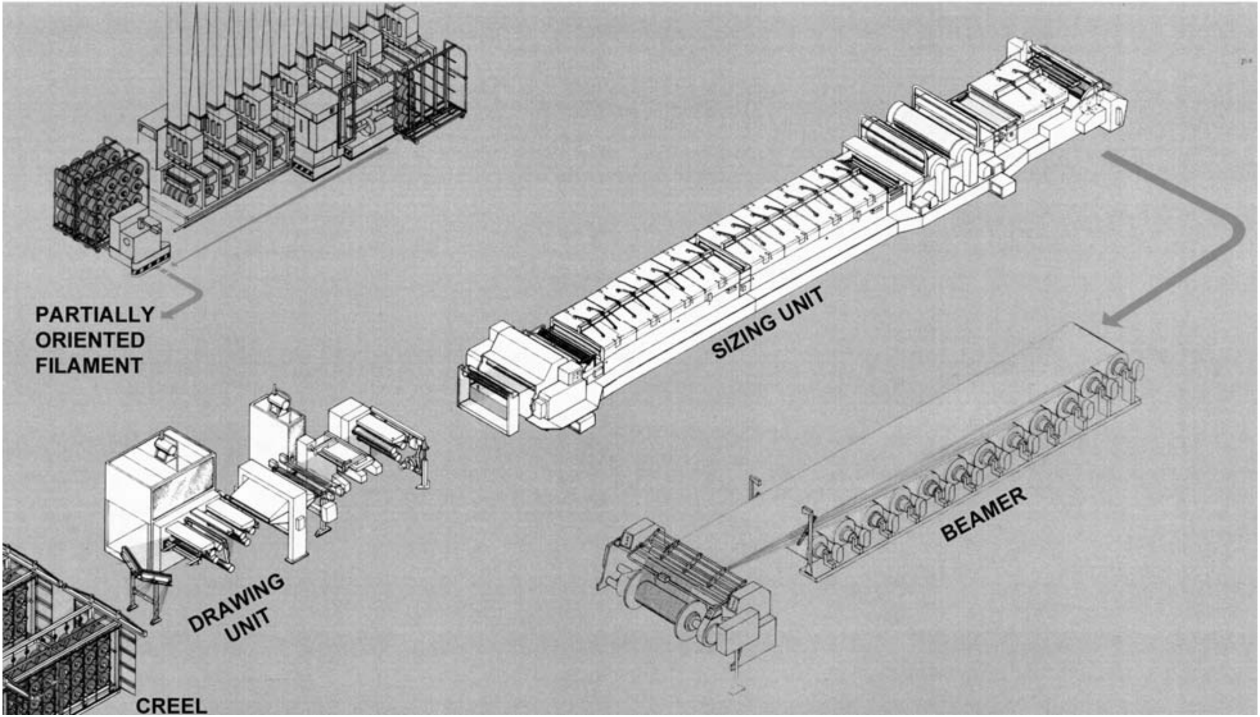


Fig. 4.43 Schematics of warping–drawing–sizing line. (Courtesy of Barmag-Tsudakoma, Japan.)

2. The rates of breakage due to drawing can be significantly reduced, thus minimizing slubs due to piecing.
3. The system produces very level and uniform beams, and consumption of sizing agents is also reduced.
4. This system produces very uniform warp shrinkage. If required, the shrinkage can also be minimized.

4.7 SIZING OF DIFFERENT YARNS

Sizing of different types of yarns, such as spun and filament yarns, requires different approaches besides different chemicals. The task is further complicated due to the fact that the speed and weft insertion technique of the weaving machine, environmental laws, construction and weave of the fabrics, type of fiber, yarn structure in case of spun yarn and textured or flat filament in the case of continuous filament are a few factors that influence the sizing parameters. Table 4.3 summarizes the factors which influence the sizing parameters.

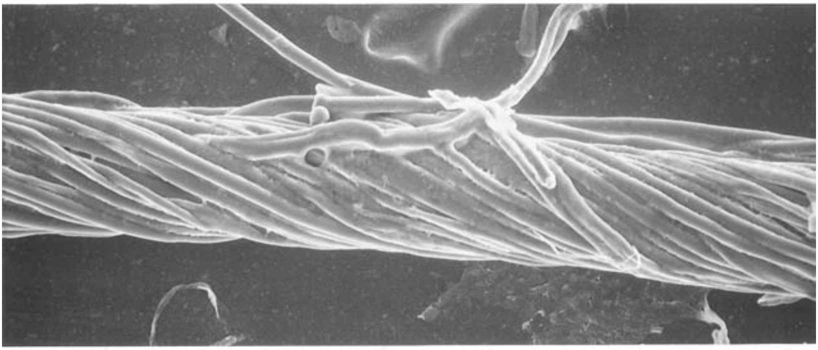
The difference in the mechanism involved in spun and filament sizing is shown in Fig. 4.44. For spun yarns, the size must bind the protruding and surface fibers to the yarn matrix by laying them down and encapsulating them with a protective coating of appropriate sizing chemicals. Because the filament yarns are regular and smooth and do not have protruding fibers, they need to be spot-bonded by the size to prevent the fraying of individual filaments. In general, multifilament continuous filament yarns are stronger, and an improvement of strength due to sizing is not required.

4.7.1 Sizing of Ring and Open-End Spun Yarn

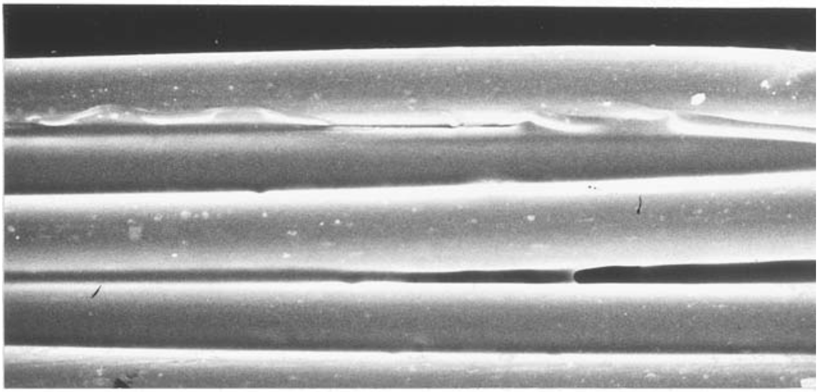
The yarn structure produced by two different yarn systems, namely, ring and open-end, are quite different [28–30], as discussed in Chapter 2. The open-end yarns are

Table 4.3 Factors Influencing Sizing Parameters

Type of yarn, spun or filament
Spun yarn parameters such as twist, count, and fiber blend
Spinning system, i.e., ring, rotor, air-jet, compact, etc.
Type of weaving machine, i.e. shuttle, projectile, rapier, air-jet, water-jet, multiphase, etc.
Type of fiber, natural or manmade
Fiber blend
Construction and weave of fabric
Environmental laws



ENCAPSULATION IN SPUN YARNS

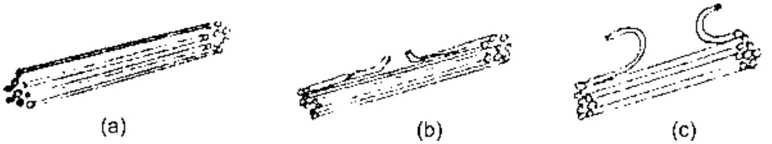


SPOT BONDING IN FILAMENT YARN

Fig. 4.44 Mechanism of sizing in spun and filament yarns.

About 20 to 30% lower in hairiness
Relatively porous and have an open surface structure
About 10 to 20% weaker in tensile strength and less elastic at similar twist levels
About 20% bulkier (larger diameters)
Lower in abrasion resistance

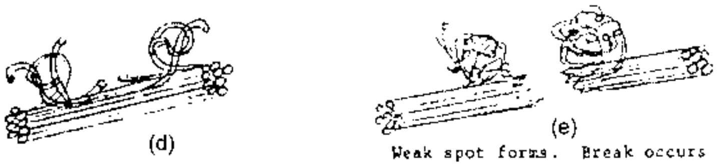
These differences in properties of open-end spun yarns require them to be sized in different ways as well. In general, higher size add-on will be required for open-end spun yarns to compensate for their inherently lower tensile strength. Because of the bulkier and porous nature of open-end spun yarns, the viscosity of the size formulations should be higher to control excessive penetration of size, thereby preventing the yarns becoming too stiff. Generally, open-end yarns will require more precise tension control at the unwinding zone and at the size boxes. The application of the size for open-end yarn should be at a lower temperature than that normally used for ring-spun yarns, which have a more compact structure. As size formulations with higher viscosity and lower application temperature are used, open-end spun yarns will have a thicker coating of size on their surface. This normally poses a problem in splitting of fibers after drying. Therefore, wet splitting and wet separation of the sheet are recommended by using large diameter splitting rods. Because the size add-on required for open-end yarns is generally higher, sometimes a ‘‘false’’ drying phenomenon occurs. The surface of the yarn appears dry while the core remains wet. Therefore, the moisture content of the dried yarns leaving the slasher should be set at least one percentage point below that used for the equivalent ring-spun yarns. The temperatures of the drying cylinders, sizing machine speeds, and calibration of moisture indicators must be controlled carefully to prevent the problem of under- or overdrying of open-end yarns.



(a)
Multifilament Fiber

(b)
One monofilament breaks due to loom action

(c)
Filament begins to peel back due to action of loom parts.



(d)
Assisted by loom action, entangled end is now large enough to cause rupture of other filaments

(e)
Weak spot forms. Break occurs since load must be distributed over fewer filaments, or the fuzz ball becomes large enough to catch on a loom part and results in fiber breakage

Fig. 4.45 Mechanism of filament peeling that results in loom stop. (From Ref. 31.)

Spot Welds of Size

Spot Weld Preventing Fuzz Ball Formation

Fig. 4.46 Concept of point bonding for the filament sizing. (From Ref. 31.)

4.7.2 Sizing of Filament Yarns

Multifilament yarns are continuous with no hairiness but contain occasionally some broken filaments which may cause problems during weaving [31,32]. Such filaments may have broken during spinning and winding or during the preparatory weaving processes of the mills. The broken filaments can create problems during weaving by entangling in loom parts, causing them to ‘‘peel back’’ until a ball is formed, which ultimately results in a break in the yarn and resultant loom stoppages, as shown in Fig. 4.45. Therefore, point bonding of filaments with size as shown in Fig. 4.46, is an important objective, which requires size with high adhesion and good film strength [31,32]. The requirement of a protective coating on filaments is far lower because of spin finishes that the spinner applies during production. These spin finishes and lubricants applied during sizing result in improved abrasion resistance. The size add-on required for filament sizing typically varies from 4 to 6% as opposed to 10 to 15% in the case of spun yarns. The concentration of the size and add-on depend upon the following factors:

Yarn denier—lower deniers (finer yarns) have higher surface areas and therefore require more size.

Construction of fabrics—the higher the number of warps per unit space, the higher the size requirement.

Type of weave—plain weave fabrics are more difficult to weave due to a greater number of interlacements compared to weaves with long floats such as satin.

The loom type, for example, shuttle or shuttleless, and weaving conditions influence the type and amount of size to be applied. The use of a water-jet loom also influences the characteristics of the size selected. The size should be water soluble during application but should be water insoluble when dried, so that when the pick is inserted by the water jet the size is not removed.

Type of sizing machine—conventional, predryer type or single-end sizing; each has different application procedures and constraints.

The size considerations for filament yarns, in terms of fiber type and loom type, are shown in Table 4.4 [31]. The suitability of ingredients for filament sizing and the application procedures are discussed and reviewed in the literature [31–35]. Size requirements for filament yarns are summarized by Hall [31] as follows:

The size solution must wet-out and penetrate the filament bundle. This may not be an inherent attribute of the basic size since it can be achieved through the use of compatible binders and additives, such as emulsifiers and wetting agents.

The viscosity of the size solution must be low enough to allow for good penetration into the filament bundle.

The size must have good adhesion to the particular filament type being sized, as shown in Table 4.4.

The sizing agent must have quick drying without a delayed set or producing a tacky surface.

Table 4.4 Size Considerations for Filament Yarns

		Type of loom		
Size	Fiber	Shuttle	Air-jet	Water-jet
Dispersable polyester	Polyester	Suitable	Suitable	Suitable
Polyacrylates (esters)				
Sodium	Polyester	Suitable	Suitable	Not suitable
Ammonium	Polyester, nylon	Suitable	Suitable	Suitable
Polyacrylic acid	Nylon	Suitable	Suitable	Suitable
Polyvinyl alcohol				
FH	Viscose rayon	Suitable	Suitable	Not suitable
PH	nylon[a], acetate, polyester	Suitable	Suitable	Not suitable
Styrene/maleic anhydride				
Sodium	Acetate	Suitable	Suitable	Not suitable
Ammonium	Acetate	Suitable	Suitable	Not suitable
Polyvinyl acetate	Acetate, polyester	Suitable	Suitable	Suitable

[a] Fabrics requiring a neutral pH.

Source: Ref. 31.

The size should produce an elastic and flexible film which matches the elasticity and flexibility that the yarns have to withstand during weaving.
The size should be antistatic or should not contribute toward static build-up.
The size shedding on the loom should be minimized so that deposition of size on heddles, reeds, and other loom parts are avoided or minimized.
The size film properties should be insensitive to changes in humidity conditions. Ideally, the size should be brittle when bone dry on the sizing machine so as to achieve separation of individual yarns at the splitting rods, but when the moisture is equilibrated in the weaving room at high humidity the size should be tough and flexible.
The size should be easily removable during desizing.
The size should not be detrimental to the yarn, processing equipment, or human health.
The size should be easy to prepare without the need of special equipment or costly controls.
The size properties should not be affected by the type of producer spin finish used.

4.8 PREWETTING OF SPUN YARNS

The concept of prewetting spun yarns with hot water before impregnating them with size solution is not new, but it has received considerable attention in recent years [36,37]. Prewetting, in essence, is a washing process which improves the specific adhesive force of the size on the surface of warp yarns. The effect of prewetting was tested on 100% cotton, polyester/cotton blended and 100% polyester ring, and rotor-spun yarns [38]. The principle of prewetting spun yarns before sizing is shown schematically in Fig. 4.47. Depending upon the application range and operation, two basic technologies are used commercially, namely,

Prewetting in a separate compartment with two immersions and two squeezes
Combined prewetting and sizing

In a conventional two–size box sizing machine, the first size box may be used for prewetting yarns with hot water. A temperature as high as ~90°C is used to ensure adequate washing out of pectin in the case of cotton yarns. The unsized yarn coming from the warp beams is passed through the first size box containing hot water. Generally, a double immersion, double squeezing system containing two sets of immersion rolls and a pair of squeeze rolls is used, as shown schemati-

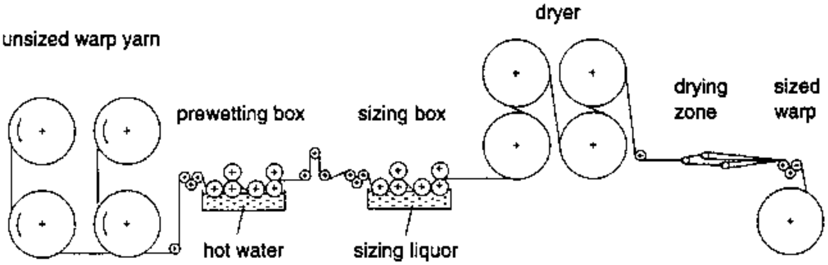


Fig. 4.47 Schematic showing prewetting concept in a conventional two box sizing machine. (From Ref. 38.)

cally in Fig. 4.47. Industrial practice has proved that such a system yields the best results [36]. This intensive wetting and washing enables the hot water to penetrate the warp yarns adequately, and the resulting washing action is optimized. The hot water partially dissolves the waxes, dust, and other material loosely held by the fibers. The first squeezing action holds back the dirt and also expels the air from the yarns so that more water is absorbed during the second immersion. The longer dwell time in the wetting compartment permits the increase in sizing speeds even for coarser yarns. Generally, high pressure squeezing of up to 10,000 daN is required to ensure adequate prewetting and to avoid dilution of the size in the size box [36–38]. The wet warp sheet emerging from the prewetting box is fed to a second size box containing the sizing solution. The process after prewetting remains as normally followed in conventional sizing. In the other commercially available system the prewetting and sizing compartments are combined in a single unit; nevertheless the principle employed remains the same.

The improvement in surface adhesion of the size to the yarn takes place because the outer surface of the yarns is wetted with size, whereas the yarn core, already wet with water due to prewetting, prevents the excessive penetration of the size. Such improved surface coating and lesser penetration due to prewetting allows the size add-on to be reduced by up to 30 to 50% depending upon the sett of the fabric and the type of loom on which it is woven. Figures 4.48 and 4.49 show the cross sections of 20 tex cotton ring-spun yarn conventionally sized and prewetted for wet-on-wet sizing, respectively. Better adhesion of the size to the yarn surfaces increases the warp yarn tensile strength by 15 to 20% and also reduces the hairiness of the yarns, which in turn improves weaveability due to lower end breaks on the loom resulting from reduced

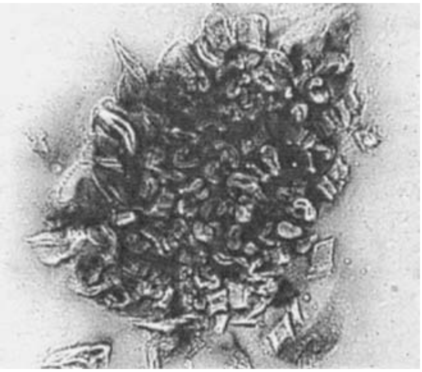


Fig. 4.48 Cross-sectional photomicrograph of conventionally sized yarn. Size add-on 7.2%, 20 tex cotton ring-spun yarn. (From Ref. 38.)

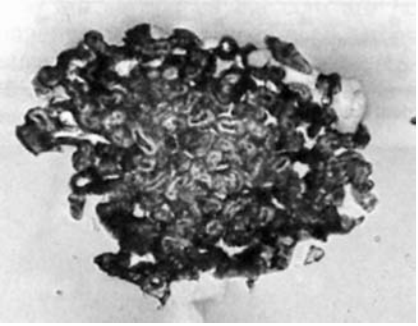


Fig. 4.49 Cross-sectional photomicrograph of prewetted sized yarn. Size add-on 8.9%, 20 tex cotton ring-spun yarn. (From Ref. 38.)

clinging tendency during weaving. The reduction in size add-on results in direct cost savings due to reduced consumption of sizing ingredients and also the resultant decrease in effluent loads. It is well known that sizing is responsible for 50 to 70% of total effluent pollution [37]. The estimated savings due to reduced size consumption per machine, with a typical production of about 2500 tons/year, is in the range of US$5000 to US$150,000 depending upon the sett of fabric, sizing chemicals, and yarn characteristics.

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