5

WARPING

Key Words: *ball warping, band warping, contracting-vee reed, creel, duplicated creels, drum warping, headstock, lease bands, leasing rods, magazine creels, multiple-package creels, nose, pattern warping, section warping, single-end creels, stop motion, tension devices, travelling package creel, truck creel, warper's beam, weaver's beam.*

The stages involved in warp preparation are:

(a) Winding from spinner's package to cones.
(b) Winding from cones to warp (i.e. warping).
(c) Application of size and lubricant to warp (i.e. slashing).
(d) Drawing-in or tying-in.

Stage (a) has already been discussed in Chapter 4; stage (b) is considered in the present chapter; stages (c) and (d) are dealt with in subsequent chapters.

Types of Warping

As mentioned earlier, there are two main types of warping,

(a) *Section, or beam warping.*
(b) *Pattern, band or drum warping.*

N.B. The term "section warping" is used in some districts to describe (a) and in others it is used to describe (b).

There is also a third type which must be considered:

(c) *Ball warping.*

General Discussion

A weaver's beam may have up to 10,000 ends and if this were to be produced directly it would be necessary to have up to 10,000 creel packages. Such an arrangement would be very difficult to accommodate and manage; consequently, it is normal practice to produce intermediate or *warper's beams* which may contain up to about 1000 ends and these are combined at the slashing stage. Because of the difficulties involved in combining the ends, patterned warper's beams are seldom produced on the direct system and any pattern that is produced is achieved by combining beams of various colors at the later stage of slashing. As mentioned previously, this imposes limitations which can only be overcome by changing to pattern warping. In the latter case, sections are made sequentially and, because of this, the process is rather slow; it is the practice, therefore, to produce no more than is required to fill a single weaver's beam. The result is that section warping is used mainly for short runs or for complex color patterns.

Because many warper's beams are combined in the direct system, this is usually regarded as a high speed process particularly suitable for single color work. Providing the warper's beams are of a single color, it is possible to combine them to produce simple patterns distributed over the warp width.

Ball warping is an intermediate process for storing yarn for transport, dyeing or reserve; it does not produce a beam. The usual form is a cross-wound cheese in which multiple ends are wound at the same time in a ribbon which contains perhaps fifty or a hundred ends.

In all cases the warping machine consists of a *creel*, a *headstock* and control devices. The details of these vary according to the type of warper and they will be compared on this basis.

Creels

There are three main types of creels (which can be further sub-divided), i.e.

(1) *single end creels,*
(2) *magazine creels,*
(3) *traveling package* or *multiple package creels.*

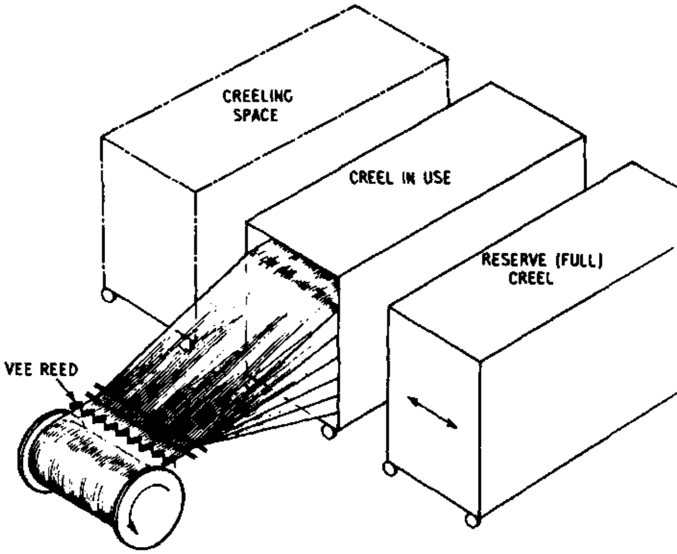
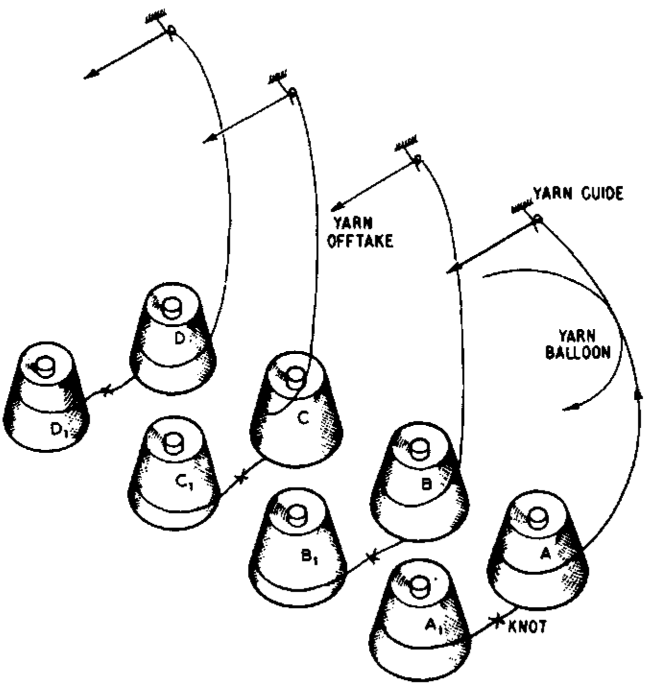


Fig. 5.1. Truck Creels

The so-called single end creel is one in which a single package is associated with each end being wound; this does not necessarily mean that only a single end is wound at any one time. It is usual to make the creel package of such a size as to produce an integral number of beams, and remnants are usually sent for rewinding. Since creeling takes a considerable time, it is essential to make it possible to transfer from one creel to another and this may be done by moving the headstock with respect to some fixed creels or by moving the creels with respect to fixed headstocks. Because of space limitations it is usual, in the case of a movable headstock, to restrict the system to two creels which are known as *duplicated creels*. In the case of the fixed headstock only two creels are used, but an extra space is required into which the exhausted creel can be moved before the full one can be brought into action. This is known as a *truck creel* (see Fig. 5.1).



THE LEADING END OF A_1 IS TIED TO THE TAIL OF A
SIMILARLY FOR B_1 AND B, C_1 AND C ETC.

Fig. 5.2. Magazine creel.

The magazine and traveling package creels are multiple package creels. They are systems in which two or more packages per end are warped. In the case of the magazine creel, two packages per end are used, the tail of the one in use being tied to the leading end of the other one as shown in Fig. 5.2. This permits creeling to proceed while the warping operation continues uninterrupted. The obvious economic advantages of this are offset by the following factors: (1) about 1 per cent of the ends break at the time of transfer from one package to the other, and (2) there cannot be as many ends per creel because of the space taken by the reserve packages. Also, it is desirable to avoid concentrations of knots. In normal practice, the knot is used merely to thread the new packages and efforts are made to prevent knots in the body of the warp.

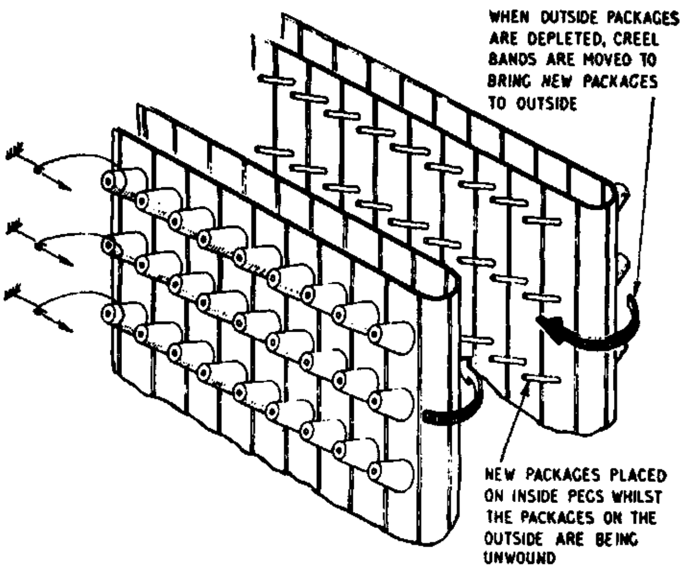


Fig. 5.3. Travelling package creel.

With the traveling package system, the package carriers move in loops so that, while the yarn is being withdrawn from the outside of the loops, the inside carriers may be creeled as shown in Fig. 5.3. At change time, the full packages are moved as a body to the outside of the loop and the newly exhausted packages are moved to the inside ready for replacement. Unfortunately, some threading time is needed at each change over and this reduces the efficiency appreciably.

An assessment of typical comparative performances may be made by considering the efficiency of warping. Assume that in each case the beam has 540 ends of 30 Tex (20s cotton) yarn and a capacity of 250 kg (550 lb). Also assume that the warping speed is 800 m/min (880 yd/min). The creel packages contain 2 kg (4½ lb) of yarn. The end-breakage rate is 0.15 breaks per 100 ends per 1000 meters, and it takes 0.9 min to mend an end break. The calculations are set out on p.91 and summarized in Table 5.1, where it can be seen quite clearly why the magazine and duplicated creel systems are more attractive than the single end system. The difference between the duplicated and magazine creels is not so significant because the relative merits depend on how long it takes to change the headstock in one case and the rate of transfer failures in the other case. Clearly, the assumptions made here are fairly critical and any decision should be made on the facts relevant to the particular cases. Generally, the magazine creel can only deal with a limited number of creel packages and may not be suitable where a large number of ends is required.

Headstock

It is a requirement that the yarn speed should remain reasonably constant throughout the warping operation and there are several ways of achieving this. In the case of section warping, the thickness of yarn built up on the drum is never great, the drum diameter is usually large and therefore there is little error in using a constant speed direct drive to the drum. In the case of direct warping, the error would be unacceptable and the solutions used in winding are adopted. Of these, the surface friction drive is the simplest, but it is also possible to use a variable speed drive to the beam spindle. The latter is usually used with continuous filaments because, at the higher speeds involved, the surface friction can be troublesome and the extra machine cost is not a large proportion of the total.

$$\text{Length of one end} = \frac{300\ \text{kg}}{540\ \text{end}} \times \frac{1\ \text{km}}{30\ \text{g}} \times \frac{1000\ \text{g}}{\text{kg}} \times \frac{1000\text{m}}{\text{km}}$$

$$= 18{,}500\ \text{meters/end}$$

this is the same as the warp length, *i.e.* 18,500 m

TABLE 5.1
Comparison of Warping Efficiencies

Item	*Calculations*	*Type of Creel* (all figures in minutes unless otherwise stated) *Single End*	*Duplicated*	*Magazine*
U = running time	18,500 ÷ 500	37·0	37·0	37·0
Repair time	$\frac{18{,}500}{1{,}000} \times \frac{540}{100} \times 0{\cdot}3 \times 0{\cdot}9$	27·3	27·3	27·3
Beam doffing	say 5 min	5·0	5·0	5·0
Comb threading	say 15 min/creel (two creels)	7·5	NA	NA
Creeling packages	say 0·1 min/end/beam Creeling time = 540 × 0·1 =	54·0	NA	NA
Headstock change	say 1·5 min/beam	NA	1·5	NA
Transfer failure	say 1% of ends one transfer/2 beams. Time lost = $1 \times \frac{1}{2} \times \frac{540}{100} \times 0{\cdot}9$ = 2·4	NA	NA	2·4
T = total times		130·8	70·8	71·7
η_w = warping efficiency = $\frac{U}{T}$		28.3%	52.3%	51.6%

For 400 end/beam with 25 km warp length on the same basis,

η_w	39%	60%	60%

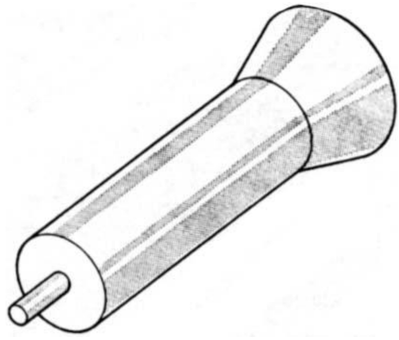


Fig. 5.4. Section warping drum.

The two types of machine require different designs of winding surface. In direct warping, all the yarn can be wound at once and it follows that, in this case, a simple flanged beam will suffice; however, in the case of indirect (or section) warping, the surface onto which the yarn has to be wound must be more complex. The reason lies in package stability. When a direct warp is wound, the edges are supported by the flanges, but when a tape-like section is wound there is no such support; consequently, it is necessary to taper the unsupported edge. In fact it is necessary to build a structure somewhat similar to a cop or quill except that multiple ends are wound rather than single ones. One important difference is that each layer of warp must contain the same number of ends and for this reason it is necessary to make one end of the winding drum tapered as shown in Fig. 5.4. The angle of taper of the conical portion (often referred to as a wedge or conical flange) is a variable, and limiting angles are bounded on the high side by package stability and on the low side by the amount of yarn which can be warped for a given traverse.

It will be noted that modern machines are long traverse low angle machines which give good stability and yet permit sufficient yarn to be warped. Consider the volume of yarn stored, and refer to Fig. 5.5. The radial depth or thickness of warp on the cylinder $= (D - d) \div 2 = x \tan \alpha$.

Let S > x so as to maintain stability

L = axial length of warp on the drum = Σ S

and V = volume stored on drum

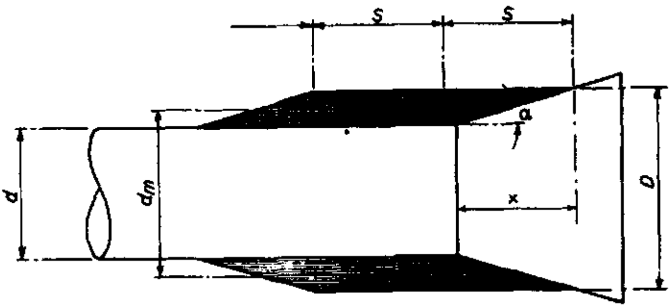
$$V = \frac{\pi}{4}(D^2 - d^2)L$$

$$= \pi\left(\frac{D+d}{2}\right)\left(\frac{D-d}{2}\right)L$$

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

$$\frac{D+d}{2} = d_m = \text{mean diameter}$$

then $$V < (\pi d_m L)(S \tan\alpha)$$



SEE FIG. 5.6 FOR PICTORIAL REPRESENTATION

Fig. 5.5. Section warping

The group $\pi d_m L$ is approximately constant for a given warp, therefore the volume which can be stored may be considered to be proportional to $S \tan\alpha$. In other words, if S is small it is necessary to increase α to get sufficient volume. With large traverse machines, the need to alter α from one operating condition to another tends to vanish;

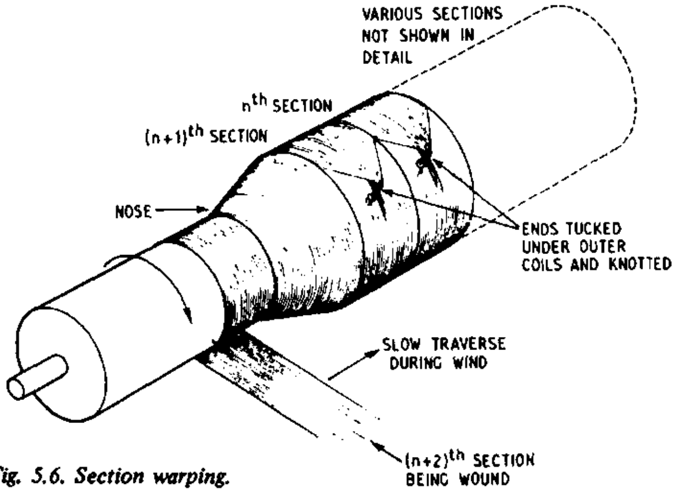


Fig. 5.6. Section warping.

modern design adopts this solution because of the simplification and it is common for such machines to be capable of storing 1000 kg (2200 lb) of yarn on a 1 meter (40 in) diameter drum.

In making the warp, each end of the tape-like section is threaded through *tension devices*, *stop-motion*, *leasing rods* (or reed), *contracting vee reed* and then is led over a measuring roller to the drum. The leading end of the section (which is normally knotted) is then attached to the drum so that the edge of the section lies at the *nose* formed either by the conical portion of the drum or by the previous section, as shown in Fig. 5.6. After an initial few turns, *lease bands* are inserted in a direction parallel to the drum axis in the fashion shown in Fig. 5.7. These lease bands make it possible to identify the correct layers of yarn to be used in unwinding so as to give a continuous sheet of warp across the width of the beam. It is usual to insert about six of these bands, after which the traverse is set in motion so that the build required is obtained. At the end of the build of that section, the tape-like section of yarns is cut, the ends are knotted and the end attached to the drum is fixed by tucking it under a previous layer. The next section is then wound and so on. The measuring roller ensures that the same length of yarn is wound for each section and, since this is important, the machine is normally stopped automatically after the predetermined length is wound.

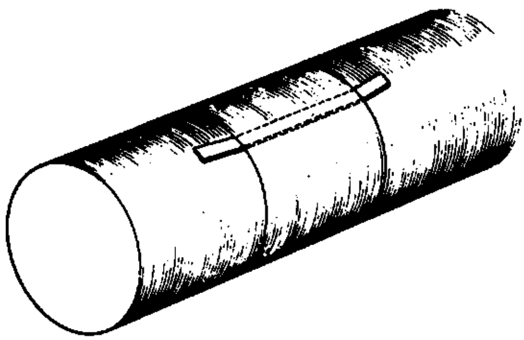


Fig. 5.7. Lease band.

After completion of the warp, it is later wound onto a beam and the lease bands which were originally on the inside now come to the surface; these are very helpful during the subsequent processes. It is possible, however, to have transportable drums for use in subsequent slashing and, in this case, it is necessary to carry out the leasing operation at the end of each section wound instead of at the beginning. The choice between the two systems is determined by the relative costs of an extra wind as against the extra capital tied up in a transportable drum.

Control Systems in Warping

As is usual with most textile operations, it is necessary to control tension such that all ends are as nearly alike as possible. The tensions are not high and it is usually sufficient to apply just enough to prevent the yarn snarling and entangling. Each end has to be controlled, therefore one tension device per end is needed; it is normal for the device to be sited in the creel very near to the package. Also, since many are required and the tension is low, a simple disc type tensioner is usually preferred.

A simple tensioning device is only able to increase the tension and it is necessary to ensure, therefore, that the input level is considerably lower than that ultimately required. In the case of warping, this means that the ballooning of the yarn coming from the creel package must be controlled. It is important that the yarn guides be placed in the correct position with respect to the package and that there is sufficient space between packages. It is helpful to arrange all packages to unwind in the same direction so that the balloons do not interfere and cause entanglements. In high speed warping, the unwinding tensions become somewhat more important and variations caused by the progressive exhaustion of the creel packages should balance as far as possible to maintain similarity between all ends. This is particularly relevant to section warping, where the tension in the last section may be quite different from that in the first.

It is necessary to have a stop motion since a good warp should not contain many broken ends. A drum of perhaps 1 meter (40 in) in diameter or even a simple flanged beam together with its drive will have considerable inertia, especially at high speed, and the stopping time is considerable. Consequently any stop motion must be sited in such a way as to allow sufficient time for any stop to occur before the broken end reaches the headstock. Once an end is allowed to reach that point, there is little or no possibility of repairing it, especially since warping is irreversible. Any attempt to unwind the warp at this stage is likely to lead to entanglement. For these reasons, the stop motions are usually sited as a group near the creel exit, the stop devices are usually electric to give quick response and the machine is always fitted with powerful brakes.

Some designs of warper incorporate a warp storage system which allows a limited amount of warp in transit to the beam to be stored at the time of a break. When a break occurs the fault zone can be retrieved from storage and this enables higher warping speeds to be used.

Normally, the yarn on the creel packages has passed through a clearing operation and no further clearing is required during warping. With some of the new methods of yarn production it is possible to obtain uncleared packages of the correct size and build which, if warped, might give subsequent trouble. Even here, the best solution would appear to be to clear the yarn elsewhere rather than stop the entire warping operation for a single break.

It is most desirable, especially in pattern warping, to control the length of warp wound and a measuring roller is used in combination with a suitable counting device to stop the machine at the appropriate delivered length.

As mentioned earlier, it is desirable to control the surface speed of the warp particularly when a large change in warp diameter is involved. The frictionally operated surface drive needs no further comment but it may be helpful to consider the variable speed spindle drive in a little more detail. In any control system, it is necessary to measure the parameter to be controlled, hence in this case one would have to measure the yarn velocity or compute it from a measurement of the warp diameter. The latter method is popular, but it will be realized that if the sensing element depresses the surface of the warp to any appreciable extent, then an error will arise. Much electrical equipment has become progressively cheaper over the last few decades and speed measuring control devices might be expected to gain in popularity.

The density of the warp on the beam has to be controlled, depending on whether it is prepared for slashing or dyeing. The density may be controlled by tension, pressure or a combination of both. In the case of frictional drive, an element of pressure control is unavoidable and it is not easy to produce a very soft warp beam because of the pressure needed to drive it. In the case of spindle drive, it is possible to use tension alone, but it is a common practice to use a pressure roller, the pressure of which is often hydraulically controlled.

In warping yarns made from man-made fibers, a considerable degree of static electrification may be produced and some form of elimination is required to avoid yarn entanglements. There are several means of control, viz: (a) chemical fiber finishes, (b) ionization of the air and (c) humidification of the air. The chemical finish introduced by the fiber producer has to be compatible with all the operations and may be insufficient to meet the need at this stage. Consequently, it is usual to apply one of the other methods or a combination of them. Excessive humidification can produce unpleasant working conditions which may affect the labor force and it can cause machine damage by deposition of dew during non-working periods. The hazards of ionization have to be considered, and the expense must be weighed against the savings.

With staple fiber yarns, lint and fly can cause trouble, particularly at the tension control and break detector points. Also, they bring about a deterioration in working conditions. Blowers are frequently used to remove the fly and lint from the creel, but this would be useless unless the air-conditioning system is capable of removing the material from the environment. Preferably, the air-conditioning system should remove the contaminated air from points as near to the source as possible.

6

SLASHING (WARP SIZING)

Key Words:
beam creel, breaker bars, byrometer, clearing, comb crimp, cylinder drying, desizing, direct sizing (slashing), drawing-in, drying section, dusting off, end breakage, exfoliate, fibering-off, clearing, fly, gelatinization, hot-air drying, immersion roller, indirect sizing, lease bands, lease rods, leasing, loom state, mixing beck, penetration (of size), slashing, shed opening, size box, size liquor, size shedding, size take-up, softeners (in size), squeeze roller, tying-in, viscosity, warp sheet, warp sizing, wet finished.

Introduction

The primary purpose of *warp sizing* is to produce a warp which will suffer the least damage in weaving. In some cases it is also used to modify the character of the yarn so as to have an effect on the fabric weight, stiffness or hand, but if this secondary use should interfere with the primary one, then the process has been misapplied. Warp sizing achieves its primary purpose by causing fibers mutually to adhere in such a way as to make the warp yarns stronger, smoother and better lubricated (see p. 36). However it is also important that the sizing materials should not interfere with the processes following weaving. Wherever possible the sizing should aid in these processes and not hinder them. Hence it is necessary to consider not only the way in which size is applied and its effects in weaving, but also the effects on subsequent processes (such as dyeing) and on the resulting fabric.

Although the ultimate aim should be to eliminate all sizing (and other preparatory processes) to achieve minimum cost, this is not at present practicable. Indeed, not only does adequate preparation reduce overall costs by making the weaving operation more efficient, but it is almost impossible to weave most warps found in industry without sizing. Size is often applied to yarns to give them added strength, but even with continuous filaments where the strength is adequate, lack of size may allow slack or broken filaments to protrude from the body of the yarn, especially in the cases of low twist and textured yarns. These protruding yarns can entangle or form fuzz balls and cause end breaks. In general, the higher the twist level, the less the amount of size required. If the twist is exceptionally high, it is possible to weave a warp without size, but the resulting fabric is harsh and unacceptable for most purposes. Acceptable fabrics may be obtained by weaving unsized ply yarns but the cost of plying has to be set against the cost of slashing. Usually slashing is used in preference to plying unless the fabric demands the use of plied yarn. Towels frequently fall into this latter category.

Looking to the future, new yarn structures may modify sizing requirements. Twistless yarns (in which fibers are held together by an adhesive) obviously need little or no further sizing and it is quite possible that any attempt to slash them would cause yarn damage especially if the original adhesive were water soluble. Composite yarns (in which the fibers may be held in position by frictional or chemical forces and in which there are both staple and filament components and perhaps other polymeric material) may need special treatment which could differ quite radically from present experience. Open-end spun yarns (which have a more open structure in the outer sheath of the yarns) require a diluted size liquor. Furthermore, the weaving apparatus is undergoing change; shuttle-looms are giving way to shuttleless looms and the conditions imposed on the warp are altering. The water-jet loom, for example, is a special case in which the filling is inserted by a jet of water, and this obviously introduces sizing problems when a water-soluble size is used.

Water pollution has become a matter of increasing concern in our modern world, and there is mounting pressure to prevent industrial wastes (of which size is one) from contaminating rivers and other waterways. Consideration must be given to the question of recycling the material removed during de-sizing. One possibility is the use of reverse osmosis through membranes to separate the clean water and another is to use non-aqueous solvents in the size, but such solvents are either toxic or flammable and need great care to prevent hazards to the workers. Meanwhile most industrial plants continue to use water-based solvents and the rest of the chapter will be written assuming that water soluble sizes are used.

Warp Breaks During Weaving

A warp end will break when the tension applied is greater than its breaking strength. Failure may be caused either by an increase in tension or by a decrease in strength.

Tension may increase for several reasons; these fall into two categories, viz. :–

(a) Controlled by machine design parameters *or* (to a limited extent) by the setting of the loom.
  Too large a warp shed opening.
  Insufficient tension compensation.
  Heavy beat-up.
  Improper warp let-off.
  Loom settings.

(b) Controlled by operational parameters.
  Passage of knots.
  Entanglement between warp yarns (often caused by slack ends).
  High friction between warp and machine.

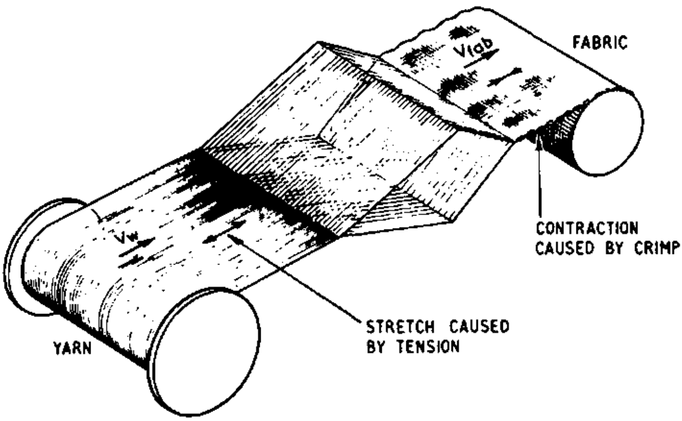


Fig. 6.1. Warpwise length changes during weaving

Nicks, cuts and roughnesses in machine part surfaces in contact with the warp (particularly important with textured yarns).

Decreases in strength of the warp yarn may be caused by the following:

Yarn damage caused by the machine.
Weak places in the yarn supplied.
Uneven distribution of load over all the warp ends.
Inadequate knotting or joining.

Causes of High Tension

Tension levels in a warp may be sub-divided into three components, viz:

(a) Constant mean tension.
(b) Cyclic variations about the mean.
(c) Transient variations which occur randomly.

Constant Mean Tension

The mean tension is determined by: (1) the relative rates of take-up of the cloth and let-off of the warp; (2) the contraction of the warp due to *crimp* created by weaving; and (3) the stretch of the warp due to the tension (Fig. 6.1). With proper setting, high mean tensions are rarely the cause of high *end breakage rates* and the topic need not be further discussed at this point.

Cyclic Variations About the Mean

The principal cyclic variations in tension are caused by the shedding and beat-up. The *shed opening* has to be sufficient to allow the shuttle to pass; also, the shed must be changed periodically to give the desired weave, which means that the path of the warp end through the shedding zone changes in length. Without compensation, this would lead to large variations in tension. Tension compensation devices are commonly used to reduce tension variation but, because of dynamic effects, it is not possible to eliminate the variations entirely. The cyclic variations due to beat-up tend to consist of sudden pulses and the magnitude of the pulses is a function of the cloth structure. A dense fabric gives a much higher amplitude of pulse at beat-up than a more open fabric. The point of highest tension in the cycle (which might be at shedding or beat-up) is the point in time where a weak yarn is most likely to break and where yarn damage is most likely.

Transient Variations Which Occur Randomly.

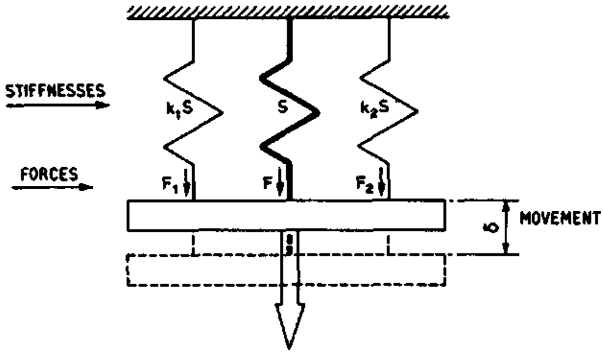
The randomly occurring transient tension peaks are the most important of all, being frequently the cause of breaks. For example, a large badly-shaped knot may be unable to pass through the reed (or heddle eye) producing a very high tension peak in that particular yarn, which may break even though it has no weak spot. Of course, the conjunction of such a knot with a weak spot almost certainly leads to an end break. Similarly, entanglements of (a) fibers or broken filaments protruding from yarns, (b) the yarns themselves, or (c) knot tails may give similar results except that in some of these cases several adjacent ends are likely to be involved.

Relative movement and pressure between the warp yarns and the various parts of the loom lead to tension build-ups along the warp yarn. The relative movement is not unidirectional and in places there is a sort of chafing action superimposed on the general movement from the beam to the cloth roll. The tension build-up at the rubbing point depends upon the direction of movement, the coefficient of friction, the mean tension in the yarn as well as the geometry of the contact between the yarn and machine part. This is somewhat complex but it is important to understand the phenomenon at least qualitatively. If these tensions are allowed to become large, as they can be, then the end-breakage rate would become totally unacceptable. In marginal cases, the difficulty is ameliorated by the application of lubricant whereas a more complete understanding might have eliminated the problem.

Causes of Low Yarn Strength

The chafing mentioned earlier may damage the yarn; fibers may be torn from the yarn, disrupting its internal structure and weakening the yarn more than might have been expected from the removal of a single fiber. Other fibers may be cut or damaged, especially on the yarn surface, and this further weakens the yarn and adds to the problem of generation of *fly* which can accumulate and create a fire hazard or can collect in clumps on the yarn and create faults. High peaks in tension tend to cause permanent elongation which usually reduces yarn strength and increases local stiffness. Since a yarn of greater than average stiffness takes more than its fair share of the load, it has an increased tendency to break. Clearly, such overstraining of the warp is to be avoided.

Obviously a yarn with many weak places will give many end-breaks and it is desirable for the yarn strength and



ΣF = TOTAL APPLIED LOAD

$$F_1 = (k_1S)\,\delta$$
$$F_2 = (k_2S)\,\delta$$
$$F = S\,\delta$$
$$\text{TOTAL LOAD} = \Sigma F = F_1 + F_2 + F = (k_1 + k_2 + 1)\,S\delta$$
$$\frac{F}{\Sigma F} = \frac{1}{(k_1 + k_2 + 1)}$$

If k_1 and k_2 are small, central member takes a large share of the load
If k_1 and k_2 are large, central member takes only a small share of the load
i.e. load acting on a given member depends upon the associated system

Fig. 6.2. Redundant structures

linear density to be as uniform as possible; indeed, this is one of the main reasons for *clearing* warp yarn to remove thick and thin (or weak) spots from the yarn.

Yarn stiffness is an important factor. Consider three springs as shown in Fig. 6.2. The two outer springs have a lower stiffness than the center spring, which is seen to take a large share of the load. The model may be regarded as a simplified version of a warp, in which the warp yarns are represented by the springs. Consequently, the relative stiffnesses of the warp ends are important. For example, with a striped warp in which the tensile stiffness of the yarns forming one stripe is higher than the rest, the yarns in that one stripe will suffer higher tensions than the rest and this could lead to excessive end breaks in that stripe. Similarly with single warp ends. Uneven sizing can affect the yarn stiffness and this in turn can affect the end breakage rate and distribution.

In normal operation the extension is fixed by the machine and the stiffness of the yarns will affect the tensions generated. With very stiff yarns, such as glass or improperly sized yarns, small variations in the extension can increase end-breakage rates. Deflections in the loom itself may cause bad distribution of load among the ends, sufficient to present problems in the case of very stiff yarns. Such variations might be of little significance, however, in the case of more extensible yarns in which the variations are offset by the stretching of the yarns during weaving. After weaving has been in operation for some time, tension differences due to local effects (including local stiffnesses, repaired ends, slackness, etc.,) tend to disappear or "weave out".

TABLE 6.1.

Ingredients For Water Based Sizes

Adhesives	*Lubricants*	*Additives*
Potato starch	Mineral waxes	Salicylic acid
Starch from cereals (corn, wheat, rice, etc.)	Vegetable waxes	Zinc chloride
	Animal fats	Phenol
Carboxy methyl cellulose (CMC)	Mineral oils	Emulsifiers
Polyvinyl alcohol (PVA)	Vegetable oils	
Polyvinyl chloride (PVC)		

TYPICAL SIZE RECIPES

STARCH	KG			45									
	LB				100								
STARCH GUM	KG									45			
	LB										100		
PVA	KG	23								9			
	LB		60								20		
CMC	KG					20		9					
	LB						45		20				
ACRYLIC BINDER	KG					2				4.5		136	
	LB						5				10		300
FAT	KG			3									
	LB				6								
WAX	KG	1		0.5		1				1			
	LB		2.5		1		2.5				2.5		
VOLUME AT FINISH	LITER	378		378		378		378		378		378	
	GALLON		100		100		100		100		100		100
TAKE-UP	%	8	8	12 to 14	12 to 14	8	8	3	3	12 to 14	12 to 14		
NOTE: To use table, select any one column according to fiber and system of units	UNITS	POLYESTER COTTON		COTTON		SYNTHETIC COTTON		SPUN RAYON		NYLON COTTON		FILAMENT	

Table 6.2

Size Ingredients

A warp yarn should be strong, elastic, extensible and smooth. The ingredients used in sizing are usually starches, gums or synthetic adhesives and fatty or oily substances (to act as lubricants and plasticisers or softeners). The two types of ingredient tend to have opposing effects on the yarn and a compromise has to be made to yield the lowest end-breakage rate for the given yarn under the given conditions. With some synthetic sizes, particularly those used for textured yarns, it is not necessary to add an additional lubricant and in those cases it might even be harmful to do so. In many instances, antiseptics, anti-mildew agents etc., might be added to the recipe. Typical ingredients for water based liquors are shown in Table 6.1.

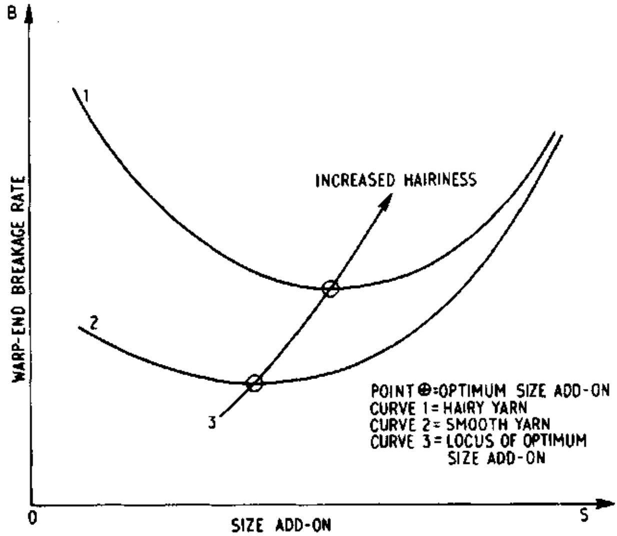


Fig. 6.3 (a). Typical B-S curves.

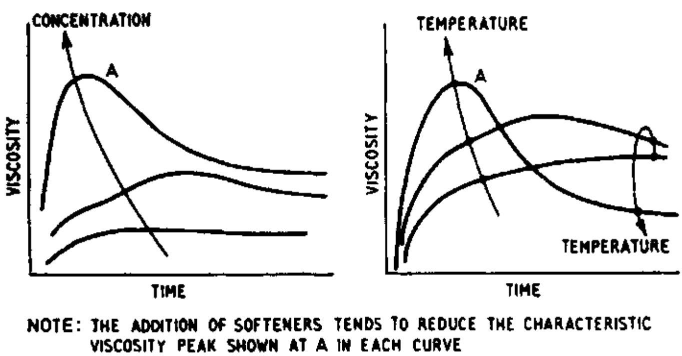


Fig. 6.3 (b). Typical size cooking curves

It is possible that non-aqueous liquors will be used in the future, but as yet there is little experience in this area. Consequently, only aqueous solutions are considered and typical recipes are given in Table 6.2.

The adhesive, usually in granular form, is mixed with water and heated to form a paste which ultimately becomes a viscous fluid. Starch is a complex carbohydrate which combines with water; this causes the material to swell and change character. The *viscosity* of the boiled starch is controlled to a great extent by the amount to which the surface of the granule is dissolved. This in turn is affected by the recipe, the degree of mechanical mixing, the temperature and time of boiling. Typical viscosity curves are shown in Fig. 6.3. It will be seen that under certain conditions prolonged boiling will cause a decline in the viscosity. Similar effects can be obtained by over-vigorous mechanical working. In both cases, this is caused by breakage of the fairly weak hydrogen bonds formed during the gelatinizing phase. The viscosity is one of the important factors influencing the amount of size picked up by the yarn.

Other sizes behave in a somewhat similar manner and the temperature of the size liquor and the time factor both affect the viscosity with similar effects on the ultimate size add-on.

Lubricants, soaps, and waxes are commonly used as *softeners*. Without such softeners in certain sizes, the yarns would not be sufficiently extensible; the size would crack and particles would drop away from the yarn (i.e., *exfoliate* or *dust off*) and this in turn would create local stress concentrations which would encourage end-breakage.

The most important factors in choosing size ingredients are:

(a) The recipe should be that which gives fewest end breaks.
(b) It should be that which gives the least exfoliation.
(c) It should be that which permits easy *de-sizing*.
(d) It should give good fabric characteristics.

(e) It should be compatible with the machinery (*e.g.*, it should not cause size build-ups during weaving or blockages during slashing).
(f) It should not cause any health hazard.
(g) It should not cause any degradation of the textile material.
(h) The cost of sizing plus the cost of weaving and finishing should be a minimum.

Lubricants or Softeners

Tallow

This lubricant is the fat of beef or mutton, or a mixture of the two. The weight of tallow used in a size based on sago flour as the adhesive is up to 10% of the oven dry weight of the starch (sago). In many cases tallow substitutes are used to reduce the cost of sizing.

Soap

This lubricant is used with many sizes as a softener but it is not used alone. It is often mixed with tallow before introducing to the size in the *mixing beck.*

Japan Wax

This softener is popular in the U.S.A. It melts at 50°C (122°F). If adulterated with paraffin wax, it is difficult to remove in finishing.

Factors which Affect the Properties of Sized Yarn

The most important factors affecting the properties of the warp yarn after sizing are:

(1) Lubricant added to fiber or filament prior to slashing (i.e., *fiber finish* or *coning oil*).
(2) Lubricant added to the adhesive as part of the size recipe.

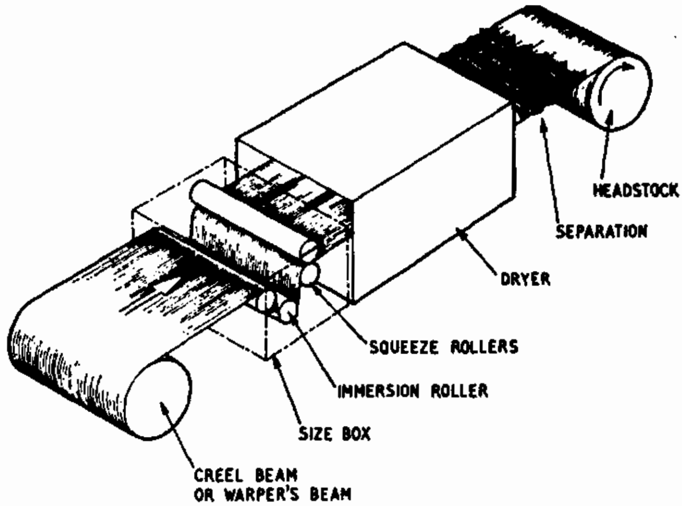


Fig. 6.4. Warp Sizing (Simplified)

(3) Adhesive type.
(4) Recipe (i.e., percentage adhesive, percentage lubricant, etc.).
(5) Size add-on (the amount of size put on the yarn).
(6) Technique of sizing.
(7) Operational conditions such as yarn speed, temperature of drying, yarn tension etc.,
(8) Weave room relative humidity.

Man-made fibers usually have some sort of fiber finish to act as a lubricant during fiber and yarn manipulation and to reduce static electrification of the fiber. Common natural fibers, (unless scoured), have a fatty or waxy coating. In some cases, extra lubricant is added to the fiber or yarn during yarn manufacture (such as coning oil). Such oils and additives may plasticize the polymer used as size and, if

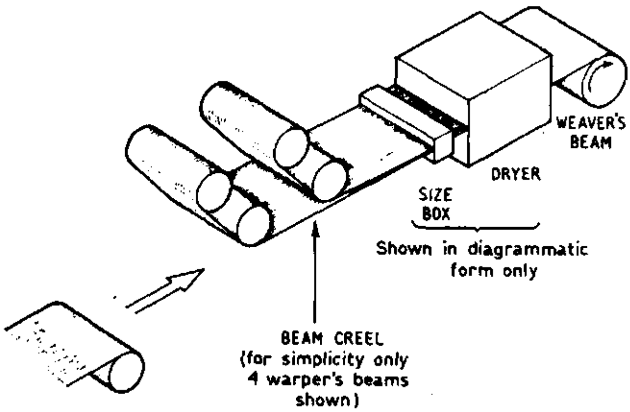


Fig. 6.5. Use of Section Beams

such plasticization is excessive, the material will become tacky to the point of being unusable. Furthermore the oils or additives may adversely affect adhesion between the size and the fiber and thus the additives must be compatible with the size recipe. Also, the percentage lubricant on the yarn prior to slashing must be minimised, just sufficient lubricant being needed for the prior processes. A typical maximum percentage at this stage is 1%. The total lubricant percentage will determine adhesion and toughness of the size, and the size recipe may have to be varied to take into account the lubricant already on the yarn. For example, if one were to attempt to use a knitting yarn for a warp, it might be found that the yarn oil level is high for weaving purposes. It might be necessary to reduce the lubricant in the size or it might even be impossible to slash the yarn satisfactorily because of too high an oil level.

For spun yarns there is a wide choice between the various sizes, such as starch, PVA, CMC, etc., and the choice is commonly determined by cost. For filament yarns the

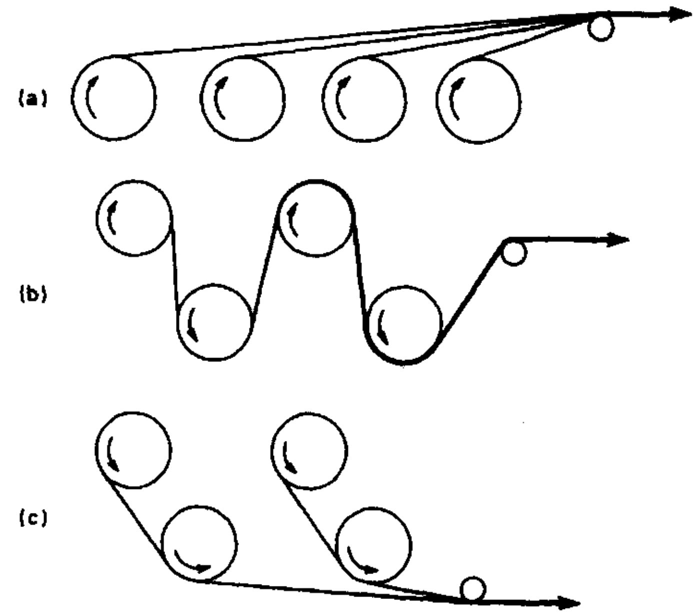


Fig. 6.5(a) Beam creel arrangements
Note: For simplicity, only four warper's beams are shown in each arrangement. Normally there are more.

choice is not so wide because compatibility between fiber and size becomes more important. For example, with nylon, polyacrylic acid is frequently preferred because of the adhesion properties, whereas with polyester, acrylate sizes are usual. In this latter case, care must be taken in respect of plasticization from either the lubricants or the moisture in the air. In other words, the weave-room relative humidity is important and it may be necessary to vary the size formulation according to the weave room conditions expected.

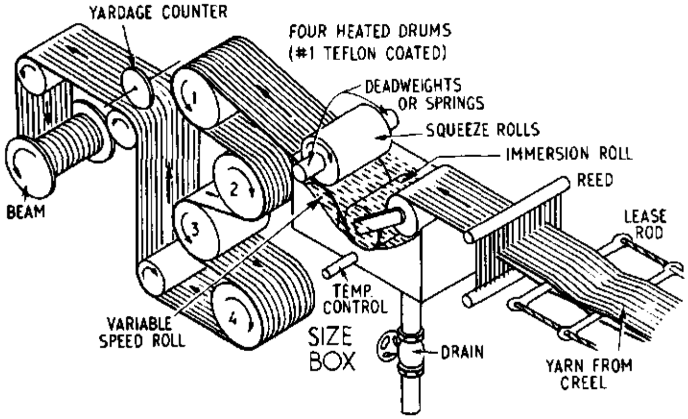


Fig. 6.6. 'Single-end' slashing (creel not shown).

The amount of size add-on depends on yarn structure and size recipe, thus there are significant differences between the requirements for flat filaments, textured and spun yarns. Also, the roles of bulk, hairiness and twist levels vary according to the type of yarn. One major function of slashing is to control the surface of the yarn; in general, the more size add-on, the smoother the yarn, and a smooth yarn will weave better than a hairy or non-smooth one; thus one might expect a curve such as (1) in Fig. 6.3(a) to indicate performance. As the size add-on is increased the yarn becomes stiffer, less extensible and more difficult to weave. At low add-on, the yarn is more likely to break because of lack of strength and increased hairiness. The net result is that there is an optimum add-on level at which there is a minimum end-breakage rate and the best add-on level varies according to the smoothness of the yarn.

Warp sizing techniques and the operational requirements are discussed in the following sections.

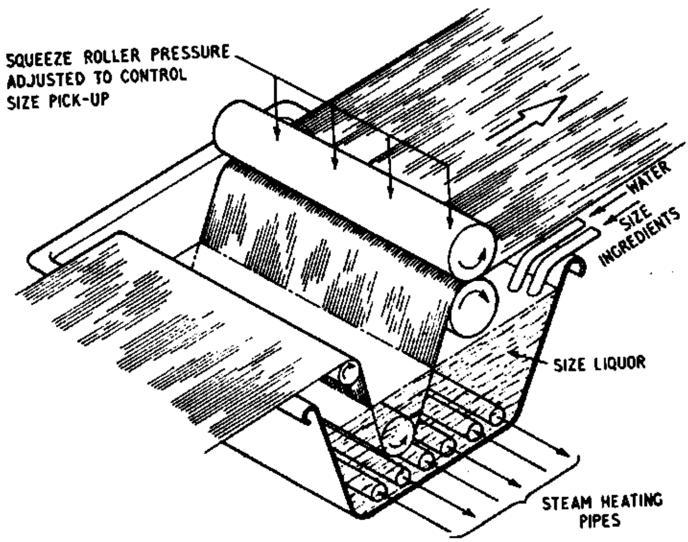


Fig. 6.7. Section of a size box

Warp Sizing Techniques and Operational Conditions

Sizing or slashing machines can be classified according to the method of drying as follows:-

(1) *Cylinder drying.*
   (a) Two cylinder types.
   (b) Multi-cylinder types.
(2) *Hot air drying.*
(3) *Infra-red drying.*
(4) *Combined systems.*

Machines may be further classified according to the method of yarn supply, *i.e.*, direct (Fig. 6.4), indirect (Fig. 6.5) or "single-end" (Fig. 6.6) slashing. Unfortunately the term 'single end' is also used to describe a machine in which only one yarn end is sized rather than a sheet of yarns from a beam or creel as discussed above. In the single-end slashing referred to in the present context, yarns are taken from a creel rather than from a beam; this is a particularly valuable technique for slashing textured yarns, since individual yarns can be controlled separately especially in the matter of tension. The direct and indirect methods are used frequently for spun yarns, although it is possible to slash textured yarns also if proper care is taken. In both the direct and indirect systems, beams are used to supply a sheet of yarn to the size box and in the indirect case a *beam creel* (not to be confused with the creel in single-end slashing) is used and there are several possible beam arrangements (Fig. 6.5(a)). Negative let-off is normally used because of its simplicity, but occasionally the beams are directly driven and controlled to give constant warp tension.

The *size box* is used to apply the *size liquor* to the yarn (Fig. 6.7). The warp sheet is guided through the solution by means of the *immersion roller*, and then passed through the *squeeze rollers* where the yarns are pressed to maintain the desired percentage of size material on the yarns. The size-box temperature is usually maintained by means of steam pipes and the steam flow is regulated to control the temperature. It is also necessary to control the level of the solution in the size box as well as the concentration of size. The latter is controlled by a byrometer which measures the density of the solution and controls the relative supply rates of the various ingredients. The density and concentration are related and the byrometer is thus an effective control device, but it must be realised that the squeeze rollers also play an important part. The bottom squeeze rollers are usually made of stainless steel and the top ones are usually covered with felt or rubber. The hardness of the top roller is an important variable; furthermore, it is a variable which can change with time as the covering hardens with use. The roller hardness is usually measured in terms of the Shore hardness and should be checked from time to time. Variations in roller hardness and weighting alter the pressure acting on the yarns in the squeeze zone and will cause variations in size add-on. In some cases more than one pair of rollers are used and this is said to improve control.

The *drying section* determines the maximum throughput rate. It is required to dry the wet sized yarn rapidly, thoroughly and uniformly. A simple two-cylinder machine is too slow as it is difficult to get a sufficiently high heat transfer rate. By introducing more cylinders, more drying surface is made available and the contact time for a given yarn speed is increased.

On a multi-cylinder machine, it is possible to control accurately the drying temperature cycle to which a given element of yarn is subjected. In practice, it is found desirable to increase the temperature during the first phases of drying and to decrease it during the last phases, but too high a temperature causes too deep a size penetration. A typical range of temperatures used is from 80 – 105°C (180 – 220°F). In the case of filament yarns, and textured yarns in particular, it is desirable to have the last cylinder unheated to enable the yarn to cool sufficiently to make the size less plastic before splitting. In the case of staple yarns using starch, CMC or PVA etc., there is less need to so reduce the temperature and the last cylinder is commonly heated to raise the overall evaporation rate and increase speed.

In cylinder machines it is possible to assess the evaporation rate in terms of the mass of water evaporated per unit time per unit area of contact between warp and drying cylinder. A typical figure for a modern machine is about 12 kg/hr/m^2 ($2\frac{1}{4}$ lb/hr/ft^2).

A disadvantage with the multi-cylinder machine is that the yarn leaves the first rollers in a wet condition. The consequent adhesion between yarn and roller can be overcome by using a Teflon coating but this increases the cost of the machine. Most modern machines use this technique and are capable of working at some 120 m/min (400 ft/min). If the yarn leaving the last cylinder is completely dry, it is probable that it will be flattened by contact with the cylinder. Also, overcrowding of yarns on the cylinder surface can cause changes in the yarn cross-sectional shape and in either case the shape changes are likely to cause a streakiness in the final fabrics. This is especially so for textured yarns. Furthermore, if complete drying is achieved, higher tensions will have to be used for separation and this can cause considerable stretch; this especially critical with textured yarns, and undue stretch will produce so-called 'shiners' in the fabric caused by the different reflective capabilities of an overstretched textured yarn. To overcome these problems, pre-dryers are often used between the size-box and the first cylinder. The yarn is separated in the wet state and is partially dried by hot-air or infra-red heating. This tends to make it more nearly possible to retain the uniform and round yarn cross-section desired.

When hot-air drying is used it is difficult to obtain adequate heat transfer without unduly extending the distances between the cylinders. If the distance is too great, entanglement and involuntary stretching may be increased and there are difficulties in threading and piecing. For this reason, a combined system is often used in which the rollers are heated. In either case, it is necessary to use an air temperature of the order of 150°C (300°F) and it is essential, therefore, that the temperature should be reduced automatically if the machine should stop. This ensures that there can be access to the drying section (to piece broken ends) and prevents local over-drying which could lead to local brittleness and to the probability of end breakages during weaving. Air drying is usually more expensive than cylinder drying, but in the form of a combined system it can lead to an increased throughput.

In order to prevent adhesion between the yarns, it is necessary to separate each sized end from the others before

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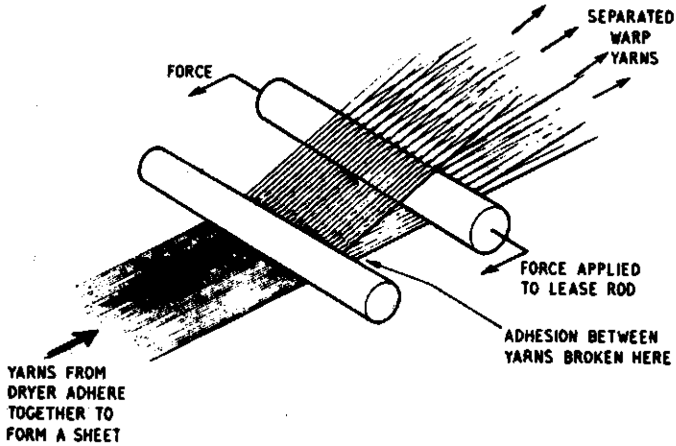
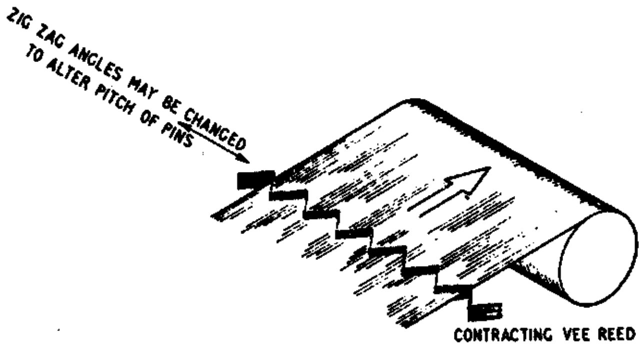
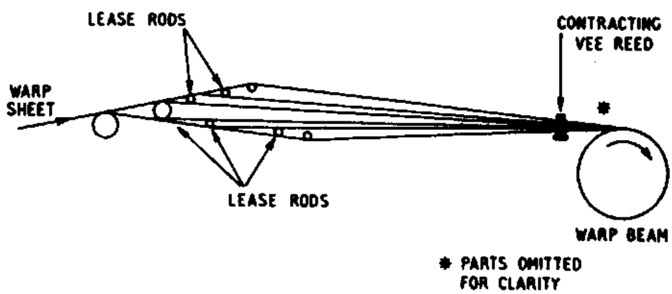
Fig. 6.8. (Opposite). Typical leasing system (not to scale)


SEPARATED WARP YARNS
FORCE
FORCE APPLIED TO LEASE ROD
ADHESION BETWEEN YARNS BROKEN HERE
YARNS FROM DRYER ADHERE TOGETHER TO FORM A SHEET


ZIG ZAG ANGLES MAY BE CHANGED TO ALTER PITCH OF PINS
CONTRACTING VEE REED


LEASE RODS
CONTRACTING VEE REED
WARP SHEET
*
LEASE RODS
WARP BEAM
* PARTS OMITTED FOR CLARITY

the warp can be used for weaving. To separate the ends, the outgoing sheet is divided into two sections. These are then further divided, usually in such a way as to give a pattern similar to that used in combining the sheets on the ingoing side of the machine. This maintains strict order which facilitates rapid *drawing-in* and the finding of broken ends. It also permits the *leasing* of the completed warp (the placing of *lease bands* or tapes across the width of the last layers of warp). Leasing facilitates the subsequent drawing-in or *tying-in* operations. *Lease rods* or *breaker bars* (Fig. 6.8) are used to divide the main sheet as described. A single *comb* is used to maintain the division of the sheets into separate ends and to position them for winding on to the beam. The comb is usually an expanding one which enables the number of ends per unit width to be controlled.

Energy has to be expended in dividing the yarns and the yarns become heated in the process. Separation of the splitting zones allows heat generated by the division process to disperse. It is common practice to cool the yarns in this zone by means of an air stream. If such measures were not taken, the temperature of the yarn might increase to the point at which the yarn could suffer damage.

Mechanism of Size Take-up

The size liquor is viscous and does not penetrate the yarn structure very quickly. In a production machine the time is limited and there would be difficulty in causing even a low viscosity size to penetrate to the core of the yarn without squeeze rollers. In any case, it would be undesirable for the size to penetrate completely because the yarn would be very stiff and unmanageable. On the other hand, it would be equally undesirable for the size merely to coat the yarn because the size would tend to crack, chip or peel off, especially when the yarn was bent or twisted. Thus whilst the coating initially would serve the purpose of producing a smooth yarn, it might not yield a smooth surface after the yarn had been worked. Also, for the yarn to have added strength, some size penetration is needed.

Lubrication is another factor, because lubricant can exist at the surface or exist inside the structure and later work itself to the surface as the yarn rubs over a friction surface. It is also possible to *overwax* (put a coating of wax over the already slashed yarn) but care must be taken to avoid over plasticisation of the size and the generation of wax build-ups during weaving.

The degree of size penetration determines the stiffness for a given yarn bearing a given size. If some fibers are free to move relative to one another the stiffness will be reduced and so will the tendency for the size to crack. Consequently, the sizing machine has an adjustable squeeze roller to control the size penetration, (Fig. 6.7) but, as was mentioned earlier, the roller hardness and size viscosity and type all affect the issue. The size penetration also depends on the yarn structure, as does the stiffness generated by a given percentage size add-on. There is a considerable art in optimising all the various factors to give a satisfactory warp which will weave well under the prevailing circumstances.

With novel yarn structures, such as those likely to be encountered as new spinning methods develop, it will be necessary to alter the size viscosity, squeeze roller pressure and machine speed to meet particular requirements. For instance, with open-end spun yarns, it is desirable to reduce the size concentration in the liquor to about 85 per cent of that normally used and to avoid excessive tension during the process. The reason for this is that the fibers in the outer layers of the yarn are less densely packed than in the core, and excessive strain tends to break fibers in vital areas where the load is concentrated within the yarn. It is impossible to foresee the requirements for types of yarn, but an understanding of the sizing process and the principles of sizing will enable these requirements to be worked out.

The chart in Fig. 6.9 shows the chief factors which, in ordinary sizing practice, can affect the percentage size put on the yarn. This percentage depends initially on the

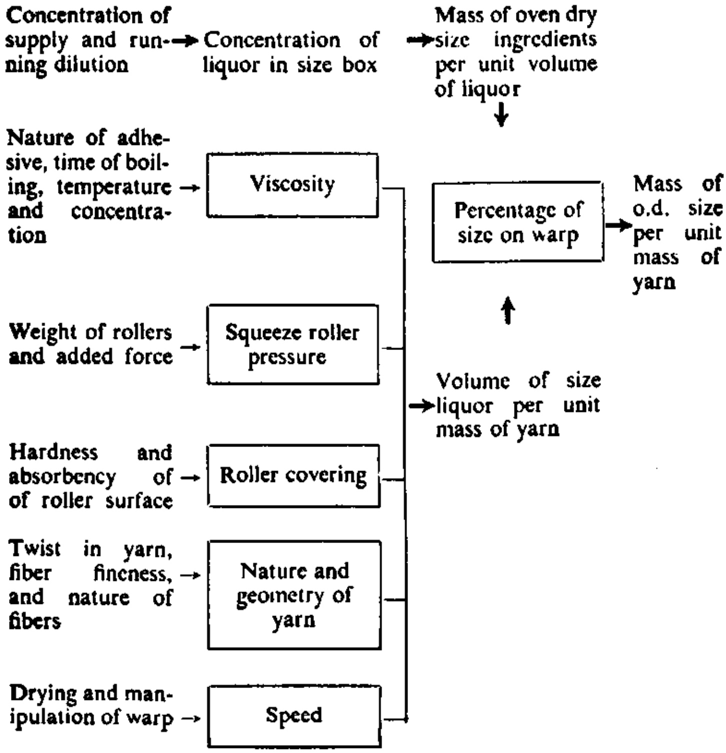


Fig. 6.9.

concentration of sizing liquor and the amount taken up. These quantities depend, in turn, upon other factors.

As viscosity increases with concentration, an increase in concentration causes more than a proportionate increase in the percentage of size applied to the warp for the usual type of take-up. A change in concentration from 6 to 8 per cent could bring about an increase in the percentage of size applied from about 8 to 16 per cent.

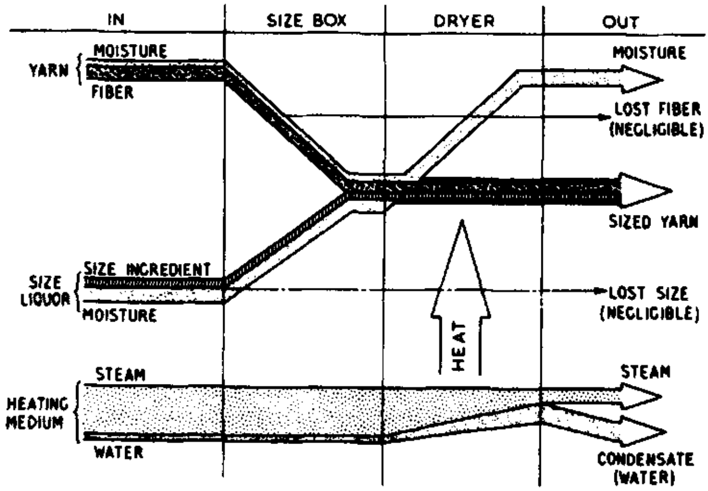


Fig. 6.10. Heat and mass transfer in sizing. N.B. The flow of air has been ignored to simplify the diagram

Automatic Control of Size Application

The basic principle of the technique of automatic size regulation is that, at equilibrium, the substances entering the size box must leave at the same rate, so that there is no gradual accumulation or depletion in the system (i.e., mass flow is conserved).

For full control it is necessary to maintain equilibrium and this implies that:

(1) Mass flow must be conserved for all ingredients severally and totally.
(2) Levels must remain constant at equilibrium values.
(3) Temperatures must remain constant in respect of time and position across the width of the machine.

There is little difficulty in maintaining levels and temperature, but control of the mass flow of ingredients can present problems. There is no reliable method of measuring continuously and immediately the percentage of size on the warp as it leaves a sizing machine. The control of size application by instrumentation has so far been based on the measurement of viscosity and size concentration; these two quantities must be measured simultaneously. Although such measurements have been carried out successfully under research conditions, it has been difficult to apply them in commercial practice. The system of measurement is essentially an open loop which relies upon a calculated relationship and this is usually satisfactory once the proper coefficient has been determined and proved. It is somewhat difficult to predict this coefficient, especially in the case of unusual yarn structures.

The flow diagram in Fig. 6.10 shows that there is both heat and mass transfer in the process. In particular, adequate heat transfer is essential in the drying section and the heat transfer surfaces must be kept clean.

Man Made Fibers

Most synthetic fibers have poor moisture absorption characteristics, as shown in Table 6.3. Sizing materials must have high adhesive power and, in general, the requirements of man-made fibers are different from those of natural fibers. Nevertheless, some sizing materials are suitable for both types of fiber. For example, CMC is suitable for many synthetic fibers and can also be used for cotton, wool and cellulosic fibers. For a given fabric construction, the amount of size on the warp has to be increased if synthetic fibers are used, and a lubricant is essential.

Some man-made fibers (such as rayon) are relatively weak in the wet state. Also, most man-made fibers are highly extensible, especially at high temperatures. Therefore tension and temperature controls are very important in slashing such yarns. Static electricity is also a major

TYPICAL FIBER CHARACTERISTICS

FIBER	GLASS	POLYESTER	COTTON	NYLON	MODACRYLIC	ACRYLIC	VISCOSE
TENACITY mN/tex	840	300-800	300	500-800	200-380	180-370	550
(gf/tex)	(85)	(30-81)	(30)	(51-81)	(20-39)	(18-38)	(56)
(gpd.)	(9.5)	(3.4-9.1)	(3.4)	(5.7-9.1)	(2.3-4.3)	(2.0-4.2)	(6.2)
ELONGATION AT BREAK %	4	15-40	8	18-45	30-40	20-55	11
MOISTURE REGAIN %	neglig	0.4	7	4.5	0.4-4.0	1-2.5	11.0

TABLE 6.3

problem. In most cases static eliminators must be used after the yarn has been dried; the eliminator is usually situated at the headstock just before the beam.