3

AN INTRODUCTION TO WEAVING PREPARATION

Key Words: *beam warping, clearing operation, creeling, cross-wound package, coning, doffing, drawing-in, drop wire, over-end withdrawal, parallel wound package, piecing, precision winding, quilling (pirn winding), section warping, side withdrawal, sloughing off, snarl, traverse (chase) tying-in, warping (beaming), warp winding, weavers' beam, yarn ballooning, yarn guide.*

Introduction

The selection of suitable yarns and the preparation of yarn for weaving have a considerable influence upon the efficiency with which the weaving operation itself can be performed. For maximum efficiency, yarn breakage at the loom must be reduced to a minimum and this is only possible if: (a) care is taken to select yarn of uniform quality; (b) the yarn is wound on to a suitable package in the best possible way; and (c) the yarn has adequate treatment before use. These requirements apply to varying extents to both warp and filling. The preparation of the warp differs from the preparation of the filling and it is necessary to deal with each of them separately. However, winding is common to both and may be considered in general terms.

Warp Preparation

The essential features of a good warp are as follows:

1. The yarn must be uniform, clean, and as free from knots as possible.
2. The yarn must be sufficiently strong to withstand the stress and friction of weaving without excessive end breakage.

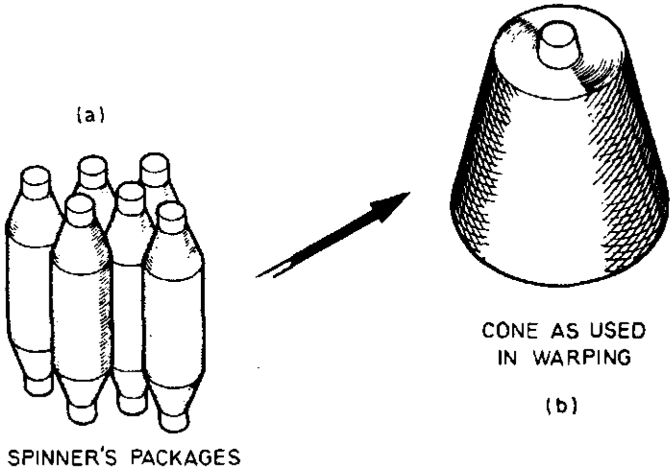


Fig. 3.1.

3. Knots should be of standard type and size, enabling them to pass easily through the heddles and reeds of the loom.
4. The warp must be uniformly sized and the amount of size added must be sufficient to protect the yarn from abrasion at the heddles and reed so as to prevent the formation of a hairy surface on the warp threads.
5. The ends of the warp must be parallel and each must be wound on to the loom beam at an even and equal tension; also, each warp end must be of the correct length and there should be no broken end therein.

The object of warp preparation is to transfer yarn from the spinner's package to a weaver's beam which can be placed behind a loom ready for weaving. A *weaver's beam* usually contains several thousand ends and, for a variety of reasons, it can seldom be made in one operation. It is usual to divide the warp preparation processes into the five sections described in the following pages.

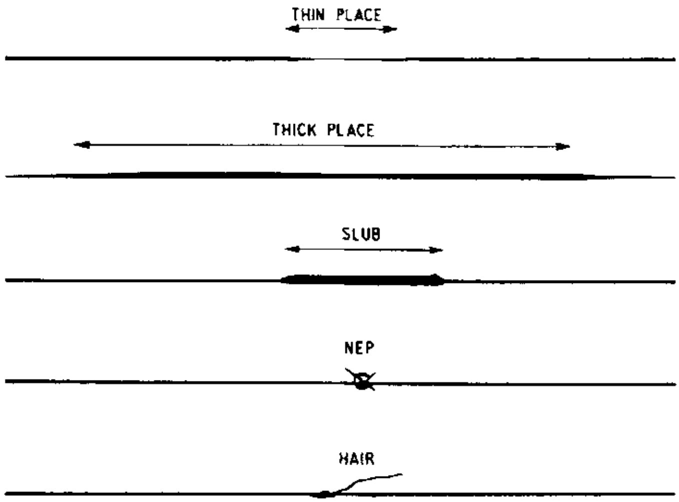


Fig. 3.2. Some typical yarn faults

Warp Winding (Coning)

One of the main purposes of warp winding is to transfer yarn from the spinner's or doubler's package (Fig. 3.1(a)) to another suitable for use in the creel of a warping machine (Fig. 3.1(b)) or for dyeing. Warping requires as much yarn as possible on each package and also a package which has been wound at comparatively high tension, but dyeing requires a soft wound package so that dye can penetrate; a compromise is sometimes needed, therefore, in the matter of winding tension.

A second main purpose of warp winding is to make it possible to inspect the yarn and to remove any thick or thin places, slubs, neps or loose fibers (Fig. 3.2). This *clearing-operation* applies mainly to staple fiber yarns where such faults are more prevalent.

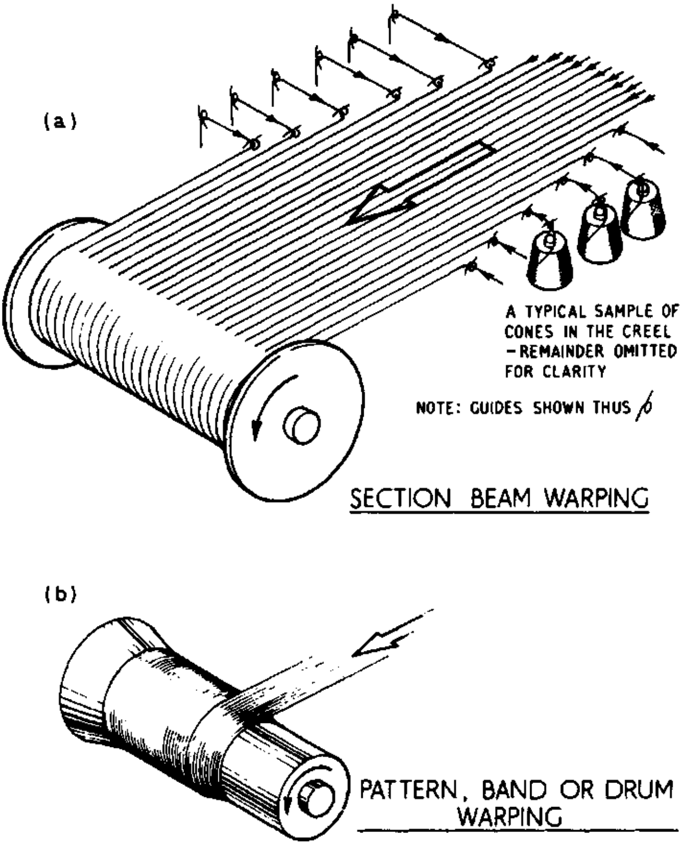


Fig. 3.3.

Warping (*Beaming*)

The purpose of warping is to arrange a convenient number of warp yarns so that they can be collected on a single warper's beam. There are two main types of warping: (a) beam warping and (b) section warping.

(a) *Beam warping* is used for long runs of grey fabrics and simple patterns where the amount of colored yarn involved is less than about 15 per cent of the total. The broad principle is depicted in Fig. 3.3(a). This is sometimes referred to as direct warping.
(b) *Pattern warping* is used for short runs, especially of fancy patterned fabrics where the amount of colored yarn is greater than about 15 per cent of the total. The broad principle of this type of warping is shown in Fig. 3.3(b). This is sometimes referred to as indirect warping or pattern warping.

Sizing (Slashing)

It is necessary to size the warp yarn for several reasons, namely:

(a) to strengthen the yarn by causing the fibers to adhere together;
(b) to make the outer surface of the yarn smoother so that hairs protruding from one yarn in the warp should not become entangled with hairs protruding from a neighboring yarn;
(c) to lubricate the yarns so that there is less friction when they rub together in the weaving process. Lubrication also reduces the friction between the yarns and the loom parts. The reduction of friction reduces the forces acting on the yarns during weaving.

Thus, the problem of reducing the warp end breaks during weaving is attacked from two different angles; that is, every attempt is made to reduce the loads imposed upon the yarns and also the yarn is strengthened. The warp breakage rate is important because, if a single warp end breaks, the whole loom has to stand idle until the warp break is repaired.

Drawing-in

At the sizing stage or afterwards, all the threads required for the warp are brought together on the weaver's beam. At this stage the beam is almost ready for use, but there remains one more operation—drawing-in—before the beam is mounted on the loom.

The loom is stopped whilst the new beam is being mounted, and in order to reduce this wasted time to a minimum each thread is provided with its own series of attachments. When running on the loom, the warp yarn is threaded through a heddle eye and the reed; it also supports a drop wire which will signal the loom to stop if that particular yarn end breaks. Bearing in mind that there might be several thousand such warp ends on a beam, it may take a considerable time for all these to be threaded; it is the practice, therefore, to carry out these operations away from the loom. Each warp end is threaded through an appropriate heddle eye and reed dent and is supplied with its own drop wire. Thus the beam brought to the loom has the required number of harnesses and reed as well as a multitude of drop wires. The beam in this state is useful only for the particular job at hand and can rarely be used to produce a different fabric structure without re-looming.

Tying-in

When fabric of a particular type is being mass produced, the new warp beams will be identical with the exhausted beams on the looms. Therefore, if every end on the new beam is tied to its corresponding end on the old beam, the drawing-in process can be omitted. Tying-in may be done by means of a small portable machine on the loom or as a separate operation away from the loom. In the latter case, there is then an opportunity for cleaning and lubricating the loom, but the "down time" (i.e. the time the loom is stopped) should be kept to a minimum. The former is normal practice.

It should be realized that one or more of the foregoing operations may be omitted or combined with other operations, but in general all operations are necessary. The particular system employed will depend upon whether the warp is grey (i.e. unfinished) or colored. If it is colored, the sequence will depend upon the stage at which it is dyed. The yarn may be dyed in one of the following ways:

(a) Pressure dyeing on the spinner's package before winding.
(b) Hank dyeing, which necessitates an additional reeling operation.
(c) Pressure dyeing on cones or cheeses after warp winding.
(d) Warp dyeing (where the warp is dyed before sizing). This can be achieved by ball warp dyeing or by pressure dyeing on the back beam itself.

The form of dyeing chosen is determined by the type of dyestuff to be applied and the fabric style.

Filling Yarn Preparation

On conventional looms the filling yarn is inserted by means of a shuttle carrying a bobbin. This bobbin should be tapered at the end so that the yarn may be pulled without interruption through the eye of the shuttle as the shuttle travels from one side of the loom to the other. This bobbin (filling bobbin) is termed a "quill" or "pirn". The machines used for winding these bobbins are known as "*quillers*" or *pirn winding machines.*

Spinning Filling Yarn on Quills

The quill is wound either on the spinning frame or on a twister frame. Because this method eliminates the winding process, it does not provide any opportunity for yarn inspection which is usually achieved at the winding stage; consequently, the technique is of diminishing importance.

The yarn on the quills has to be conditioned by wetting or steaming before it can be used, as the moisture content affects the character of the yarn and unconditioned yarn will not weave properly.

Staple yarns are commonly rewound after spinning to permit the removal of faults and to provide package sizes suited to the machines available. Filament yarn is not spun on a spinning frame as used for staple yarns. It may be received in the form of packages known as tubes, cops, cones, cakes, or cheeses which can vary greatly in size. Hence it is necessary to rewind the yarn onto quills of the required size.

Quill winding is usually carried out on automatic quillers or automatic pirn winders, the latter being the European term. These machines are automatic in the sense that when a quill is filled with yarn, an automatic device stops the rotation of the spindle, the full quill is ejected, a new empty quill is automatically placed on the spindle and winding recommences to continue until the quill is full, when the cycle is repeated. As the full quill is ejected from the quiller, it either drops into a quill box directly under the quiller or it is carried by mechanical means to be placed on a pin board.

In most newly designed looms, the shuttle is no longer used and alternative means of inserting the filling are employed. Generally, such systems do not require a small package capable of being transported through the warp shed. Rather, a length of yarn is removed from a large package and is then inserted into the fabric. Most of these new loom systems employ an intermediate yarn storage system so that the yarn package does not have to suffer the extremely rapid and intermittent yarn withdrawal that would otherwise be the case. Nevertheless, the average unwinding speed can still be high, and it is necessary to provide a package which can be unwound at a rapid rate and which can cope with sudden demands. The package should be as large as possible and yet still permit good unwinding; this often involves some compromise. It costs money to replace packages on the loom and from this point of view, the larger the package the better; on the other hand, poor unwinding will create loom stoppages which are equally undesirable. Cones

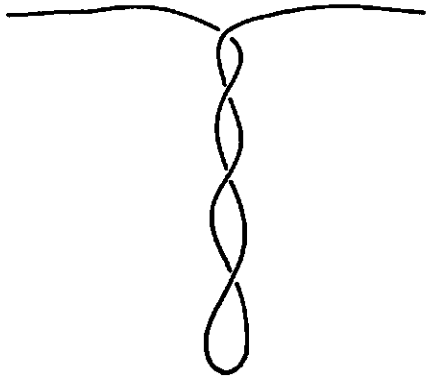


Fig. 3.4. Yarn Snarl

are preferred for looms of these types, but cheeses can be used; in general, any package suitable for high speed unwinding will be adequate for the filling supply.

Advantages of Filling Preparation

The advantages of a filling preparation are:

1. Removal of slubs and weak places during processing which otherwise would impair the running of the loom.
2. The production of tighter packages having more yards per quill. This reduces the number of quill changes in the loom which, in turn, reduces the possibilities of flaws and wastage.
3. Greater uniformity of quills used on the loom. This improves the uniformity of the fabric.
4. The easy handling of small lots.

Conditioning of Filling

This process is the same whether quills are made on spinning or twister frames, or wound on a quiller. It involves the wetting or steaming of the filling yarn to stabilize it so that it will weave satisfactorily. An unconditioned yarn is usually "lively"; if allowed to go slack, it will snarl as shown in Fig. 3.4.

Winding Machines

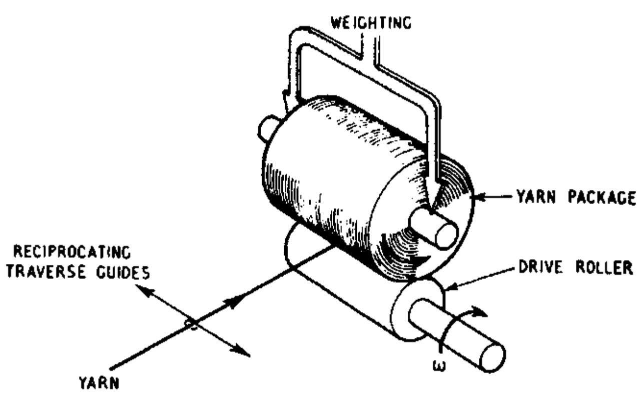
Driving the Package

The package may be rotated by one of three methods:

(a) Surface contact between the outer surface of the yarn on the package and a drum or roller. This gives a constant surface speed to the package and the yarn is taken up at an approximately constant speed. The system is illustrated in Fig. 3.5(a).

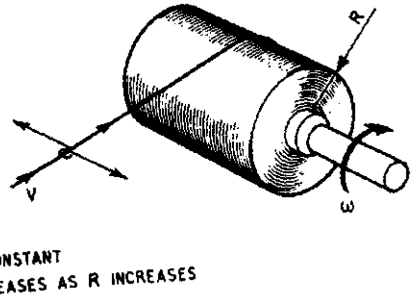
(b) Directly driving the package at a constant angular speed. This causes the yarn take-up speed to vary as the size of the package changes. The system is shown in Fig. 3.5(b).

(c) Directly driving the package at varying speed. To give constant yarn speed, it is necessary to cause the rotational speed to vary inversely with the package radius.

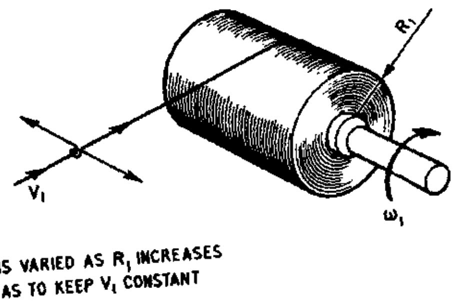


(a) CONSTANT SPEED DRIVE ROLLER

Fig. 3.5. (Above and following page) Package drives



(b) CONSTANT SPEED SPINDLE DRIVE



(c) VARIABLE SPEED SPINDLE DRIVE

Fig. 3.5. (cont.).

$$\text{package speed} = \frac{\text{constant}}{\text{package radius}}$$

(see Fig. 3.5(c)).

An expensive transmission system is used in method (c), and for this reason, it is seldom used except for delicate yarns. In general, method (a) is used for staple fiber yarns.

Yarn Traversing

There are three fundamentally different types of packages: (1) the parallel wound package; (2) the near-parallel wound package; and (3) the cross-wound package.

(1) *The Parallel Wound Package*

This comprises many threads laid parallel to one another, as in a warp. It is necessary to have a flanged package or beam, otherwise the package would not be stable and would collapse (Fig. 3.6(a)).

(2) *The Near-parallel Wound Package*

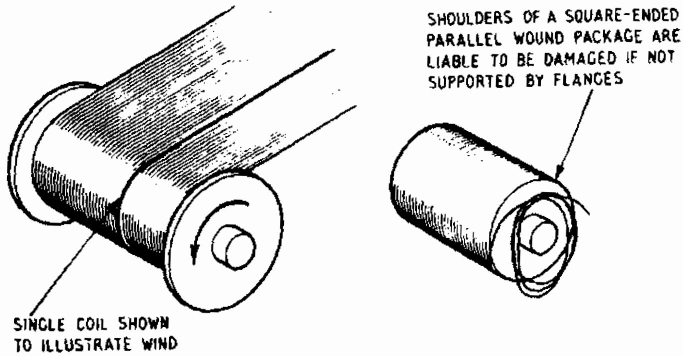
This comprises one or more threads which are laid very nearly parallel to the layers already existing on the package. It may be tapered as in Fig. 3.6(b) or have flanges as in Fig. 3.6(a).

(3) *The Cross-wound Package*

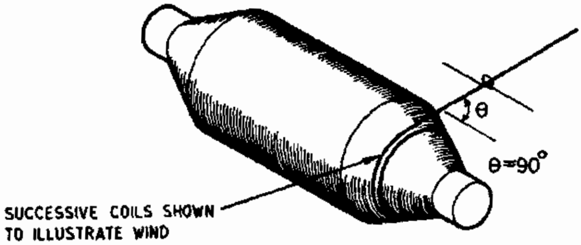
This type usually consists of a single thread which is laid on the package at an appreciable helix angle so that the layers cross one another to give stability, as shown in Fig. 3.6(c).

The second and third types of packages require a traversing mechanism on the winding machine to give the correct build.

The to-and-fro movement of yarn as it is laid on to a package, usually called *traverse* or *chase*, is controlled by a movable guide. When winding a type 2 package, the pitch between successive coils needs only to be small and the minimum distance traversed for each revolution of the



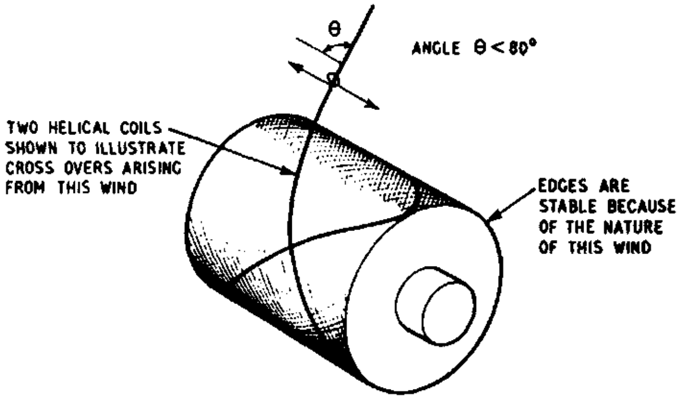
(a) PARALLEL WOUND PACKAGES
(TYPE 1)



(b) TAPER WOUND PACKAGE
(TYPE 2)

Fig. 3.6. (Above and opposite page).

package is determined by the yarn diameter (see Fig. 3.6). The yarn approaches the laying-on point almost perpendicularly.



(c) CROSS WOUND PACKAGE
(TYPE 3)

Fig. 3.6. (cont.)

When winding cones and cheeses (which have no flanges and are of type 3) the pitch between successive coils must be relatively large if the package is to be stable (see Chapter 4). For such packages the winding angle must, in general, not be greater than about 80°.

Traversing methods are as follows:

(1) *Reciprocating*

(*a*) Single guide rod and traversing cam serving many winding spindles.
(b) A guide and cam for each spindle (Fig. 3.7).

(2) *Rotating*

(a) Grooved roller with single groove (split drum).
(b) Grooved roller with multiple grooves (Fig. 3.8).

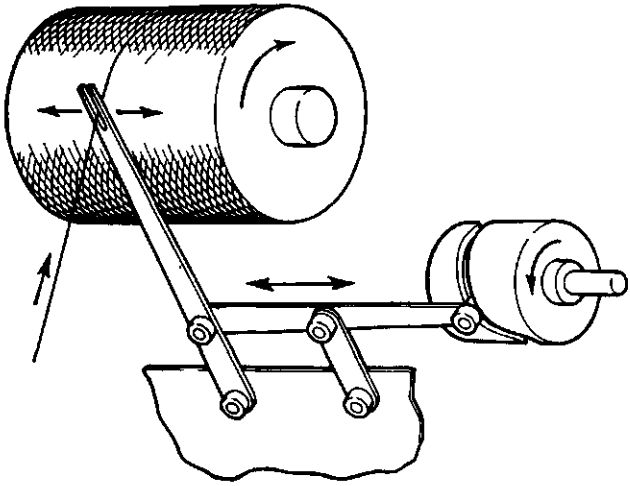


Fig. 3.7. Schematic diagram of a cam-driven reciprocating traverse mechanism

Precision and Non-precision Winding

When the successive coils of yarn on a package are laid close together and parallel, it is possible to produce a very dense package in which a maximum amount of yarn is stored in a given volume. With a cross-wound package in which the pitch between successive coils is large, a considerable number of voids are created because of the multiple cross-overs and consequently the package is much less dense. To get a dense package, it is necessary to control very precisely the position of the yarn as it is laid on the surface. Since this is best achieved by a reciprocating guide placed close to the laying-on point, it is usual to find that so-called "precision" packages are wound with a reciprocating traverse.

As the diameter of the package grows during winding, so the yarn helix angle and the distance between adjacent coils change. It is possible that, in successive layers, one yarn may be wound immediately on top of another. This causes a patterning which is visible on the surface and which interferes with subsequent unwinding. This patterning or

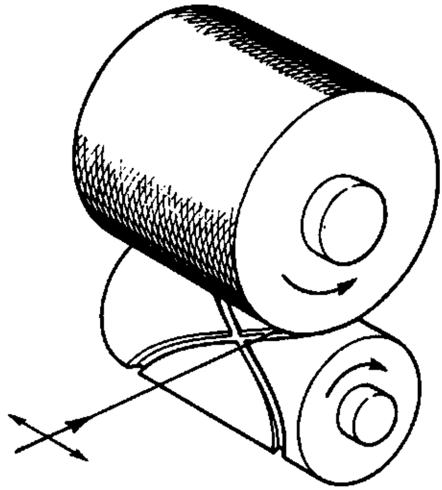


Fig. 3.8. Grooved roller traverse

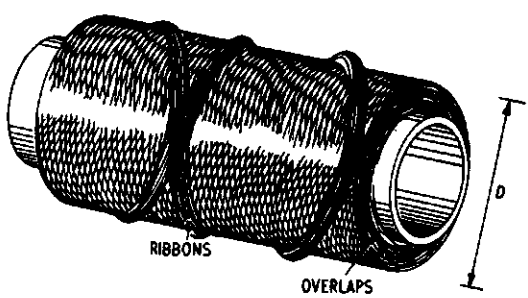


Fig. 3.8 (a). Ribboning or Patterning. This occurs, with its associated overlaps, when the yarn traverse guide oscillates in synchronism with the surface of the package and causes adjacent yarns in the wind to lay on top of one another. Patterning occurs only at specific values of D.

ribboning is shown in Fig. 3.8(a) and it will be observed that the closely packed yarns within the ribbon are unlikely to allow dye to penetrate as easily as elsewhere. Also, during unwinding, there will be marked yarn tension increases as yarn from the ribbon is removed; this is likely to cause an increase in *end breaks* during any rapid unwinding operation. In addition, the shoulders of the package will show *overlaps* where the ribbon reaches the edge of the package and this too can cause unwinding problems. It is usual to arrange the traverse speed to avoid this as far as possible; also, auxiliary mechanisms are sometimes introduced to break up the patterning. A precision winder works with pitches which are fairly close to patterning because this gives a dense package, but the patterning has to be avoided or it would persist throughout most of the wind. Non-precision winders work with relatively large pitches that often give intermittent patterning which is difficult to avoid and, as mentioned earlier, the package density is reduced and the package stability is improved.

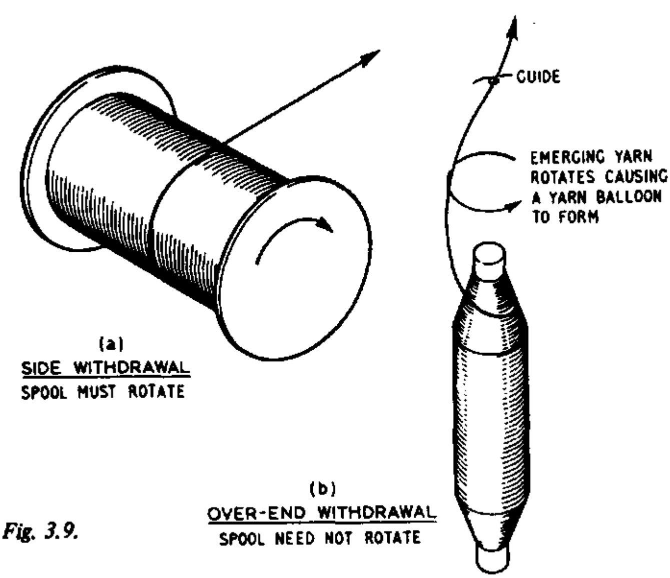


Fig. 3.9.

Yarn Withdrawal

There are two ways in which a yarn package may be unwound, viz. (1) side withdrawal as shown in Fig. 3.9(a), and (2) over-end withdrawal as shown in Fig. 3.9(b). With over-end withdrawal, the package is stationary, but a special package build is required to permit clean withdrawal; furthermore, the yarn twist changes by one turn for each loop removed, but this can usually be neglected.

Broken Yarn Stop Motion

On winding machinery it is necessary to stop winding if a thread breaks or if the yarn supply is exhausted. Usually the yarn is made to support a light feeler; if the yarn breaks, the feeler moves and causes the package drive to be disconnected.

Auxiliary Functions

The functions previously described are common to most forms of winding machines, but there are other functions which pertain only to certain types.

These auxiliary functions may be performed manually or automatically. The latter class contains machines which are called automatic winders*. The auxiliary functions include:

(a) Creeling.
(b) Piecing.
(c) Doffing.

Creeling is the placement of full packages in position ready to be unwound as part of the transfer operation. An alternative meaning is the removal of the exhausted packages and their replacement with full ones.

* At present, automatic winders of large packages seldom doff the packages automatically but it is likely that this will become the practice in the future. The technique of automatic doffing is now being applied to ring spinning, but it may be some time before it is economic to doff the larger packages found on winding machines. Nevertheless, it is logical to consider automatic doffers as part of automatic winding.

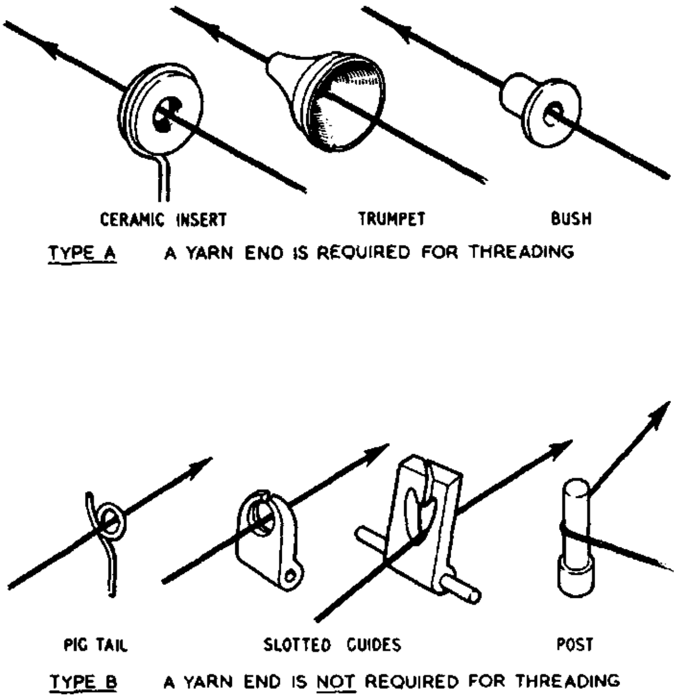


Fig. 3.10. Types of guide

Piecing is the finding and connecting of the ends on the packages. The connection between the ends can be made by knotting, adhesion or welding but the former is by far the most common. Such connections are required whenever an end breaks or when a creeling operation has been completed.

Doffing is the removal of the newly wound packages and (usually) the replacement of these by empty packages which will receive yarn during the transfer process. It will be noted that creel packages are emptied as the packages to be doffed are filled.

Yarn Guides

In winding or unwinding, it is necessary to control the yarn path. If side withdrawal is being used, it is possible for the yarn to pass along a smooth unvarying yarn path, but if there is some vibratory force present the yarn may vibrate between the guides. These vibrations can be controlled by the strategic placing of guides along the yarn path. If over-end unwinding is used, the yarn does not move along a fixed path because a rotary motion is imparted as the yarn unwinds. Any given section of yarn moves not only along the length of the yarn, but also in a circular fashion; this is called *ballooning*. For a given yarn speed and package size, the position of the yarn guide will determine the balloon shape; this, in turn, determines the yarn tension. The guide position is thus important.

Guides are normally made of hard smooth steel or ceramic. Many man-made yarns are surprisingly abrasive and frequently it is essential to use ceramic guides. Guides of various shapes may be used, the choice depending on the yarn motion to be controlled (see Fig. 3.10).

Tension Devices

Yarn tension plays an important role in winding. Too high a tension can damage the yarn, whereas too low a tension can lead to unstable packages which will not unwind cleanly. A common fault associated with certain loosely wound packages is their tendency to "*slough off*" more than one turn to give a tangle. Variations in yarn tension in different parts of a wound package can cause undesirable effects. For instance, with many man-made fibers, high tension can cause molecular change which affects the dyeability, so that variations in tension ultimately show as apparently random variations in color shading.

In winding staple yarns, sufficient yarn tension is used to cause breaks in thin places whilst the yarn is being wound. This permits the thin places to be cut out, the yarn to be repaired and the winding to continue. Variations in running tension after the level at which the thin places are removed

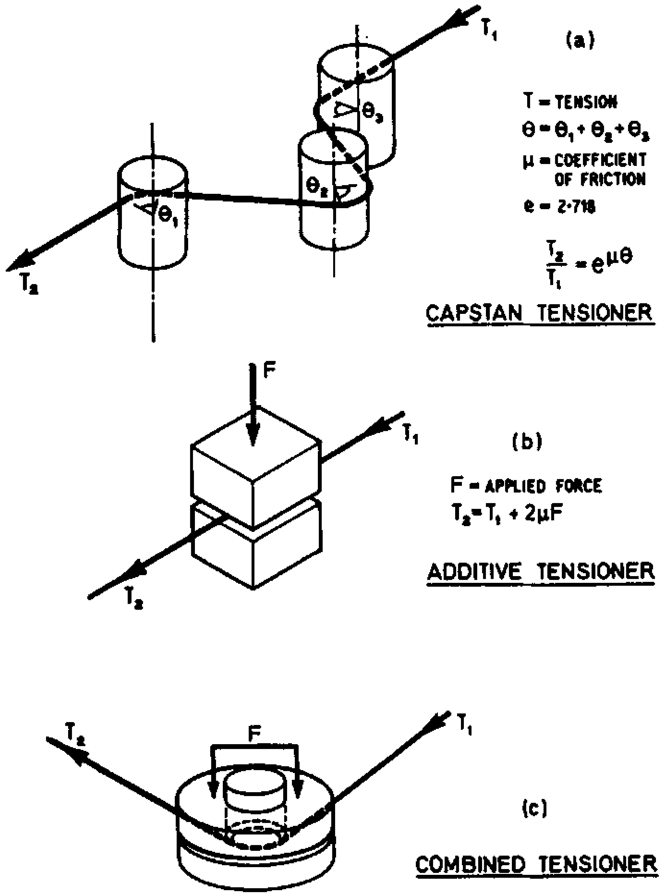


Fig. 3.11.

and so affect the yarn regularity in the final product.

There are many forms of yarn tensioner, the simplest of which works by merely deflecting the yarn around fixed posts. This induces a capstan effect which follows the classical law

$$\text{Output tension} = \text{input tension} \times e^{\mu\theta}$$

where μ = coefficient of friction between yarn and post
θ = angle of lap measured in radians
$e = 2{\cdot}718$

This is illustrated in Fig. 3.11(a).

It will be noted that a definite input tension is required before a tension increase can be obtained; in other words, it is a multiplicative device.

Another simple technique is to use a deadweight or spring to give a fixed increment of tension; this is called an additive system (see Fig. 3.11(b)).

The two systems can be combined as shown in Fig. 3.11(c).

These devices permit the tension level to be raised to any desired extent, but they do not permit a reduction in tension. The only way to decrease the tension is to use a positive drive which tends to overfeed. Such devices are seldom used.

More sophisticated systems of tensioning are also used, some of which incorporate automatic control. Of these, the

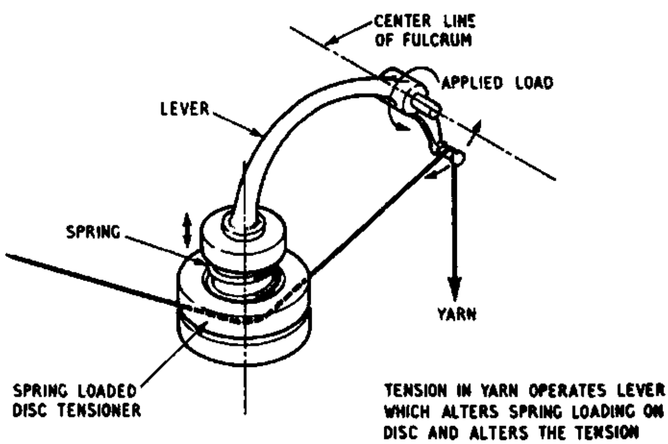


Fig. 3.12. Schematic diagram of one sort of lever-type tensioner

simplest and most common is the lever operated compensator tensioner, an example of which is shown in Fig. 3.12. The yarn tension operates on the pin at the free end of the lever and alters the amount of load applied in the disc region, which in turn changes the tension. The device is arranged so that when the measured yarn tension is too high, the pressure in the disc region is reduced to bring the tension back to its proper level. In control terminology, this is called "negative feed back".

There are several requirements which influence the choice of a tensioning device, including:

1. The device must be reliable.
2. It must be easily threaded.
3. It must neither introduce nor magnify tension variations.
4. It must not introduce differences in twist.
5. It must not be affected by wear.
6. It must be easily adjustable.
7. It must not be affected by the presence of oil or dirt.
8. It must not encourage the collection of dirt and lint.
9. It must be capable of easy cleaning.
10. The operating surfaces must be smooth.
11. It must be inexpensive.

Stability of the Package

The stability of a package is best defined in terms of its ability to withstand deformation. A package which disintegrates causes disorder in the yarn which makes it useless and results in excessive wastage. Most forms of package deformation create wastage in this way, and cause difficulty in subsequent operations. A package must be capable of retaining its shape and build even after considerable handling, permitting orderly and rapid removal of the yarn in the subsequent process.

As an extreme and hypothetical example of an unstable package, consider the winding of a perfectly smooth yarn on a flangeless bobbin in a truly parallel fashion as shown in Fig. 3.13. Since all coils making up the package are perfectly parallel, there can be no lateral forces to hold them together other than those arising from contact with the bobbin. If the package is loosely wound, the outer coils will be able to move

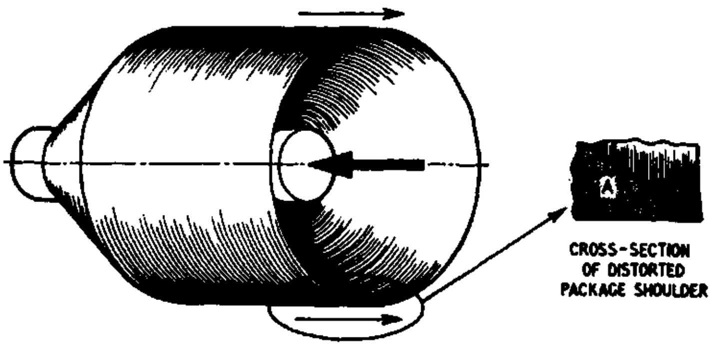


Fig. 3.13. Instability of package due to looseness of wind

relatively freely in a direction parallel to the bobbin axis, and the situation depicted in Fig. 3.13 could easily arise. The portions shown shaded at A are completely unsupported and would collapse into a hopeless tangle. In any case, the shoulders are very vulnerable to damage, with similar results. A solution to this is to use flanges to provide lateral support as shown in Fig. 3.14. The flanges, however, impede unwinding when the yarn is withdrawn parallel to the bobbin axis (i.e. over-end unwinding) and the use of bobbins with large flanges is commonly restricted to cases where the yarn is removed tangentially from the cylindrical yarn surface (i.e. side unwinding).

Most yarns are not completely smooth, so hairs and loops can intertangle to some extent and provide a degree of stability; the shoulders are still very vulnerable, however, and to use such a package without flanges it is necessary to taper the ends as shown in Fig. 3.14. Since the main purpose

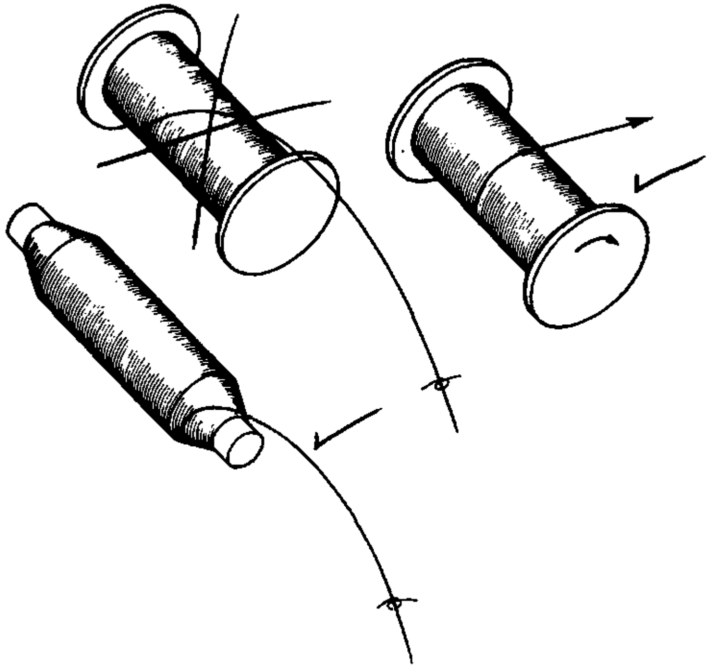


Fig. 3.14. Unwinding parallel-wound packages

of dispensing with flanges is to permit over-end unwinding, the consequences of this must be considered.

Consider the point where an element of yarn is just leaving the surface of the package. The ballooning will cause a yarn tension to exist at that point and this tension may be resolved into three mutually perpendicular components. One of these components may be parallel to the bobbin axis, another tangential to the cylindrical surface and the third one will be radial as shown in Fig. 3.15. The parallel one (P) must be opposed by frictional and cohesive forces between the subject yarn element and the neighboring material or the cylindrical surface. The tangential one (T) will be balanced by a com-

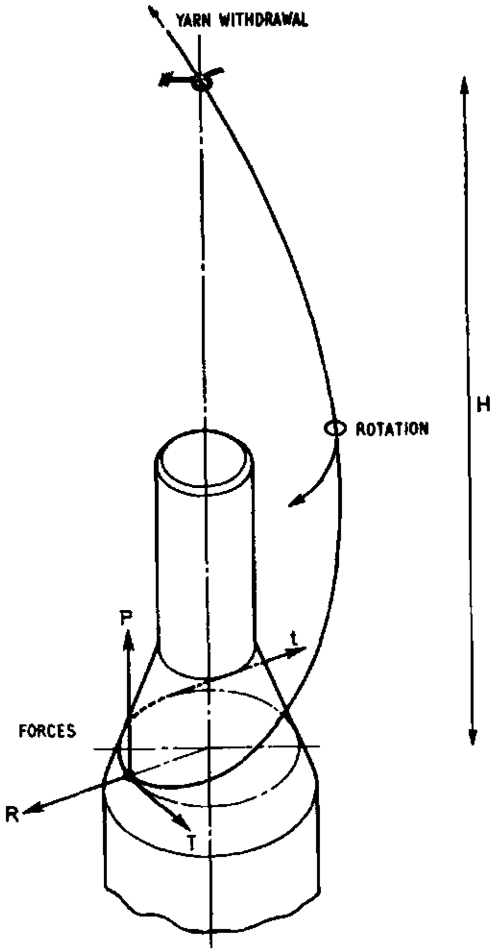


Fig. 3.15. Yarn ballooning

ponent of the tension in the yarn just about to be removed and the radial one (R) will be balanced by the tension t plus the frictional and cohesive forces which act in that direction. The angle of yarn departure will automatically adjust itself until these conditions are met. The radial cohesive forces will tend to lift the coil of yarn below the departing element and loosen it; the parallel cohesive force will try to move that underlying coil laterally from its proper position. If the tension in the underlying coil is sufficiently high, it will not lift and it will not be displaced laterally by the departing yarn. On the other hand, if the tension is low, a whole coil can be displaced and in bad cases it will slough off as shown in Fig. 3.6(a). This is especially true if the package is tapered in such a way that the displacement of the coil further loosens it.

So far, it has been assumed that the coils are parallel to one another. If the coils are helical and the helices cross one another as shown in Fig. 3.6(c), we have a cross-wound bobbin which is much more stable.

Firstly, the parallel force P is now opposed by a component of the yarn tension as it exists on the package. Secondly, the cohesive forces acting are no longer concentrated locally and extend over a much larger surface of the package so that many more coils are involved in contributing to the stability. This reduces the chance of local variations giving trouble. Thirdly, the cross-overs give an interlocking effect which can result in great stability.

Special Requirements

It would seem to be desirable always to use a cross-wound package in which the traverse extends over the full length of the package, since this appears to give the maximum stability. Unfortunately, there are circumstances in which such a package cannot be used and a degree of compromise is required. An example is the quill used in a shuttle. One requirement is that the quill should carry the maximum mass of yarn in the space available in the shuttle. To get the maximum density it is necessary to use a parallel wind, but this could cause stability problems and a progressive conical traverse is used therefore, as shown in Fig. 3.16. This provides a sufficient degree of stability. It might still be argued that a cross-wound package with a full traverse could be

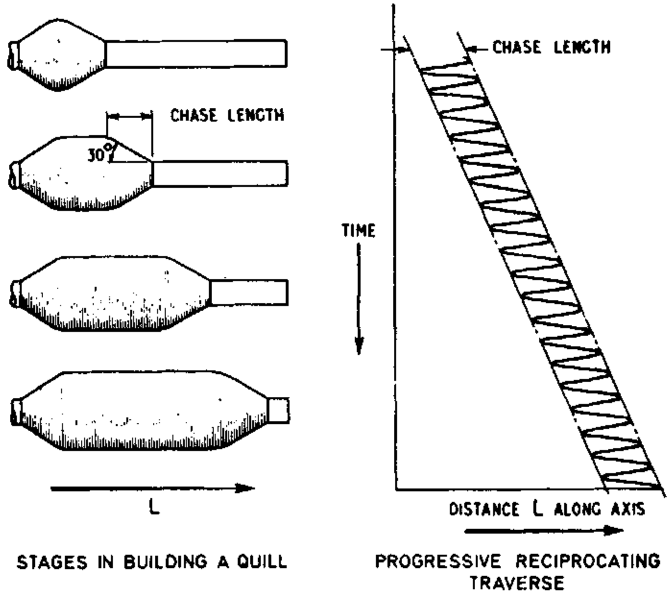


Fig. 3.16

used, but this is to ignore the special unwinding conditions which exist within the confines of a shuttle. Since a full balloon cannot develop, the coils of yarn rub the surface of the quill between the yarn removal point and the quill tip. With a traverse from end to end, yarn coils would be dragged over others causing them to move and perhaps even to be damaged. With the wind shown, the yarn has little chance to touch the other yarn and in the main it slides along the polished wood of the quill.

A further reason for using this type of build is to limit the tension variations induced in the original winding of the package. Grishin's formula for the tension generated in a ballooning yarn states that the yarn tension is a function of the balloon height as well as other factors which need not be considered here. Thus if a large traverse is used, the balloon height (H in Fig. 3.15) during spinning will vary considerably and the tension acting on the yarn will be affected. This will be detrimental to the smooth progress of subsequent operations.

All these factors suggest that it is desirable to reduce the traverse length on the quill to a minimum. However, a limit is imposed by the incidence of sloughing-off, and there has to be a compromise between mass storage and tension variation on the one hand and package stability during unwinding on the other.

4

WINDING

Key Words: *automatic winder, balloon, bobbin, bunch, chase length, cheese, clearing, cone, cone angle, creel package, creeling, doff, doffing, down time, feeler, knotting, magazine creeling, magazining, negative let-off, package, package build, picks, piece, quill, quillers (pirn winders), ring tube, sloughing-off, spool, spindle, spindle efficiency, winding head.*

The Need for Winding

At first sight, winding machinery appears to fulfill no purpose other than a simple transfer of yarn from one package to another. This is, however, an oversimplification of the winding process.

Clearing

At one time it was a common practice to spin yarn directly onto the quill or pirn to be used in weaving. However, yarn from the spinning machine has imperfections in the form of faults and blemishes which can cause trouble in later processes.

Thin spots in the yarn are usually weak spots which may break during weaving, causing the loom to be idle until a repair is made. The breakage of such a weak spot in a single warp end will bring the entire loom to a stop, even though there may be a thousand or more perfectly good warp ends in the loom. Thus if there is a potential break in every 100 m (110 yd) and there are (say) 4000 warp ends, there will be (on average) a loom stop for every 100 ÷ 4000 = 0.025 m of fabric. Thus the incidence of thin spots and other blemishes is a very important matter and it is essential to remove them and replace them with standard knots. The operation of removing these undesirable elements of yarn, called *clearing,* is usually carried out during the winding process. The cost of the winding/clearing operation is usually less than that of allowing the flaws to remain. Left in the yarn, such flaws would increase the cost of weaving and reduce the value of the fabric.

Package Size

Other factors to be considered are the practicability and economics of transferring yarn from the spinner's package to the form in which it is ultimately required. Consider the problems in mass production where beam after beam has to be produced, each identical with the others. With staple yarn produced on a ring frame, each package (ring tube) might contain some 4000 m (4400 yd). The actual length, however, would vary from spindle to spindle and if the ring tubes were used as the *creel packages** in winding the beams, creel package replacement would eventually become random. If winding then proceeded at 800 m/min and there were 900 creel packages, the machine would only run for 4000 ÷ (800 x 900) = 1/180 minute (i.e., 0.33 second) before a new creel package would be required. Assuming it takes (say) 5 seconds to remove the empty package, replace it by a full one and *piece*†, then the machine would run less than 6.25 percent of the time. If, however, the package were 50 times larger, the machine would run 77 per cent of the time; hence package size is of great importance and it is usual to wind yarn from the ring tube to a large creel package in order to improve the efficiency of warping. Also, random replacement of creel packages is avoided since this too diminishes the efficiency.

* A creel package is a supply package.
† "Piecing" is joining the ends of two yarns.

Textiles are subject to the vagaries of fashion and long runs are not always possible; in consequence, only one warp of a given kind may be required. This means that each creel package will need to have about the same length of yarn as that required in the warp. Variations in this length on the creel package will lead to waste in one form or another. Too short a length in a single package can stop the whole operation whilst a new one is pieced in (also introducing an unwanted knot). Too great a length will leave excess yarn which must be discarded or rewound and pieced onto another end for subsequent use (yielding a different sort of waste as well as a knot). When it is realized that this might be multiplied a thousandfold in a single warp, the virtues of winding the creel packages to a specification can be appreciated. Add to this the fact that winding provides an opportunity of clearing and rewinding the package to a build most suitable for high-speed warping, and it is apparent why expensive winding machinery is found to be an economic necessity.

With some of the newer methods of spinning (for example, open-end spinning) the spinners' package is much larger and may prove suitable for direct use, but there still remains the problem of clearing. It is possible that this might be carried out on the spinning frame, eliminating one of the stages in conventional preparation. However, such things take time to develop and it will probably be necessary to retain the rewinding stage for certain purposes even if a new system does evolve.

Synthetic yarns are usually supplied on packages containing large quantities of yarn. The many users of such yarns employ a wide variety of fabric-making machinery which demands many different package sizes, shapes, and builds. There is thus a problem of matching the requirements of supplier and user. If the supplier has to provide many types of package for each of a wide variety of yarns, he has an expensive inventory problem. A partial solution is for the yarn supplier to use standard packages and for the user to rewind the yarn according to his particular needs. The cost can be minimized in this way. Similar considerations apply to large staple spinners' packages.

Package Build

Sometimes the yarn has to be dyed or otherwise treated between spinning and weaving. In such cases it is usually necessary to wind the yarn on a special package to permit this treatment. In the case of dyeing, the package must allow even penetration of dye so that all parts of the yarn are similarly treated. The tube or cone on which the yarn is wound is usually perforated, the yarn is wound rather less tightly than normal and the build is such as to create many interstices through which the dye may pass. The cost of rewinding has to be weighed against the extra cost of using a less dense package which might be of an unsuitable shape and build for subsequent use in the following process.

When there is a disparity in size and shape of package between the output of one process and the input of the next, there is an obvious need to rewind. For example, the ring frame produces small almost parallel-wound packages, whereas the warping operation requires large cross-wound cones if it is to work efficiently at high speeds. As another example, texturized yarn may come on large capacity cheeses whereas the shuttle can only accept small long packages which have a special type of wind.

Even when the sizes match reasonably well, there can still be good reasons for rewinding. For instance, it would not be possible to use a cross-wound package of type 3 (Fig. 3.6) in a shuttle; such a package would not unwind properly. In a shuttleless loom, it is possible to use large packages but it is very doubtful if smaller packages could be used. These examples illustrate the importance of obtaining the correct build as well as the correct size of package.

During the winding process, tensions are created which can damage the yarn in subtle ways. A continuous filament when stretched can change in several of its characteristics, so if the yarn tension is high and varies in some periodic manner along the length of the yarn, the woven fabric will exhibit an undesirable patterning. With some structures of staple yarns, overstraining weakens them; an example of this category is the open-end spun yarn referred to earlier. On the other hand, a sufficient tension is required to give the package stability and density.

Winding Requirements

The requirements for winding may be summarized as follows:

(i) The fault level in the yarn must be reduced to an acceptable level.

(ii) The yarn must not be damaged in any way in the winding process.

(iii) The yarn must be wound in such a way as to permit unwinding in the following processes with a minimum of difficulty at the required speeds.

(iv) The package size, shape, and build must be the most technologically suitable for the particular end use.

(v) The package size should be controlled to meet the particular economic requirements.

(vi) The winding operation must be geared to give the best possible economic performance of the whole process of fabric manufacture.

The Winding Operation

The normal winding operation consists of unwinding one package and rewinding onto another. The user may not have a free choice in the sort of package he unwinds but he does have a choice when it comes to the package he builds. Consequently, it is necessary to consider in some detail the structures which can be built to withstand reasonable handling and use.

In this section, winding is considered under three main headings, i.e. unwinding, package stability, and winding. The first deals with the creel package and the unwinding thereof, the second with the limitations which apply in the matter of the structure of the package, and the third with the winding of the package which is about to be doffed. The latter includes the tension control which is vital to the proper performance of the package produced.

Bearing in mind that the package *doffed* from one machine becomes the creel package for the next, it will be realized that the principles discussed are bound to go beyond the narrow topic of winding.

Unwinding

(i) *Side Withdrawal*

If paper is pulled from a roll, the roll has to rotate; similarly, when yarn is withdrawn tangentially from a package, the package must rotate (Fig. 3.14). If the package is driven, its rotational speed must be capable of variation if the yarn is to be delivered at an even rate. Such a system is usually too expensive for practical use and, where side withdrawal is used, the package is usually dragged round by the departing yarn. This is called *negative let-off.*

At high speeds, the inertia of the package has to be considered because any change in operating speed will cause the yarn (or yarns) to go slack or to suffer appreciable changes in tension depending on the magnitude and direction of the speed change. At very high speeds the package tries to grow larger due to the centrifugal forces; for this reason, the layers of yarn may become loose and slip over one another, thus impairing the stability of the package. Side unwinding, therefore, is usually restricted to low yarn withdrawal rates and to negative let-off systems. Typical uses of side unwinding are to be found in the various operations on a warp; in view of the multiplicity of ends in a warp it is virtually impossible to use anything but side withdrawal.

Since tension is so important in winding and subsequent operations, it is relevant to consider the various means of control available for use with side withdrawal. Yarn tensioners can be used to increase the tension to the required level, but with negative let-off systems this leaves the relatively massive *spool* uncontrolled. It is quite normal to use a brake acting on the spool to achieve at least part of the required tension in the yarn, because this also gives some control of the package rotation and tends to prevent over-runs when the demand for yarn is reduced. If an unvarying braking force is applied to an unvarying diameter of a portion of the spool, then as the diameter of the yarn wound on the spool varies, so will the tension in the yarn being withdrawn. If the torque applied by the brake is constant at T g. cm, the radius at which yarn is withdrawn is r cm and the corresponding yarn tension is t gram, then if all other forces are ignored

$$T = t \times r \quad \text{g. cm} \tag{4.1}$$

Since the radius diminishes as unwinding proceeds, the tension increases and there is an inverse relationship between tension and radius. If the spool speeds up during unwinding, then it is possible for the torque to increase because of changes in the braking force and this will alter the relationship somewhat.

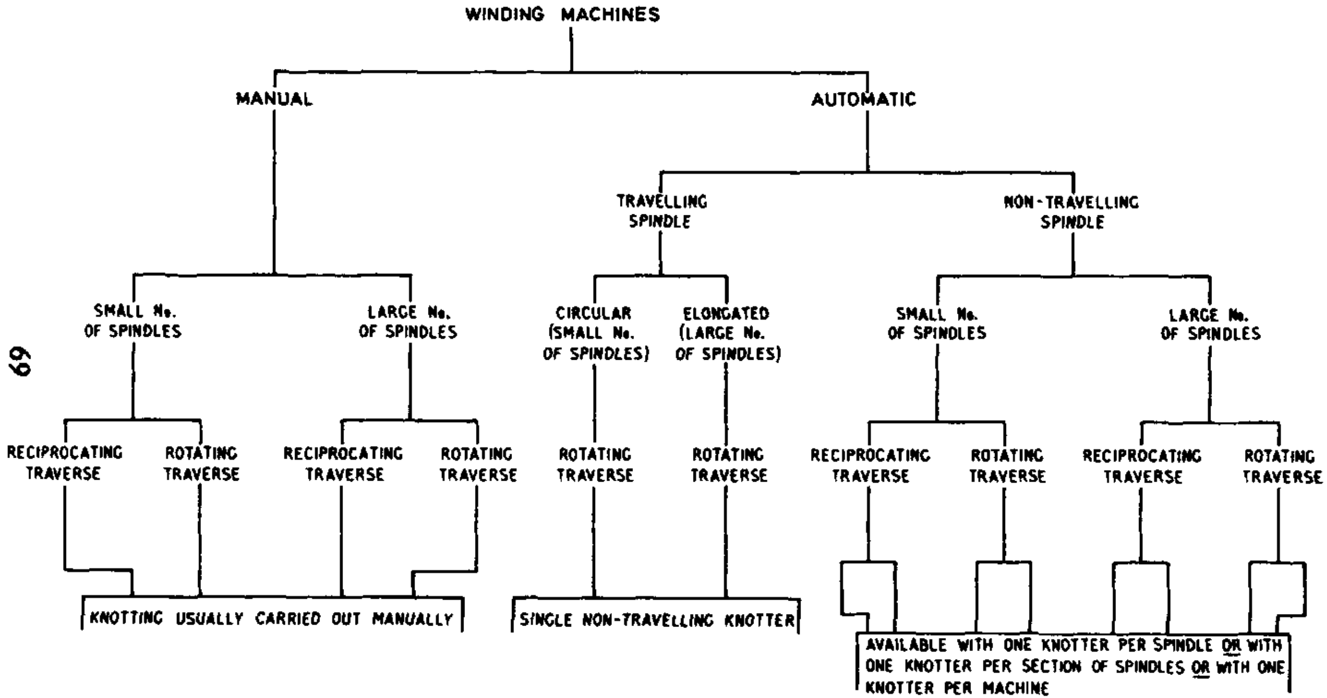
If the tension is to be kept constant, it is necessary to use some control device. Leaving aside the possibilities of controlling by additional tensioners, let us assume that the spool brake is the sole means of generating the tension. Basically, the control systems may be divided into two classes, viz. (a) those which measure the radius of the yarn package on the spool and adjust the torque accordingly and (b) those which measure the yarn tension and adjust the torque until the tension reaches the desired value. Method (a) works on dead reckoning but is relatively simple whilst method (b) is a control system of greater complexity which tends to be too expensive for wide use. Also, where many ends are involved—as with a warp—it is not easy to measure a tension which is always truly typical of all the ends and it is impracticable to measure the tension of all the ends, of which there may be several thousands. Consequently, the dead reckoning system based on measurement of the package radius is frequently used. It must be appreciated, however, that a periodic calibration of the control can be of value; because of changes in the coefficient of friction at the brake, there is not a unique relationship between the force applied to the brake and the torque produced. Consequently, the figures used in the dead reckoning may not in fact be constant and the tension would then be in error. For example, a spot of oil on the brake drum could affect the yarn tension; therefore, care is needed to ensure the proper functioning of the device.

(ii) *Over-end Withdrawal*

The second method of yarn withdrawal is to take the yarn away along a line which roughly coincides with the axis of the package as shown in Fig. 3.9. Using the technique it is not necessary to rotate the package; this avoids some of the difficulties associated with side withdrawal and permits very high rates of yarn removal. Consequently, it is used in circumstances where high unwinding speeds are required, such as in high-speed beaming and the removal of yarn from weft packages.

With over-end withdrawal from a stationary package, there is a change of one turn of twist in the yarn for each coil removed from the package. A simple experiment in which two yarns of different colors are wound side by side on a package and then withdrawn over-end will demonstrate the phenomenon; the yarns withdrawn will show a ply twist. Suppose the length of yarn in one coil is L cm, and it originally contained S turns/cm, then before unwinding, the length will contain SL turns. After unwinding it will contain $SL \pm 1$ turns (the $\pm$ sign has to be included to account for the directions of wind and twist being in opposition or not). The twist rate after unwinding is $S \pm (1/L)$ turns/cm, and since L is at least 5 cm and S is frequently greater than 10 turns/cm, the change in twist is rarely greater than about 2 per cent.

The rotation applied to the departing yarn during unwinding sets up centrifugal forces which cause the yarn to move in circular fashion rather like a skipping rope. The


WINDING MACHINES
MANUAL
AUTOMATIC
TRAVELLING SPINDLE
NON-TRAVELLING SPINDLE
SMALL No. OF SPINDLES
LARGE No. OF SPINDLES
CIRCULAR (SMALL No. OF SPINDLES)
ELONGATED (LARGE No. OF SPINDLES)
SMALL No. OF SPINDLES
LARGE No. OF SPINDLES
RECIPROCATING TRAVERSE
ROTATING TRAVERSE
RECIPROCATING TRAVERSE
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ROTATING TRAVERSE
RECIPROCATING TRAVERSE
ROTATING TRAVERSE
KNOTTING USUALLY CARRIED OUT MANUALLY
SINGLE NON-TRAVELLING KNOTTER
AVAILABLE WITH ONE KNOTTER PER SPINDLE OR WITH ONE KNOTTER PER SECTION OF SPINDLES OR WITH ONE KNOTTER PER MACHINE

Fig. 4.1.

rotating yarn assumes a form known as a *balloon*, the name arising because persistence of vision causes the yarn to appear as a three-dimensional object resembling a balloon.

Winding Machines

Types

Winding machines in common use may be classified as shown in Fig. 4.1. All the classifications can be further subdivided into *cone* and *cheese* (spool) winders; generally, these are not mixed on any one machine but it is possible for sections of some machines to produce cones while others produce cheeses.

An *automatic winder* is commonly defined as a machine in which *creeling* (including tying) and *knotting* of broken ends (which arise due to clearing flaws or to natural breakages) are automatic but *doffing* is not necessarily so. From this it is evident that knotting is crucial to the operation of an automatic winder and the knotting device provides a means of identifying the class of machine as illustrated in Fig. 4.1.

Manual Machines

Usually, a major characteristic of a manual or non-automatic winding machine is its high winding speed, and the reason for this lies in the economics of winding. With an automatic winder of other than one knotter per spindle, there is little point in winding the package in less time than it takes for the knotter to get to the package (or vice versa). Thus, with automatic winders there are several alternatives, viz. (1) the winding speed must be limited, (2) the supply package size has to be increased, or (3) the number of knotters must be increased. The third alternative is expensive, the second alternative is controlled by the spinning process and, therefore, the first alternative is the most common solution to the problem. Non-automatic winders are not so limited, and they can be operated at any desired speed within their operating limits. In the case of a one-knotter-per-spindle machine, this is not so, but such a machine has a high capital cost which affects the winding cost. In fact, the one-knotter-per-spindle machine might almost be regarded as an automated version of the manual one.

Where traveling packages or knotters are used, then the yarn count, length and characteristics should be the same for each section patrolled by the given knotter; otherwise, there would be undue interference because of differential knotting operations arising from varying fault rates, package run-outs, etc. Manual winding machines are not limited in this way and it is possible, but not always desirable, to wind a different sort of yarn on each spindle. Hence, great flexibility is one of the chief characteristics of the manual machine.

Inevitably, labor costs are relatively high in the case of manual machines. The elements of capital, labor and power costs have to be balanced to yield the most efficient operating conditions. The choice of machine is determined by these factors and generally, the higher the labor wages, the more complex and expensive are the machines likely to be.

For a given size of package, the time to unwind is proportional to the yarn number (count); hence, a package of very fine yarn needs infrequent service from the knotter whereas a package of coarse yarn needs frequent service. In the case of very coarse yarn, the machine will be stopped for knotting operations (i.e. the *down time*) for a large proportion of the available time. If the machine is very expensive, this means that the winding cost per pound will be increased and, in consequence, the manual machine can enjoy an advantage for coarse counts.

Automatic Winders with Non-Traveling Spindles

Let us consider first a specific example of a machine which has a large number of spindles per knotter. Assume that the winder works at 1000 m/min and the knotter takes 0·2 min to creel a new supply package and to find and piece the ends. Ignoring all end breaks during winding, let four different yarn numbers (yarn count) be considered and let

TABLE 4.1

N_e	n	L	L	t	τ	T	M	η_{max}
Yarn Count (Cotton)	Yarn Linear Density	Yarn Length $L=157.5N_e$	$L = \frac{85000}{n}$	Winding Time $t = \frac{L}{1000}$	Service Time	Total Time $T = t+\tau$	Max No. of Spindles Per Knotter $M = t/\tau$	Max Machine Efficiency $\eta = \frac{t \times 100\%}{T}$
hank/lb	Tex	Yards	Meters	Min	Min	Min	#	%
10		1575		1.575	0.2	1.775	7.8	89
	60		1416	1.416	0.2	1.616	7.1	88
20		3150		3.150	0.2	3.350	15.7	94
	30		2833	2.833	0.2	3.033	14.2	93
30		4725		4.725	0.2	4.925	23.6	96
	20		4250	4.250	0.2	4.450	21.3	96
40		6300		6.300	0.2	6.500	31.5	97
	15		5666	5.666	0.2	5.866	28.3	97

NOTE: In case of English Measure – Package Wt. = 3 oz. and Winding Speed = 1000 yd/min
In case of Metric Measure – Package Wt. = 85 gram and Winding Speed = 1000 m/min

the supply package be constant at 85 gram in weight (3 oz). Also for simplicity, let the doffing time be neglected.

Table 4.1 shows clearly that the maximum machine efficiency and the maximum number of spindles increase as the yarn gets finer. Conversely, a coarse yarn restricts the number of spindles per knotter to a very low figure and this shows why many coarse yarns are wound on manual machines or those having a knotter for every winding spindle. However, the most important fact that emerges from the calculation is that the maximum number of spindles per knotter, theoretically, should be varied according to the yarn number, but in practice, an existing machine cannot be varied. Thus, automatic winding machines of this type are all limited to a narrow range of yarn numbers.

It will be appreciated that many of the assumptions made in the previous calculation were rather sweeping and it is necessary to qualify them in practice.

Winding speeds vary from machine to machine and the range normally encountered varies from 600 m/min (660 yd/min) to 1200 m/min. While the knotter might take 0·2 min to creel a new package, it also has the duty to patrol and find any broken ends and repair them; consequently the machine efficiency will be reduced from that quoted in Table 4.1. It also follows that the quality of the yarn supplied and the degree of clearing demanded will affect the efficiency.

When the newly wound packages are built up to the desired size, winding stops automatically and there will be a loss in efficiency if there is any delay in doffing. The doffing time itself will decrease the efficiency because it requires a finite time to complete the operation; furthermore, it is unlikely that the waiting time will be negligible. Obviously, the larger the package being produced, the lower will be the loss in machine efficiency due to this cause; however, the size is limited by the requirements of the next process.

If there is a person or mechanical device attending to a particular spindle, then the waiting time could be zero. However, that person or device would work perhaps 10 sec in a doffing cycle which might be as much as an hour and the efficiency of the doffer would only be a fraction of a per cent. Such a situation would be intolerable and it is necessary to balance the work load of the doffer against that of the winding machine to give the best advantage.

In practice, a winding operator may look after some fifty spindles and would have duties other than doffing. These would include *magazine creeling** and watching for malfunctions of the machine. The machine efficiency seldom exceeds 75 per cent.

Let efficiency be defined as

$$\text{Spindle efficiency} = \frac{t}{T} \times \frac{n}{N} \times 100 \text{ per cent}$$

where t = productive winding time of one spindle per patrol of a single knotter (min).

T = total time spent by that knotter in patrolling its section (min).

n = number of productive patrols needed to wind the given mass of yarn.

N = total number of patrols needed to wind the same mass of yarn.

Consider a practical example based on a 30 tex (20s cotton count) yarn being wound from a 85 gram (3 oz) *ring tube* at 1000 m/min (1100 yd/min) on to a package of 1·1 kg ($2\frac{1}{2}$ lb). Let the creeling time remain at 0·2 min, and assume that the breakage rate is 4 per kg, the knotting time is negligible, an average of one patrol is lost for each doffing occasion and one half a patrol is lost for every yarn break. The value of t/T will remain the same as quoted in Table 4.1. However, in winding one package, there will be one doff

See p. 80

and $1 \cdot 1 \times 4$ end breaks; thus the total patrols lost will be $1 + \frac{1}{2} (1 \cdot 1 \times 4) = 3 \cdot 2$. In winding 1·1 kg, there will be $(1 \cdot 1 \times 1000) \div 85 = 12.94$ productive patrols, hence

$$N = 12.94 + 3 \cdot 2 = 16 \cdot 14 \text{ patrols}$$

and

$$\frac{n}{N} = \frac{12.94}{16.14} = 0.802$$

whence the average spindle efficiency

$$= \frac{n}{N} \times \frac{t}{T} \times 100 \text{ per cent}$$

$$= 0 \cdot 802 \times 0 \cdot 94 \times 100 \text{ per cent}$$

$$= 75 \text{ per cent}$$

The actual efficiency of any one spindle will depend upon the incidence of end breaks. For example, if an end break occurs as the knotter is just approaching, no patrol will be lost. On the other hand, if the knotter is just leaving, then a complete patrol will be lost. The efficiencies corresponding to the two extreme cases will be 87 per cent and 66 per cent (the average of these two is *not* 75 per cent). This example illustrates why the overall machine efficiency is not the same as the average spindle efficiency, but the difference is sufficiently small to be ignored in practice.

In machines where there is only one knotter per machine, the knotter may proceed continuously in a loop. Where there is more than one knotter, then it is usual for the knotter to patrol in a reciprocating manner. Where there is one knotter per spindle, no patrols are required but the efficiency is still less than t/T because of doffing.

Automatic Winders with Traveling Spindles

The principle of this type of machine is as follows: the machine winds from *bobbin* to cone or cheese, according to

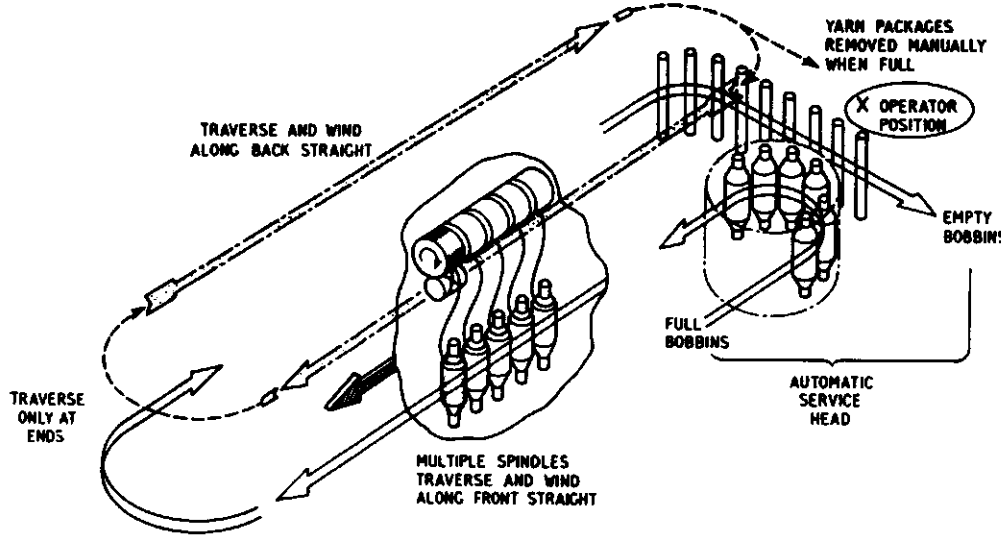

Fig. 4.2. Automatic winder with travelling spindles.

machine supplied. It consists of a number of winding heads that can be attached to and move on an endless chain at a predetermined speed around the machine during the course of which the following operations take place (see Fig. 4.2):

(1) The winding head comes up to the magazine and winding stops.
(2) The empty bobbin is ejected.
(3) The full bobbin is fed in.
(4) The threads from the bobbin and the cone are then knotted together and the loose ends cut off.
(5) The winding head continues to move forward and commences winding again.
(6) During the traverse on the endless chain, the winding head continues to wind and, when it comes to the magazine, the used bobbin is replaced by a full one regardless of whether the original one was completely empty or not.
(7) Winding is stopped as the winding heads pass round the ends of the machine because of the difficulties in driving them.

Should a thread break during the journey, the winding ceases until it approaches the magazine, when a new bobbin is fed to the *winding head* and winding is resumed as previously described. If the break occurs at the start of the journey, the rejected creel bobbin will be almost full.

The length of the frame is determined by the amount of yarn to be transferred from the bobbin to the cone. The work is brought to the operator, who is seated at a fixed position.

Since patrol times are fixed, winding speeds have to be varied considerably to deal with the variety of counts, condition and classes of yarn to be wound. The winding speed varies from 450 m/min (490 yd/min) for worsted yarn winding to cone, to 1200 m/min for cotton yarns.

The production of the machine depends upon the rate of spindle movement along the winder. A normal recommendation is that 20 heads/min should pass a single operator.

The production depends on the winding speed, the weight of the supply bobbin and the yarn breakage rate.

The automatic head does the following:

(1) Rejects all ring tubes whether empty or not.
(2) Finds the yarn end on the cone by suction.
(3) Takes the yarn end from ring tube. After dropping into winding position, the two ends are tied together while winding is still discontinued.
(4) Measures the cone size, indicates full cones and permits the continued winding of partially filled cones.

Example

If the machine winds 37 tex (16s cotton count) yarn from 0·1 kg (0·22 lb) ring tubes at 600 m/min (660 yd/min) on to 2 kg (4·4 lb) cones, how many spindles will the machine have, if maximum efficiency is obtained at the maximum knotting rate of 20 per minute? Each spindle is stopped 0·7 min/cycle for serving and passing the frame ends. Also calculate the spindle efficiency for 2·5 end breaks per kilogram. Assume one patrol lost each doffing and each piecing occasion.

Solution

Let L = yarn length = $\dfrac{1\text{ km}}{37\text{g}} \times 0.1\text{ kg} \times \dfrac{1000\text{g}}{\text{kg}}$

= 2.7km

i.e., $L = 2700$ meter

R = rate of spindle movement = 20 units/min.

W = winding speed = 600 m/min.

K = constant for units stopped (18 for a typical machine).

Then

$$U = \text{number of winding units}$$

$$= \frac{(L \times R)}{W} + K$$

$$= \frac{(2700 \times 20)}{600} + 18$$

$$= 108 \text{ spindles}$$

Running time per ring tube in creel $= \frac{L}{W} = 4.5$ min.

Patrol time = 4·5 + 0·7 = 5·2 min.
For example, consider 5 kg of yarn:

Creeling patrols	**5 ÷ 0·1 = 50·0**
Piecing patrols	**5 × 2·5 = 12·5**
Doffing patrols	**5 ÷ 2·0 = 2·5**
	Total = 65·0 patrols

$$\text{Spindle efficiency} = \frac{4.5 \times 50 \times 100}{5.2 \times 65} = 66.6\%$$

Quillers (Pirn Winders)

In most of the winding operations previously discussed, the creel packages consist of uncleared small or medium sized packages and the material doffed is wound on large packages from which most faults have been removed. In quill (or pirn) winding, the conditions are rather different. The creel package is nearly always a cone of considerable size which contains cleared yarn; consequently, no clearing system is needed in practice. On the other hand, the package to be doffed has to be small so as to fit in a shuttle. Hence there is a greater need for automation in the doffing operation than the creeling operation; consequently, most quill winding machines do not have automatic creeling systems but do have automatic doffing. There is no clearing system and creeling is fairly infrequent, therefore these machines are not fitted with automatic knotters; in fact, even manual knotting is rare because it is easier to start a new quill. Quillers might be regarded as a collection of single spindle machines on a common frame. The work load of the operator consists of manual creeling and *magazining**.

A further difference between quill winders and other winders is to be found in the package build. The yarn on the quill has to be wound on a long thin package so that it will fit in the shuttle, and the build has to be such as to permit intermittent high-speed over-end unwinding within the confines of the shuttle. This imposes special limitations; for example, it would not be possible to use a fully cross-wound package nor would it be possible to use a completely parallel package. In the one case, the tension variations would be impossibly high and in the other case the package would disintegrate. Hence it is necessary to use a compromise in which there are overlapping short conically cross-wound sections as shown in Fig. 3.16. The length of this section is called the "*chase length*" and the *cone angle* is usually maintained at about 30° because this gives reasonable stability and allows clean unwinding without undue danger of turns *sloughing off*. However, these factors are affected by yarn tension and it is necessary to control the tension during winding within quite close limits, hence it is necessary for these machines to be equipped with suitable tension control devices.

A further very important factor is the unwinding tension created when the quill (pirn) is in use in the loom. If the quill itself is merely cylindrical then there will be a large variation in tension depending on whether yarn is being removed from the tip or the base of the quill and to a lesser extent upon the position along the chase as shown in Fig. 4.3. Because the

* Magazining means maintaining an adequate number of empty quills in the supply magazine and removing the full ones from the output by the boxload.

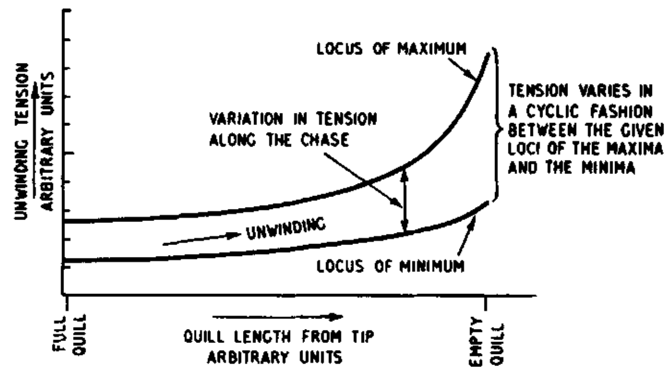

Fig. 4.3. Unwinding tensions from a straight quill.

unwinding takes place in a confined space, the balloon is collapsed and yarn exists as a helix in contact with the bare quill. If this portion of the quill is cylindrical, considerable tension will be generated by frictional contact, whereas if the quill is made conical as shown in Fig. 4.4, then the tension will be reduced. In this case the removal of yarn along the axis reduces the contact forces between the yarn and quill surface; this reduces the frictional drag which in turn reduces the tension. If the conical angle is made sufficiently large, the yarn can be induced to come free of the surface and a

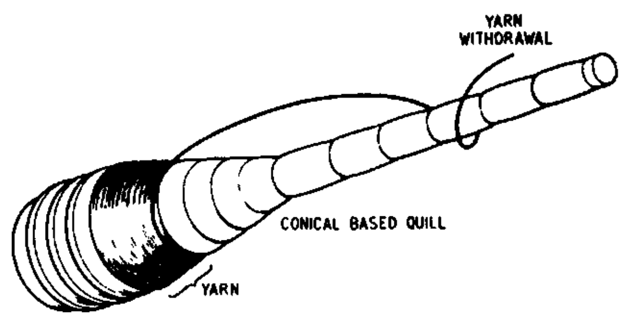

Fig. 4.4. Yarn ballooning from taper reduces tension.

form of balloon is created. Since the frictional drag is dependent on the amount of yarn wrap along the quill and this varies as the quill empties, it is advantageous to just make the yarn balloon out from the surface, thus reducing the variation in tension to a mimimum as shown in Fig. 4.5.

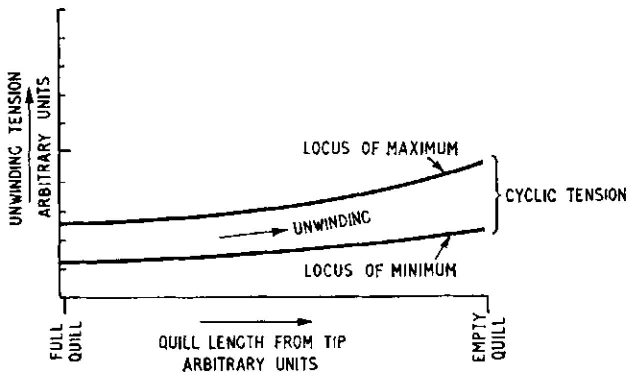

Fig. 4.5. Unwinding tensions from a conically-based quill.

While a tapered quill gives relatively even unwinding tensions, the space occupied by the enlarged base is not used to carry yarn. The economics of weaving are affected by this and it is necessary to compromise between quality as determined by tension and cost as determined by the frequency of quill supply.

In weaving it is desirable to use as much of the filling on the quill as possible and yet it is undesirable completely to exhaust the supply, in order to avoid partial *picks*. For this reason it is usual to wind a so-called "*bunch*" at the base which gives a small reserve of two or three pick lengths. The loom has a *feeler* which detects when the quill is empty. However, the feeler is not capable of detecting when the quill is nearly empty, and with the normal package construction there would be an insufficient reserve when the feeler signals for

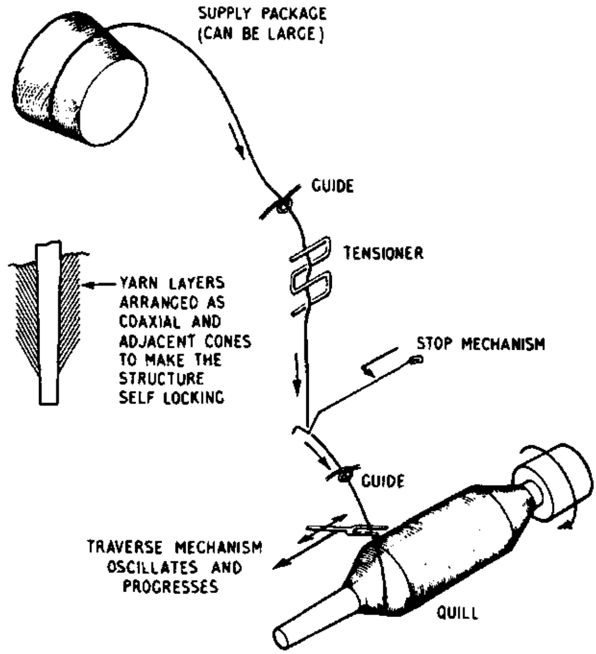

Fig. 4.6. Quill winder.

a change. Consequently, the bunch is wound in a parallel fashion over a short length away from where the feeler operates, so that when the remainder of the quill is exhausted the reserve remains.

In some cases, it is necessary to wind another bunch at the tip to permit a transfer operation in weaving.

Having set out the main requirements of quill winding, it is relevant to consider the machine itself. Fig. 4.6 shows a typical yarn path through a machine and it will be observed that many of the features are common to all winders. There are yarn guides, tension controllers, stop motions, traverse motions, and package drives which are similar to others, but there are some differences due to the particular needs. The main differences are:

(a) The supply package is large and output package is small.
(b) The output is automated and packages are delivered by the boxload.
(c) There is no clearing or knotting.
(d) The traverse has the character of a creeping oscillation in which the package diameter is controlled continuously.
(e) It is necessary to build one or more bunches which have a structure different from that of the remainder of the package.