9

Post-spinning processes

9.1 Winding

9.1.1 Introduction

Bobbins from a ring frame contain too little yarn to be useful in modern fabric making equipment and it is necessary to rewind the yarn onto larger packages. Special, high speed winding machines are used for this purpose. It is very important that the yarn which is to be sold or used in a subsequent process should be 'put up' into the correct sort of package – usually cones, cheeses, or occasionally, hanks. The transfer of yarn from the ring tube to the cheese or cone provides an opportunity to remove yarn faults. Looking towards the consumer's needs, it has to be realized that the density and structure of the package delivered are important. For transport and storage, the package should be as dense as possible. For ease in unwinding, the package should have a regular structure without over-dense portions, which might impede the unwinding process. Poor unwinding properties cause difficulties for the user and increase the costs. For dyeing, a low but regular package density is required so that the dye liquor can penetrate the package easily and evenly. Irregular dye penetration yields streaks and barré in the final product. Variations in winding tension produce similar effects. The needs of the customer or user therefore dictate the type of package and the density of winding. If the yarn is returned as a complaint, the spinner's costs are increased.

Dye packages are usually wound on sprigs (porous package centers) and are shipped mounted on pegs, which form part of a transport frame. Sprigs permit the flow of dye liquor in dyeing and the peg-frames prevent the packages rubbing together and becoming damaged.

As previously stated, ring frames produce low volume bobbins that contain blemished yarn; also, these bobbins have a combination wind, which is unsuitable for the next process. The final yarn packages are usually cross-wound and contain several pounds of yarn. This means that there must be many joins in the yarn on each package because there must be at least one join for every ring bobbin used. To these must be added another one for every blemish removed in the clearing operation. Yarn faults outside the prescribed limits are removed as the yarn is transferred from the spinning bobbins to the cones or cheeses. Faulty portions of yarn are cut out and the ends are spliced together to make, as nearly as possible, a perfect join; all of this is done automatically. This latter process is called ‘clearing’ and, while it is very effective, it is better to have as few a number of original yarn faults as possible, rather than rely on the clearing capabilities of the winding machine. Each intervention by the winder adds to the cost and slightly degrades the quality of the yarn. Winding and clearing of staple yarns are normally carried out on the same machine.

In filament production, and in certain advanced staple spinning systems (such as rotor spinning), the primary process produces a large, cross-wound package and there is no need to rewind to change the package size, although sometimes there may be a need to rewind to a low density package for dyeing and sometimes there may be a need to clear defects. However, every effort is made to avoid such costly rewinding.

The technology of winding has developed to the extent that automation is the rule. It is therefore important to consider this aspect fully. Economics and quality control become very important factors in the seemingly simple task of rewinding yarn (or ‘winding’ as it is normally called). Winding is carried out for the following purposes:

1 To change the type of wind.
2 To change the package density.
3 To remove yarn faults.
4 To create a package which is not susceptible to damage.

9.1.2 Machine principles

Machines are required to produce acceptable yarn packages as just outlined; this often involves the manufacture of a cross-wound package using a reciprocating guide, as shown in Fig. 9.1. Consequently this type of machine will be used to open the discussion. The yarn is laid on the surface of the rotating package by this reciprocating guide. The idea is that overlapping sinusoidal wraps of yarn interlock and provide a stable package. The relative rates of traverse of the guide and yarn package determine the type of build. As the package grows in size, its tangential speed increases unless it is controlled in some way. This implies that, for a given traverse oscillation rate, the geometry of each layer of yarn gradually changes as the package grows. As will be seen later, this has some important consequences.

9.1.3 Package build

The package build most used is a cross-wind in which the yarn is traversed across the face of the cheese (or cone) several times during one rotation of the package. For convenience, a cone or a cheese will be referred to as a package because many of the following remarks apply to both.

Yarn on the surface of the package is roughly sinusoidal and, ideally, out of phase with the coils lying beneath. Yarns cross one another and friction holds most of the yarn in an × formation (Fig. 9.2(b)) which is highly stable; this makes packages very durable under normal conditions if abuse in handling is avoided. The winding tension, angle of wind, and cradle pressure affect the structure and package density. The so-called ‘cradle pressure’ refers to the force acting between the package and the drive roll. The density of a regular package should be controlled because it might later be

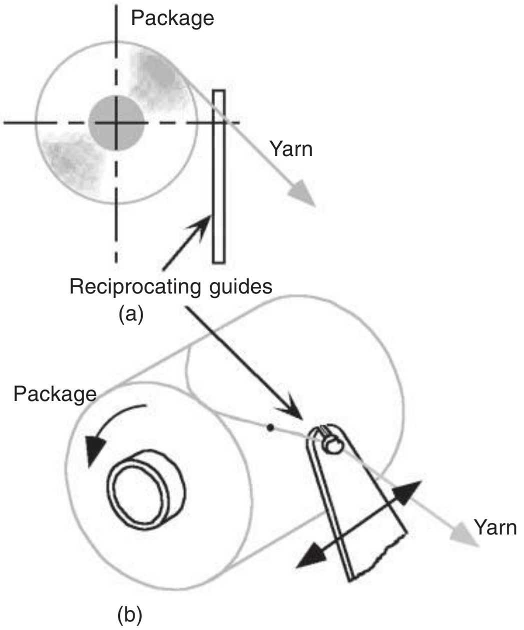


Fig. 9.1 Cross-wound package

unwound at high speed and too hard a package then gives trouble.Winding tensions should be limited due to the danger of overstraining the yarn. Changes in cradle pressure cause changes in winding tension and adjustment of the cradle pressure is a means of exerting control on tension.

As the diameter of the package builds up, the number of traverses per rotation of the package changes and this changes the structure of the package. When the package is the same diameter as the drive roll, the coils on the surface of the package lie exactly on top of the ones just laid. A number of coils laid on top of each other as the diameter builds through the critical zone produces so-called ribbons that are very troublesome (see Section 9.1.4). In the case of a dye package, the dye penetrates the ribbon at a different rate from the rest of the package; the result is a periodic difference in dye shade in the yarn. In unwinding, the yarn is reluctant to leave the surface of the dense parts and this gives rise to tension pulses which also can cause difficulty. Ribbon breakers are normally fitted to the machines to prevent the problem. Some machines cause the package to lift from the drive roll momentarily, to allow some slippage to disperse the ribbons at the crucial times. Other machines move the package sideways to achieve the desired dispersion. Some modify the drive roll speeds.

The yarn in the shoulders of the package plays a considerable role in the durability of the package. There should be sufficient traverses per revolution of the package to prevent loose portions of yarn from lying parallel to the shoulders. The shoulders should feel firm and stable, but not hard.

As has been explained earlier, yarn is sometimes parallel wound. In such a case, either the package must be wound onto a bobbin with flanges, or the package must be small and have sloping shoulders. Hank or skein winding can also be used. Sometimes skein dyeing, and occasionally skein mercerization, is used; skeins are often sold in the home craft market and they frequently consist of heavy yarns.

9.1.4 Cross-wound packages

For simplicity of explanation we will confine ourselves at first to a cheese. The reason for stability can be seen in Figures 9.2 and 9.3, where it may be noticed that the yarns on the surface of the package interlace at an angle. Each layer of yarn imposes a restraint on the sinuous ‘coils’ beneath. The best angle is between 12° and 20°. Resolving the tensions in a given layer of yarn, the radial components acting inwards at every intersection have a magnitude of F; these depend on the winding tensions, T, and the angle of wind, θ. The number of intersections depends on the wind, and θ again enters the picture. The radial component and the number of intersections determine the density of the cheese, and the package density is a function of T and θ as shown by the example in Fig. 9.3(b) and (c). The force needed to make one coil slide over the others depends on the coefficient of friction μ, as well as F, and the number of intersections, m. A force greater than μmF, acting along the length of the yarn, could cause whole coils of yarn to slip. A cross-wound cheese has a large number of intersections and it is, therefore, inherently stable. It is quite possible to build a stable cross-wound cheese containing over 10 lb (4.5 kg) of yarn. However, it still has to be remembered that the winding tension is an important factor in determining both the package density (Fig. 9.3(c)) and stability. As previously mentioned, too high a tension can damage the yarn; the aim is to maximize the stability without exceeding the tension limit. The limit depends on the type of yarn being wound.

Referring back to Fig. 9.2, a phase change, ϕ, occurs as each layer is added and:

$$\phi = \pi D - m\lambda \qquad [9.1]$$

where m is an integer, λ is fixed and D is variable. As the cheese builds up, ϕ changes periodically with the consequence that the package structure also changes periodically.

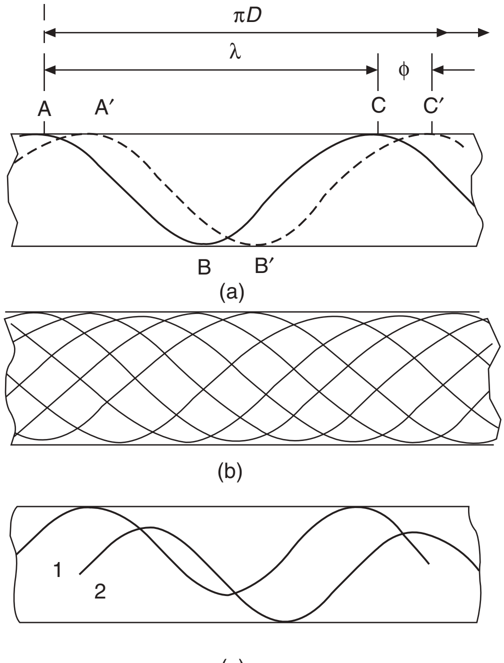


Fig. 9.2 Build-up of package surface

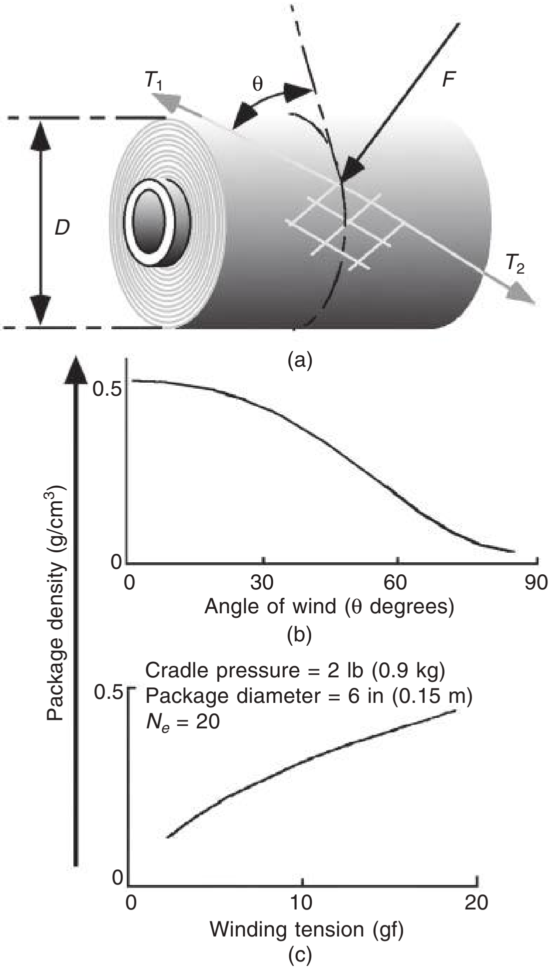
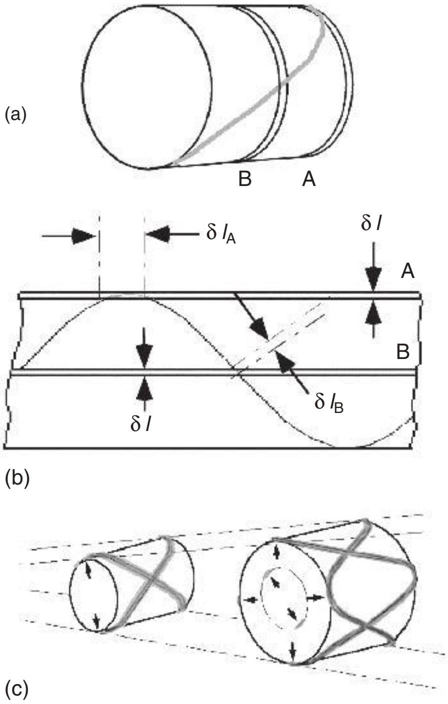


Fig. 9.3 Cross-wound packages

At the times that ϕ is reduced to zero, yarn from one 'layer' is laid exactly upon the one below and the yarn piles up in a dense sinuous ribbon on the surface of the cheese until the diameter grows sufficiently to give ϕ a significant value again. As m reaches successively larger integers, new ribbons are created; this causes considerable problems in dyeing and unwinding. The flanks of the package also show signs of the ribboning. At the critical diameters, the effective yarn traverse is increased and the reversal points protrude; these are called overthrows (Fig. 9.4(c)).

Not only do patterns occur when ϕ passes through zero but they also occur when ϕ is a fraction of πD (i.e. when $\phi/\pi D = 1/2, 1/3, 1/4, 3/2, 5/2$, etc.). A solution to this problem is to vary the lateral position of the yarn lay, as shown in Fig. 9.2(c).

There is an inherent variation in package density in a cross-wound package. Consider two slices, A and B, of equal width, δl, taken perpendicularly to the axis of the cheese, as shown in Fig. 9.4(a) and (b), where just one coil of yarn in the geometrically developed surface is shown. Of course, each slice contains many yarns. A typical length of yarn in slice A is δl_A and it lies parallel to the shoulder. In fact, all the yarns in the slice are more or less parallel. The lengths in slice B, such as δl_B, criss-cross



Overthrows shown by arrows

Fig. 9.4 Hard shoulders and overlaps

within it. Thus, the shoulders of the package at slice A are denser than those within slice B or any other intermediate slice. Therefore there is a need for several traverse motions per revolution of the cheese to keep the percentage of yarns lying more or less parallel to the shoulder.

Ribboning and dense shoulders also occur with cones and although the mathematics are more complicated, the ideas are essentially the same. Ribbons occur periodically with the same unwanted effects, and the solutions are similar to those already described. A minimum of several traverses per revolution of the cone is also required.

9.1.5 Cones

Although a cheese is easier to wind than a cone, there are advantages that favor the cone. In knitting, yarn is withdrawn slowly and there is insufficient speed to cause the yarn to balloon away from the surface of the cone. Yarn drags over the surface of a cheese and disturbs the lay of the other yarns; the drag generates more and variable yarn tension, as well as making the yarn more hairy. With a cone, the taper causes a progressive release of the yarn from the surface, providing it is withdrawn in the direction of the apex of the cone. There are fewer surface entanglements and the yarn flows more evenly. Even at the higher speeds used in warping and high speed weft insertion, the cleanliness with which the yarn is withdrawn from a cone is a considerable attraction.

If the cone and the traverse are driven at constant speeds, the yarn speed required to lay the yarn on the small-diameter end (B in Fig. 9.5) is different from that needed

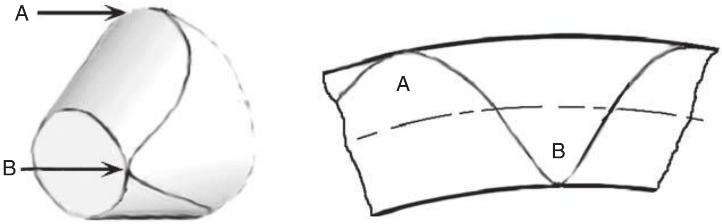


Fig. 9.5 Cone surface

at the base (A). To make such a system work, there can either be intermittent yarn storage or the traverse rate can be made to vary across the traverse.

Ideally, the yarn cone should be driven by another cone, to avoid scuffing of the surface, because two cones mesh together perfectly. However, some winders use a wide cylinder to drive the yarn cone which is kinematically incorrect. The cone tends to run with its mean surface speed in synchronization with the drive cylinder; the base runs faster and the tip runs slower, the differential movement causing scuffing. Often, a narrow cylindrical rim is used to drive the cone. Although this avoids most of the scuffing, it causes some local compression on the surface of the cone.

9.1.6 Traverse mechanisms

One common type of winder has a reciprocating traverse. As mentioned, by varying the relative speeds of traverse and package, or their relative positions, one may obtain a pattern breaking effect. A displacement of lay 1 with respect to lay 2 can produce a pattern breaking effect as indicated in Fig. 9.2(c).

Care has to be taken to keep the final guide close to the surface of the package otherwise the yarn lag can be troublesome and hard shoulders will be produced. The yarn lag is due to the uncontrolled length AB in Fig. 9.6. When the guide is moving leftwards, the yarn lies at an angle such as is shown at EF, but it lies at an angle such as GH when traveling in the other direction. The lag tends to concentrate yarns at the reversal points and give hard shoulders.

The simplest and a widely used form of yarn traverse is the grooved roller (Fig. 9.7). The grooved roller not only drives the package but it also lays the yarn on the surface at approximately constant spacing. However, since the coil spacing is fixed, there is ribboning every time the package reaches a multiple of the effective diameter

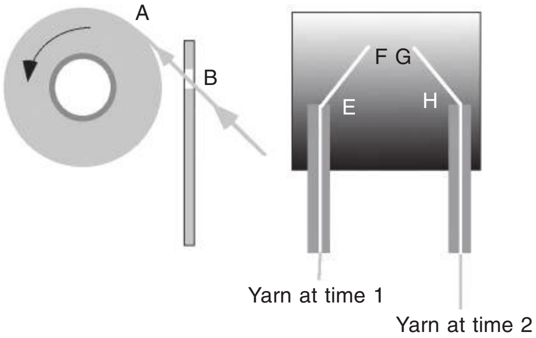


Fig. 9.6 Yarn lag in winding

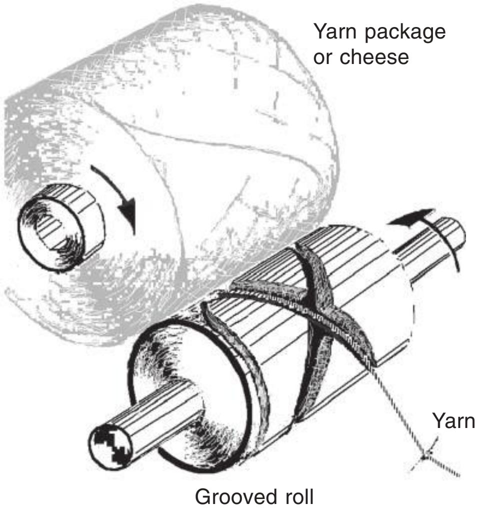


Fig. 9.7 Grooved roll traverse

of the grooved roll. There is also a fractional relationship as already explained. One solution to the problem is to use a large diameter grooved roll, and another is to use a pattern breaker. Some pattern breakers oscillate the package or the grooved roll, sideways, randomly.

Local linear speeds at which yarn is laid onto the surface of a package, which rotates at constant speed, vary with the angle of lay. If the surface speed is V_s and the yarn speed is V_y, then at special positions, $V_s = V_y$, but elsewhere this is not so because the yarn lies at an angle. One way to overcome the problem is to place a bow piece in the plane of the yarn offtake (Fig. 9.8). The length of yarn between the supply and the laying-on points varies in such a way as to take up the slack caused by the variations in wind-on position and angle. In building a cone, more yarn has to be laid on the base of the cone than on the tip. The angle of lay has to be biased away from

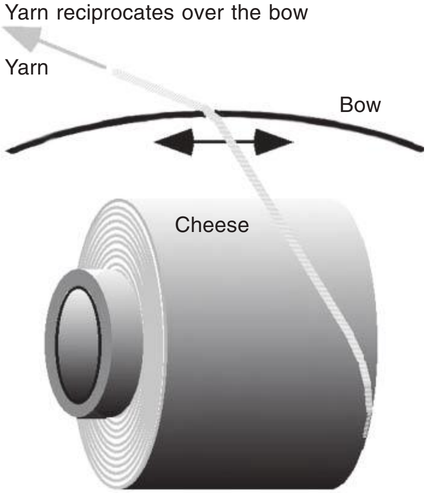


Fig. 9.8 The use of a bow to control yarn tensions

the sinusoidal and length compensation has to be introduced to prevent periodic high tensions or overfeeds occurring. A special grooved roll or reciprocating traverse may also be used.

9.1.7 Precision winding

The machines discussed so far have had a constant traverse rate and such machines produce ribbons of denser structure at periodic intervals as the package grows in diameter. There is a kinematic solution in which the traverse rate is varied. If we differentiate Equation [9.1] with respect to time, we may restate the result as:

$$d\phi/dt = K(\pi DU - m\lambda V) \qquad [9.2]$$

where $d\phi/dt$ = the rate of phase change of yarn layers, K is a constant, U = rotational speed of the cheese in rev/s, V = the speed of the traverse in oscillations/s, and the remaining symbols are as in Equation (9.1). If mV and DU are kept in synchronism, $d\phi/dt = k$, where k is another constant. If k is chosen appropriately, the ribbons can be eliminated and a denser package can be made. Separate drives are needed for the package and traverse and this makes the apparatus expensive.

Some machines use a precision wind in which the diameter is sensed and the traverse speed is adjusted to give a constant value of the coil advance.

9.1.8 Direct winding

Where the yarn is wound directly on the cones or cheeses at the yarn manufacturing stage (for example, in rotor spinning), great care is needed in setting the bow piece and traverse mechanism. Unlike the case where the yarn is being withdrawn at will from another package, the supply velocity is fixed by the process. As was seen earlier, the velocity at which the yarn should be laid on the surface of the rotating yarn package is not constant. If one requires a well-built cone with a considerable cone angle, it is necessary to have a more sophisticated yarn storage and tension control. An improperly set bow, or the operation of a bow piece system beyond its limits, gives a poor package structure and a high frequency of end-breaks during operation.

9.1.9 Winding tensions

Since yarns are visco-elastic in nature, any tension applied to them alters their characteristics. Yarns need to be wound at controlled tensions because over-tension damages the yarn; under-tension gives an unstable package of low density. Damaged yarn performs badly as can be seen from the example in Fig. 9.9. Progressively increasing the winding tension increases the tenacity at first and then it drops again. At first sight, the increase in tenacity would seem to be an advantage. However, careful examination will show that there is a progressive decrease in the breaking elongation, which implies no improvement in the energy to break. Also, the weak spots are strained more than normal, which is a bad feature. Another example, a cotton OE yarn, showed that application of stresses up to 20% of the breaking value increased the tenacity of the yarn between 1.0 and 1.5 gf/tex, but at the expense of the breaking elongation. In weaving, any lack of elongation gives problems with warp

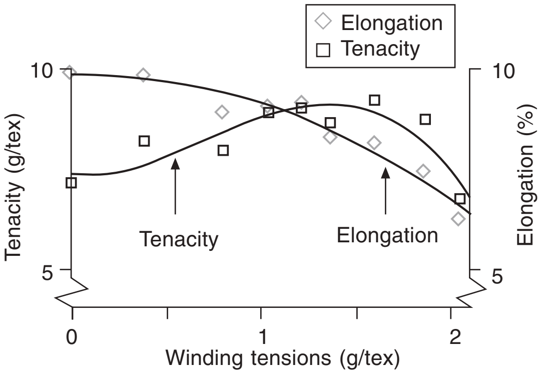


Fig. 9.9 Effects on yarn performance of high winding tensions

breaks.[1] The value of such strength increases is therefore dubious and, without doubt, over-stressing a yarn damages it. The effects on ring yarns are less because of the more organized structure. Fortunately, OE yarns are rarely rewound.

9.1.10 Unwinding

The amount of yarn on a ring bobbin is insufficient for commercial use and many ring bobbins contain faulty yarn, which has to be removed before final packaging. The yarn is transferred to cheeses or cones and this involves the unwinding of the ring bobbins as part of the transfer.

A frequent wind found among the supply packages is the filling or weft wind (which typifies the ring package as sketched in Fig. 7.4(b)). The wind-on tension varies throughout the wind because of variations in (a) tension during spinning, and (b) the balloon during unwinding. High winding tensions are frequently met when a ring bobbin is just started because of the smallness of the winding diameter, and this is frequently a time when one sees an increase in the fault rate. Thus, a cheese or cone has variations in yarn structure. Tensions change as yarn is taken from the beginning or end of the ring tube; this changes the package structure. The appearance of thin and thick spots further complicates the picture. It is not uncommon to find a thick spot followed by a length of thin, over-twisted yarn. Even after piecings are cut out, one finds that knots or splices are followed by thin, weak yarn with a different appearance. There are a number of differences that are likely to show up in the final product; often the problems are made worse by high winding tensions.

Bobbins from the ring frame have to be unwound at very high speeds as yarn is transferred from the ring bobbins to the cones or cheeses. In the ring spinning process, bobbins had rotated at high speed and new layers of yarn had been laid on to a plush-like surface created by the hairs being held out by centrifugal force. When the yarn is removed during the winding process, the yarn tends to twist as it is removed; this action removes fibers from adjacent coils on the bobbin. The consequence is a micro-unevenness that is not easily detectable on a spectrograph but is objectionable when the yarn is assembled into fabric. The problem becomes worse as the ring frame speeds increase. Also, it is a good reason to control yarn hairiness in spinning. Yarn appearance is among the largest categories of customer complaint; it has been seen

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[1] Energy to break, i.e. tenacity × elongation, is the best criterion.

to rise at times as high as 40%. Even if a yarn has adequate strength, evenness, and the correct twist, it is not always satisfactory. Rust and Peykamian [1] have shown that the hairiness of yarns increases due to the winding process. During the winding process, fibers are transferred from yarns on a supply package to the yarn just being removed. Large transfers of fiber yield yarn faults; the normal transfer rate is less than 10 fibers/m. The presence of yarn defects adversely affects unwinding performance; it may also reduce winding efficiency, not only because of the increased clearing needed but also because of the end-breakages in the process.

High speed unwinding of a package, whether it be a ring bobbin, cheese or cone, gives a balloon that is chaotic, and peak yarn tensions can be very high. The difficulties arise because the radius at which yarn is taken from the package varies rapidly because of the build. Without any form of balloon control, these peak yarn tensions severely limit the speed at which the yarn can be removed; this, in turn, limits the winding speed of the whole winder. Balloon breakers are used to reduce the tension variations and one of the latest types is shown in Fig. 9.10 [2]. All balloon breakers increase the yarn hairiness and the mean winding tension. The take-off point of yarn from the bobbin moves up and down the chase as yarn is pulled from the package; this causes variation in yarn tension. The balloon breaker, which might also traverse up and down, limits the tensions.

The yarn winding tension as it goes on to the new package is partly determined by the unwinding tension from the supply package. It is further determined by the additions and/or multiplication of tension (see next page) produced by the tension controllers and guides. Some tension increase is inherent in the design of the system; some is used as a means of control. The latter is dealt with later; for the moment we shall concentrate on the involuntary portion. A simple balloon breaker can double the

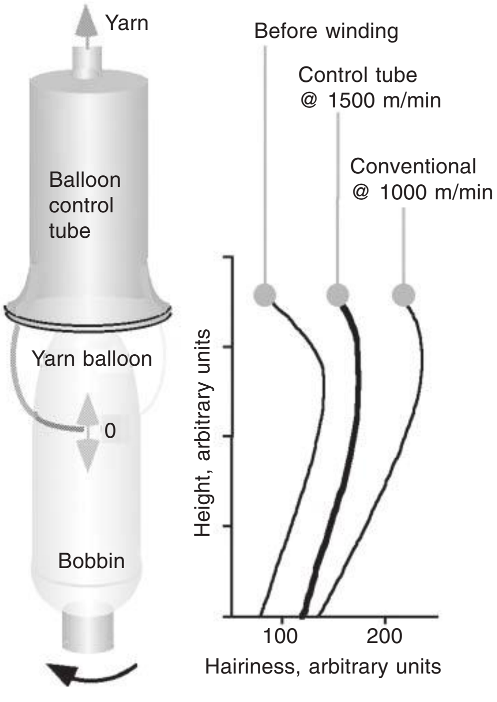

Fig. 9.10 Balloon control and yarn hairiness

hairiness of the original yarn; it also increases the winding end-breakages unless the winding speed is limited. Improved designs, such as those with a control tube, as shown in Fig. 9.10, limit the hairiness increase [2].

Turning now to the voluntary tension controllers, there are two basic forms of these, namely, addition and multiplication types. The former gives an output tension equal to the input tension plus a frictional component; the latter gives a result, which follows Amonton's Law. Many tension systems incorporate elements of both and, in general:

$$T_{\text{out}} = K_1 \mu F + T_{\text{in}} (1 + K_2 e^{\mu\theta}) \qquad [9.3]$$

where K_1 and K_2 are constants, μ is the coefficient of friction, F is the normal force acting on the element in the tensioner, T_{in} is the input tension, T_{out} is the output tension, θ is the angle of wrap in radians, and $e = 2.718$. Amonton's Law states $T_{\text{out}} = T_{\text{in}} (1 + K_2 e^{\mu\theta})$.

9.2 Yarn joining

9.2.1 Defect removal

Clearing of yarn to remove faults is a crucial role for most staple yarns. The market rarely accepts yarn with numerous and large defects; to maintain price and reputation, it is essential to remove all unacceptable slubs, thick spots, thin spots, etc. The level at which they become unacceptable is a matter of agreement between the buyer and seller of the yarn.

Yarn is sometimes wound at high tension so that weak spots are found during winding rather than at some later stage. An automatic knotter or splicer is used to join the ends created by the removal of the defect. To remove weak spots consistently, the winding tension has to be uniform. In many cases it is anything but uniform and, under such circumstances, some weak spots are missed; the efficiency of clearing is thus reduced. Furthermore, some weak spots are overstrained and this might cause problems later. Thick spots are often detected by passing the yarn through nub plates that contain slots that will pass normal yarn but not the thick spots. The rise in tension when a thick spot is caught in the nub plate causes the yarn to break; the ends are then knotted or spliced to give continuity. Again there is a periodic over-stressing of the yarn. Defects, and the consequential damage, are often concentrated in yarn taken from the base of the ring tubes (because end-breaks in spinning are more frequent there).

A satisfactory alternative is to use a sensor to detect the defects, and to use the signals from it to actuate a cutter and a knotter or splicer. Optical or capacitive sensors are frequently used. Accurate defect removal requires measurement of the linear density (or 'yarn diameter') of the running yarn. When a bad spot which is outside the prescribed limits passes through, the winding head should stop and the section of bad yarn should be removed. Any newly cut or broken ends are then joined before the winder recommences winding. A patrolling piecer assembly finds the ends on the supply and uptake packages, splices the ends and then restarts the winding head. A machine might contain tens of such piecers serving, perhaps, a hundred winding heads. The procedure is automatic and needs no human intervention unless (a) the winding head is improperly set, (b) the section of yarn is particularly bad, or

(c) there is a mechanical failure. The limits can be set independently to include the thickest and thinnest allowable linear densities at various fault lengths.

Capacitive sensors are most commonly used to detect the defective portions of yarns. Sometimes, however, optical devices are used, in which case one has to be careful with the use of external lights around the machine unless the sensors work in the infra red part of the spectrum. Optical sensors have difficulty in discriminating between thick and fluffy spots (they are not sensitive to yarn mass). On the other hand, capacitive sensors are moisture sensitive and they cannot discriminate between changes in linear density, fiber composition, or moisture content. Both of the sensors mentioned can perform satisfactorily providing that the moisture content is properly controlled by appropriate air conditioning and that there is reasonable quality control in spinning. Their use permits the setting of the winding tension to appropriate levels.

Supply packages should be conditioned for an adequate time because moisture penetrates at a relatively slow rate; it is prudent to condition them for at least 24 hours before winding. Since water is cheaper than yarn, it is necessary to define the moisture content of the yarn in the contract between buyer and seller. It might also be pointed out that many fibers swell when they imbibe water; this swelling and the subsequent shrinkage can disturb the lay of the yarn on the package. Conditioning of finally wound packages can lead to the production of hard shoulders. This leads to difficulty in unwinding the packages and yarn damage. It is preferable to condition the yarn before winding and then maintain the moisture content by appropriate control and packaging of the final cones and cheeses.

The winder is used not only to join the component yarns as just discussed, but it provides an opportunity to test the yarn for defects, cut them out, and join the new ends. The consequential reduction in defects is of the greatest importance for quality and for profitability of the mill. Clearly, if the clearers are set too close, too many minor defects are removed and replaced by splices. There can be a deterioration in quality because even the splices (as good as they may be) are still minor defects. Equally clearly, failure to remove serious defects can have serious undesirable effects on the trading relationships involved. The presence of unwanted defects may be the subject of a complaint by the customer that may involve payment of a financial settlement and a loss of confidence.

9.2.2 Splicing

Until the last decade, it was common practice to knot yarns together, but the knots were a source of weakness and were defects in their own right. Nowadays, yarns are spliced together using mechanical or air-jet splicers, which produce a joint that is usually at least 70% of the strength, and generally less than 130% of the thickness of the parent yarn. Splice efficiency is used as a measure of the strength of the spliced portion of the yarn, expressed as a percentage of that of the parent yarn. The adoption of splicing has greatly reduced problems in weaving, knitting, and dyeing.

There are two means of splicing in common use. One is in the form of a hand-held device and the other is part of a winding machine. A single winding machine might have, perhaps, ten splicers serving something in the order of 100 winding heads. A typical winder/splicer makes between 10 and 30 pieces per package and ejects from 5 to 10 mg of fiber per package into the atmosphere. The splicers are complex, expensive devices and there is a need to conserve capital by letting a single splicer serve several winding heads. Also, that way, the splicer is kept in fuller employment than otherwise would be the case. Most devices involve air splicing but there are some mechanical types. Both sorts can produce good splices providing they are properly set. A review in the early 1990s of the industrial performance of a series of splicers gave the results shown in Table 9.1 [3]. An old air splicer performed poorly compared to more modern ones; this points to the improvement in piecer design over a decade. Some spaces have figures in parentheses and these reflect the diminished performance when a single machine (of the few needed) was poorly set. This is a matter of personnel training rather than machine design. In a different survey of several mills, the CVs of the settings of a given type of splicer were found to be extraordinarily high. This is a bad sign as far as fixer training is concerned.

To make a satisfactory splice, the two yarn ends have first to be prepared to make them properly tapered. Also, the fibers must be adequately separated and paralleled so that they are capable of intermingling when the splice is made. Consider a typical machine as shown in Fig. 9.11. Remember that the winders work at high speed, and have to interrupt the winding to cut out the faulty portions of yarn before the new ends are spliced together. It will be noted that scissors are provided to cut the unwanted yarn ends after the two yarns have been laid in place. At this juncture, the ends of the yarn are parallel and face opposite directions as shown in Fig. 9.11(a). Automatically actuated clamps grasp the yarn at the appropriate places before the main splicing

Table 9.1 Performance of splicers

Splicer type	No of spinning plants	% strength efficiency	% bad splices	% CV of splice strength
Mechanical	2	98	0	10
Air (Maker 1)	4	98 (94)	0 (8)	16 (19)
Air (Maker 2)	3	93	3	12
Air (Maker 3)	3	91 (81)	0 (27)	12 (21)
Old air type	2	85	10	16

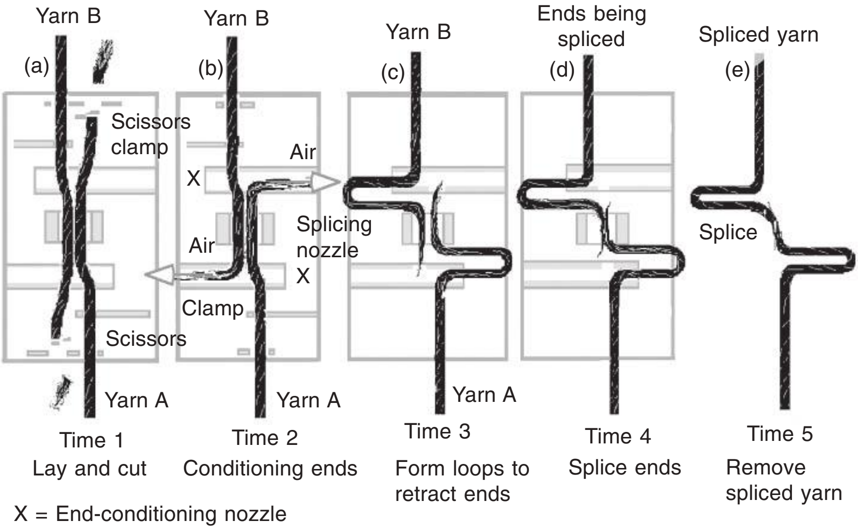

Fig. 9.11 Stages in splicing

procedure begins. The free ends of the two yarns are sucked into end-conditioning nozzles and air blasts are provided to condition them before joining. To condition the ends, the yarns have to be gripped and fibers sucked from the exposed ends to taper them (Fig. 9.11(b)).

A spectrum of fiber lengths is removed from the ends. The violent airflow causes some fiber entanglement in the remaining fibers at the yarn ends, which makes it easier for the fibers to intermingle during the splicing operation itself.[2] Splicing is carried out after the two conditioned yarn ends are laid inside the splicing chamber so they are parallel, facing opposite directions and appropriately spaced without the tips of the conditioned ends protruding. One way to do this is to withdraw loops of yarn as shown in Fig. 9.11(c). The splicing chamber of an air splicer is sometimes made in two parts which open to allow easy insertion of the yarn ends and then permit closure for the splicing phase of the operation. The two ends are spliced together by a rapidly rotating body of turbulent air inside the splicing chamber. The turbulence is induced by air that enters the cylindrical chamber tangentially. The air blast first intermingles the fibers and then causes the newly made joint to rotate to produce false twist. The yarn is then removed from the splicer (Fig. 9.11(e)) and winding is recommenced.

If properly restrained, the false twist at stage (d) accumulates on one side of the splice until the air ceases to flow, at which time the false twist flows into the joint. Twist distribution during the splicing operation is shown in Fig. 9.12(a), the yarn size having been exaggerated to show the twist directions and level. This latter is important because the twist in the splice gives the joint an appearance similar to that of the parent yarn (and strengthens the joint too). Consider the case of a splicing chamber designed for use with normal Z twist yarns. A temporarily high Z twist exists on one side and an S twist (or very low Z twist) exists on the other while the air blast operates. There is about 15 to 20 mm of zero twist between them then. After the air blast stops, the twist is redistributed to give what appears to be reasonably uniform Z twist throughout the splice. There is a distinct chance of damage to, or failure of, the portion of the yarn with low twist during splicing. Also, if the tensions within the zone are kept low, there is a probability of snarls forming in the high twist portion during splicing.

Consider the nature of a splice. To avoid a thick splice it is necessary to taper the ends to be spliced so that the joint is not obvious. These ends have to be in the proper relative positions when the splice occurs. In the case shown in Fig. 9.12(b), the tapered ends are misplaced to give a thin spot. This is also usually a weak spot, which is undesirable on that account. The yarns could have been overlapped too much, in which case there would be a thick spot and two undesirable splice-tails (Fig. 9.12(c)). These tails catch up in knitting and weaving and are often the subject of customer complaints. The splicer should be set to avoid these tails, even at the expense of a slight loss in splice strength. Figure 9.13 shows two such bad splices, the top one of which has a wrapper on the right-hand side and the bottom one a quite undesirable tail on the left-hand side.

For these reasons, and to uphold quality standards, it is very important to maintain the correct timings, settings, and tensions. The various motions described are performed by a series of cams and levers, and it is essential that the components be well maintained.

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[2] If there are 50 splices per cone, the count is 20s (≈ 30 tex), and each splice converts about 1 inch of yarn to fly, then 0.083 lb (≈ 38 g) of fiber is ejected per cone, which is a significant source of pollution.

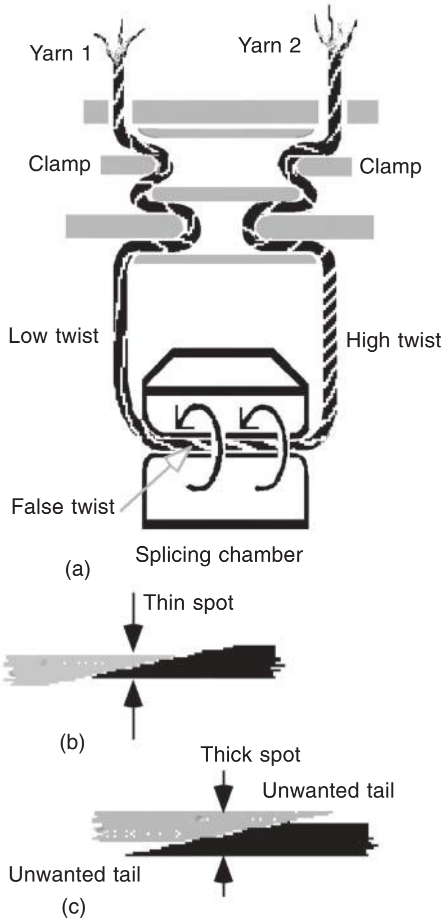

Fig. 9.12 Splice structure

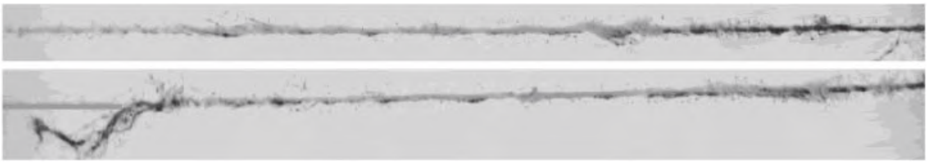

Fig. 9.13 Imperfect splices of a dark yarn with a light one

Accumulations of lint, loss of lubricant, and wear on machine parts can alter the performance of the machine and degrade the quality of the product.

The alternative method to air-jet splicing involves a mechanical device which untwists the yarn end locally and pulls the tail away, causing the remaining fibers to become parallelized. The distribution of fibers in the remaining tail gives a tapered end as required. A shear field produced by two counter-moving disks is used to produce the twisting action needed to splice the ends together. This mechanical false twister has rubber elements, which apply pressure to the assembly during the splicing operation and, again, careful maintenance is required to keep the system in good working order.

Splices are commonly tested for strength, in the field, with a hand-held dynamometer. The parent yarn on either side of the splice is normally tested also and so-called splice 'strengths' (more properly, 'splice efficiencies') are usually expressed as (100% × splice strength ÷ average of the parent yarn strengths). With a good splice, it is not easy to distinguish the splice from the rest by eye. Nevertheless, if the yarn is looped in the region of the splice, it will be seen that the splice is stiffer and does not conform to the same radius as the rest. This is helpful in finding the exact position of a splice that is about to be tested.

9.2.3 Winding machines

Most modern winding machines used in staple spinning incorporate not only the function of winding but also that of removal of faults. They involve unwinding the supply package (usually ring bobbins), splicing the yarns after cutting out faults, and winding the package that goes to the customer or to some intermediate process. On the other hand, winders for filament yarns are not concerned with the removal of faults and splicing. All winding machines are designed to produce stable packages of undamaged yarn at maximum speed.

A typical modern cone may well weigh more than 10 lb (≈ 4.5 kg) and can be composed of yarn from up to 50 ring bobbins. The winding machines work at speeds up to 1500 m/min (≈ 1370 yd/min) and the process can impose considerable strain on the yarn if the machine is not properly set. The surfaces touched by the yarn are usually coated or treated to reduce friction and abrasion. Increasingly, ceramic inserts are being used at critical places to reduce the wear on the machine. The minimization of the wear and tear on the yarn is also important; however, it is not always easy to detect the damage until it enters a subsequent process. Wear can produce hairiness, nep, and other appearance problems. Consequently, maintenance is essential.

Another function of the winder can be to meter the amount of yarn on a package. This can be important to a customer, because it is desirable that all yarn packages in a creel of a warper or knitting machine should run out at the same time. In this way, there are few or no remnants of yarn left on the package centers to become waste.

Winding is so near to the customer interface, that it should be taken very seriously. The author's experience in the 1990s was that roughly 25% of claims made on complaints arose from winding problems. This figure is not fixed; it is amenable to change through improvements in technique and equipment.

9.3 Ply yarns

9.3.1 Plying

For sewing threads, as well as certain speciality and industrial yarns, it is necessary to ply (i.e. to double or fold) the yarns to give them a smoother and less hairy character. Doubling improves the evenness; plying balances torque if carried out correctly and binds some of the hairs on the component yarns. The traditional methods include assembly winding (Fig. 9.14) to place the single yarns parallel to each other as a closely spaced pair (or group) of yarns on an intermediate package. The new package is then used as a feed for a twisting machine and the output is a plied yarn. However, the cost of assembly winding approaches 25% of the total winding costs and the system is prone to problems. If one of the ends breaks in the process, then

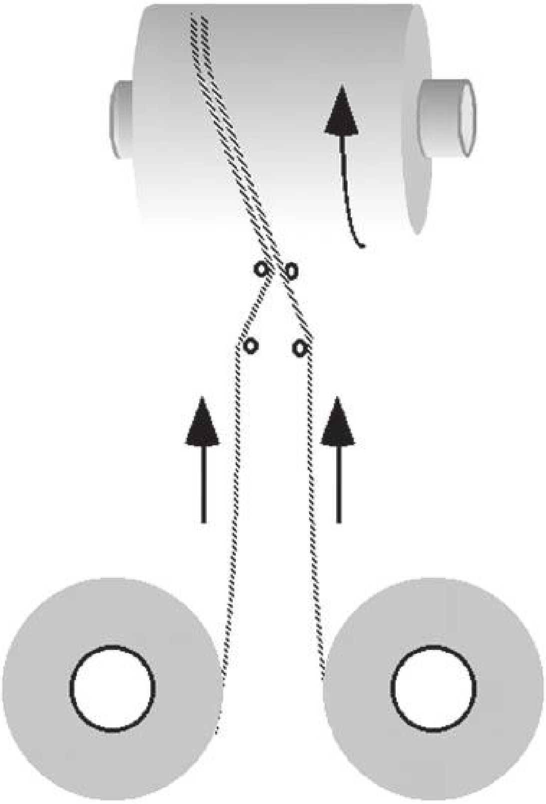

Fig. 9.14 Assembly winding

only a single yarn is wound until the machine is stopped. Another problem is that an end from an adjacent package can be caught up to form a three-fold (or four-fold), instead of the desired two-fold, yarn. Such faults, if not spotted and removed, are a sure cause for complaint by the customer. The lengths of yarn on every package are best matched to avoid wastage. Such practice also eliminates the need for the existence of partly consumed feed packages on the winding frames and is desirable since the presence of surplus packages increases the risk of the three- and four-fold yarns just discussed. Because of these problems, it is modern practice to wind and clear the ring yarn so that standard cones may be used for the feeds. This may not be the most efficient way of converting the yarn, but the field is not large enough for there to be promise of much machine development.

9.3.2 Singeing

Where smooth cotton yarns are required, as in sewing thread, they are sometimes singed (or 'gassed') to remove the hairs. Such yarns are often two-ply; long-staple cottons are frequently used to give maximum strength and resistance to abrasion. A micrograph of a typical ring yarn before and after singeing is shown in Fig. 9.15. To singe the yarn, it is passed through a flame at a steady speed; the rates of fuel gas and air are carefully adjusted so that sufficient hair is removed without damaging the core.

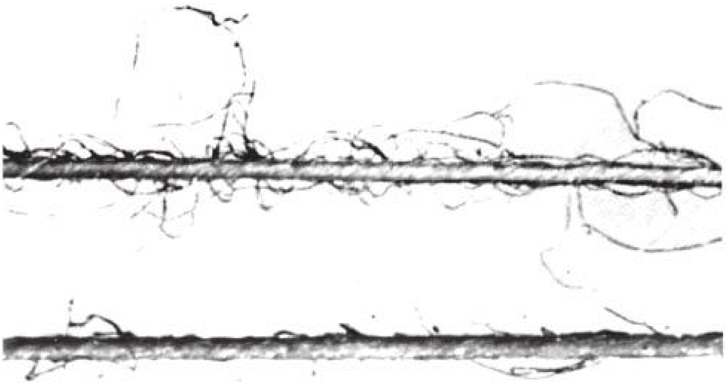

Fig. 9.15 Ring yarns before and after singeing

The process normally produces CO_2 and soot. However, if the ratio of fuel-gas to air is incorrect, the process will produce toxic carbon monoxide rather than CO_2. Therefore, care has to be taken to set the equipment properly.

Careful venting of the workspace is vital because cotton dust is highly flammable. The singeing is carried out in a walled-off space otherwise there could be explosions in the fly-laden atmospheres found in other fiber processing rooms. Other points to consider: soot deposits can ruin otherwise perfectly good yarn packages, heat of combustion needs to be removed, and the health of the workers must be preserved. Singeing of yarns containing meltable fibers, or ones that char (like wool), is not recommended.

9.3.3 Sewing threads

Although the manufacture of sewing threads does not necessarily involve new technology, it does have special requirements for the yarn structure. Sewing threads are often plied to give strength and uniformity to the product; they are often made from cotton, but special threads of linen and silk are also produced. Yarn hairiness has to be controlled to reduce the fly build-ups around the sewing needle area. To give the desired strength and smoothness, cotton threads are often singed and then mercerized. The latter is a process that swells the cotton fibers with caustic soda and stretches them to improve molecular orientation. This, together with the high twists used, makes them rather expensive. One of the reasons for using cotton is that it does not melt. With the ever-increasing speeds of sewing machines, needle melts can be a problem with many of the man-made yarns, especially with certain stitch constructions. Thus, a source of high tensile threads is denied to some garment makers unless special needle cooling arrangements are installed. There are some special man-made fibers, such as Nomex, a heat resistant aramid fiber, but they are costly and this is not a universal solution to the problem. Other solutions include the use of a man-made filament core, sheathed with natural fibers to protect it and to give the desired aesthetics.

In all cases, waxing of the yarns is essential. The wax must be sufficient to give lubrication, even at the elevated local temperatures in the needle eye. However, the quantity must not be so much as to cause clogging of the guides and needle eye.

Problems can also come from differences between the yarn and fabric in the matters of elongation, tension differences, and dyeability. If the thread contracts more than the fabric being joined, the seams pucker. If the dye affinity of the thread differs from the fabric, it becomes visible.

9.3.4 Other plied yarns

Plied yarns are used for purposes other than sewing threads. Plied yarns are not only more even and of enhanced strength, they are durable, flexible, and low twists may be used to give a soft hand. Acrylic and wool yarns are often plied for the hand knitting market; this is because of the soft hand that can be created. Aramid yarns are plied in various complex structures to give strength to ropes and load-bearing strands. Thus, plying is widely used within certain specialty markets, but for run of the mill products the process is too expensive. The improvements in quality of singles yarns over the last half-century have undermined the broad plied yarn market.

9.4 Automation

9.4.1 Patrol theory

Consider the case of manual winding. To optimize the use of a winder, a relationship has to be established between cost and the number of winder spindles to be assigned to a worker. If the assignment is too low, the machine efficiency is high, but the operator is not fully occupied and the operator efficiency is low. If the assignment is too high, spindles stand idle waiting for the operator and the machine efficiency is low. It is necessary to balance the two forms of efficiency so that the overall cost is at a minimum. For simplicity, ignore the cost of doffing the large output package and any waste. Assume that the operator progresses steadily in one direction, and only repairs end-breaks or replaces empty input ring bobbins by full ones as he/she comes to them (the interventions are called ‘events’). Spindles that have been passed have to wait until the next circuit. The theory is similar to that which applies in spinning (see Equation [12.1] in Chapter 12), except that the number of events/hr, *E,* replaces the breaks/hr, *B*, and some terms are neglected. Suffice it to say that the estimated optimum winding assignment, a_{w}, is given approximately by:

$$a_{\mathrm{w}} = \sqrt{\{C_L E/(VtC_{fw})\}} \qquad [9.4]$$

where E = number of events/yd
V = velocity of yarn in yd/hr
C_L = labor cost/hr
C_{fw} = Fixed cost/hr for winding machine
t = average time in hrs to complete one patrol during which time all spindles in the assignment are inspected once (including workbreaks).

The assignment is strongly affected by the pre-existing number of faults in the yarn. The spindle speed V_w, the patrol time *t*, and the cost ratio C_L/C_{fw} play a significant part. The performance of the winding department is strongly affected by the preceding operations. This estimate can be used where the winder transfers yarn from one large bobbin to another but with ring yarns, manual winding is onerous and expensive. It is normal to then use automatic winders.

9.4.2 Automatic winders

With automatic winders, the knotting or splicing function is taken over by a traveling automatic device which searches for the broken ends, makes a join, and then sets the spindle in production again. Operator attention is only required when the robot has failed to make the join after several attempts; a signal light draws attention to such a condition. The robot treats the exhaustion of a feed package in the same way as an end-break, except that, in this case, a new feed package is presented automatically. Various functions are carried out by separate systems that form part of the winding machine. The traveling splicer operates independently of the other functions of the winding machines. It patrols to and fro along a fixed path searching for end-breaks or exhausted supply packages. When there is an exhausted ring tube, another mechanism replenishes the magazine and then leaves it to the knotter or splicer to make the join. There is also a mechanism that detects when the output package needs doffing, substitutes an empty core for the full package, and restarts winding on the new core.

Consider the supply system. Several bobbins of yarn should be available to each spindle. When there is a need for a fresh supply, the machine will discharge the empty bobbin and bring a fresh bobbin into place. It will then find the end and join it to the end from the delivery package before continuing to wind. It will do this without assistance from the operator except when the machine malfunctions. This enables the operator to distribute his or her work amongst several machines; it is only necessary to ensure that the turret or magazine has a sufficient supply of bobbins. In modern machines, this too has been automated. A hopper of ring bobbins supplies them to an automatic device, which aligns them, rejects bad ones, and carries the aligned bobbins to the individual spindle magazines.

Suction arms move to the surface of the supply and/or uptake packages to find the ends lying on the surfaces of the packages when the operation has to be restarted. A restart is needed when a new supply package is introduced, an output package is doffed, or an end-break is detected. These ends are inhaled into the suction arms for the limited duration of the transfer. During this time, yarn is consumed, but it is under a controlled tension that makes the laying of the yarn into the piecer manageable. The suction arms move to position the yarn as is shown in Fig. 9.11(a), so that the splicing can continue. After the splice is made, the machine restarts automatically. If there is a failure to splice, the machine attempts to splice again. However, if the number of retries is beyond the pre-set limit, a warning light appears to notify the operators that the particular winding head requires attention. The frequency of appearance of warning lights is often used as a crude measure of the quality of the yarn leaving the ring spinning machine. The operator has a trouble-shooting function rather than that of a server; the operator assignment is different from that for manual winding. Similar factors operate in determining the assignments but the coefficients differ.

The capital costs of the knotter or splicer relative to the rest of the machine should, in theory, determine the assignment of the robot. The mathematics of optimum operator assignments applies (see Chapter 12); the theory indicates the importance of keeping the yarn joining frequency within the economic limits of the machines. This implies that the CV of the yarn and the defect levels should be carefully controlled so that they do not exceed the design level (which is relatively low). The defect level of the input yarn directly affects the number of joins per package, as well as the value of the yarn. The number of joins should be at a minimum. Generally, a poor performance in winding is a sign to expect poor spinning and future problems in fabric manufacture. Many problems arise in the early processes, and clearing acts as a sort of filter to buffer the impact of these early problems, but does so at a price. Clearing does not completely remove all effects of the faults produced in the early stages; the process of clearing is carried out at the expense of winding efficiency. Whilst it might be better to clear yarn and accept the low winder efficiencies than vice versa, it is better still to spin good yarn in the first place.

9.4.3 Linking

Recent practice was for spinning bobbins to be gathered in tubs as they came from the autodoffer. Tubs full of bobbins were placed randomly in the hopper of the winding machine, which sorted the acceptable bobbins from the rest. The accepted ones were then passed to the winding heads for the winding process. In the process, the bobbins suffered considerable jostling. There is a trend nowadays to connect a dedicated winder to a ring spinning machine. This has advantages and disadvantages. The bobbins pass smoothly from the autodoffer to the winding head without being subjected to jostling and possible damage. The transfer is automatic and saves labor costs. It is also possible to keep track of the source of faulty bobbins, which is of great value in quality control if appropriate records are kept and used. However, the productivity of the ring frame is highly dependent on count and the winder is less so; thus, there is a balance point between ring frame and winder at which the productivities match. Departure from that balance gives an excess of winding heads or a lack of them. The latter cannot be contemplated; the result is that a mill usually has excess winding heads. Some machines are made so that the heads can be moved from one linked system to another to ease this problem.

9.5 Two-for-one twisting

To make ply yarns, it is necessary to twist two or more singles yarns together. Following the assembly winding stage, paired yarns are often twisted using two-for-one twisters. (There are still ring twisters in use, but they are expensive to run.) The principle is shown in Fig. 9.16(a). Some yarn makers use two-for-one twisting without assembly winding, where two packages are mounted inside the balloon (Fig. 9.16(c)). However, the process is not as efficient as assembly winding because more space is used up inside the balloon envelope and the winding continues less smoothly. Figures 9.16(a) and (b) show two methods of controlling the yarn balloon, which surrounds the yarn package(s). In one case, a circular balloon rail is used and in the other, a cylindrical pot. This is analogous to the conventional balloon control ring in a ring frame. It may be compared to the control pot shown earlier in Fig. 9.10. The yarn is protected by smooth metal pots in order to facilitate start-up, to separate the yarns, and to protect the feed yarn from the ever present fly. Plastics tend to become damaged in use and stainless steel has been found to be satisfactory. To conserve valuable space inside the balloon, it is preferable to use precision wound packages because the package density can be raised by about 25% when compared with normal cross-wound packages. However, this is not always feasible, especially if the cheaper rotor spun yarn is used as a feed. Rotor spun yarn is frequently used because the packages from the spinning machine need no winding before two-for-one twisting. Sometimes, for very fine yarns, up-twisting (see Section 3.3.4) can be used instead, because the

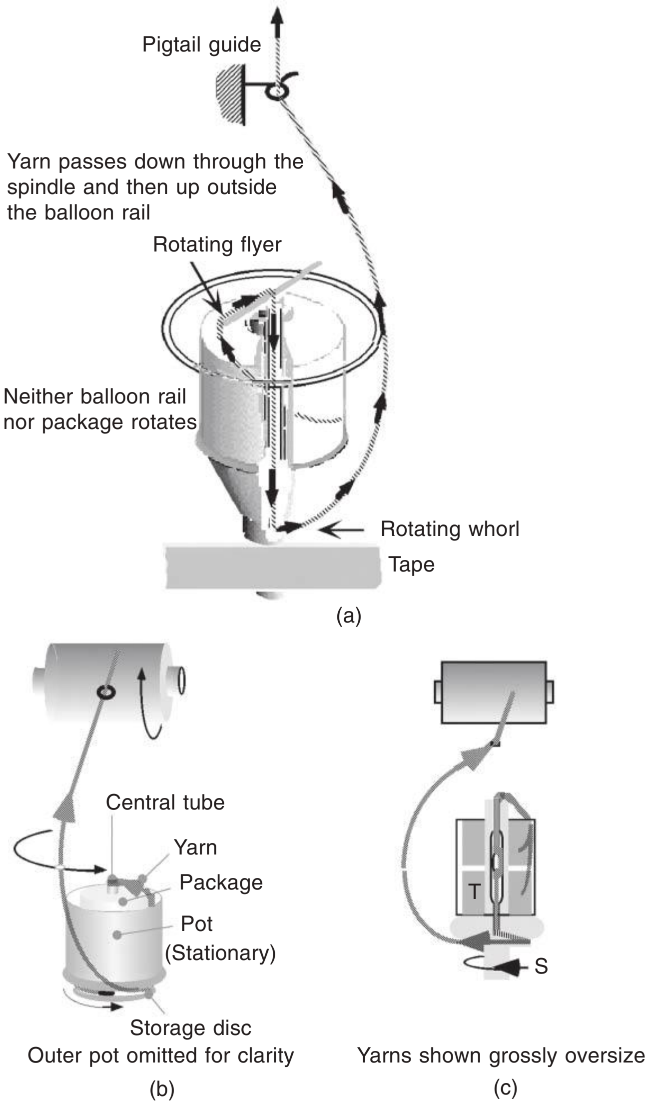

Fig. 9.16 Several forms of two-for-one twisting

damage to the surface layers of the yarn is less. The increase in cost is a reasonably small percentage of an already expensive yarn.

The package(s) inside the balloon in a two-for-one twister is/are usually held in place with magnets, which act on armatures in the yarn package center. This enables a vertical spindle arrangement to be used which conserves space. Any rotating member in the magnetic field has to be non-conducting, otherwise there is an energy loss and some local heating. Yarn tension is controlled by a choice of various spring-loaded and ball-type devices, mounted in the central hollow shaft of the winder through which the yarn travels. The use of various pots not only protects and separates the yarns, but provides some protection against balloon collapse. Tensions in this type of twisting do not vary greatly when everything is properly adjusted. All surfaces in contact with the yarn need to be polished and to have an immunity to wear and ill use.

It is normal to have a storage disk S under the rotating throw-off plate and a yarn tensioner T as shown in Fig. 9.16(c). The angle of wrap on the storage surface plays an important role in determining the tension. If the tension leaving the tensioner in the hollow spindle becomes too low, the balloon becomes unstable. In that case, the rate of wrapping the storage disk (Fig. 9.16(b) and (c)) increases, with the result that the tension in the balloon rises due to the increased capstan effect. Conversely, too high a tension has the opposite effect. The maximum yarn tension is at the balloon node because the energy for yarn movement along its axis comes from the winder. (This differs from the balloon in a ring machine where the energy for yarn translational movement comes from the bottom of the balloon.) The winding portion of the machine must be controlled (a) to preserve constancy of the twist level, (b) to be independent of variations in tension arising from the twisting unit, and (c) to produce a package structure suitable for the end use. In other words, it must be possible to unwind the yarn at speed and give a product as nearly uniform as possible in all respects. This requires a good tension controller and lay mechanism to produce the necessary structure.

Twisting machines are often used for waxing and this is usually done to meet the needs of the knitter, although the wax can help in the winding process also. Passage over guides and machine surfaces tears out fibers from the surface, especially when frictional forces are high. Waxing and plying are both methods of limiting that increase in hairiness and in wild fibers. Damage created in twisting also results in the generation of fly and dust, which brings other quality control problems. The use of correct speeds and judicious amounts of lubricant limit the problem.

9.6 Customer concerns

9.6.1 Yarn contraction

When a strand such as a yarn is twisted, it tries to become shorter. If the yarn were allowed to move freely, no tension would be generated and the yarn would become shorter due to the twist; this is known as ‘twist contraction’. A typical value for twist contraction for a typical 30s cotton ring spun yarn is about 4%. Contraction of twisted yarn after it is wound on a package generates tension, which causes the package to become more tightly packed. Absorption of moisture causes contraction in hydrophilic yarns because the fibers swell and need more room. Thus, changes in moisture content of such packages cause variations in package density, and sometimes make it difficult for the customer to unwind the package as was discussed in Section 9.2.1. The effect is greater with highly twisted yarns. Yarn is sometimes conditioned by steaming to adjust the package weight to standard conditions if it is too dry to meet the agreed specifications. Over-conditioning can make the yarns absorb too much moisture. Not only does over-conditioning affect the weight of the yarn packages, it affects the tightness of the package to the point where it creates the difficulties for the customer in unwinding as already discussed.

9.6.2 Winding and yarn dyeing

Dyeing of yarn is often carried out in an autoclave similar to that described elsewhere. Dye is forced through the package under pressure and the whole autoclave is held at a sufficiently high pressure to gain the necessary dyeing temperature. An autoclave is an expensive piece of equipment in which the yarn packages have to be closely packed to fill the working volume of the steam chamber. (An autoclave is briefly described in footnote 1 in Chapter 4) Usually a series of cheeses or cones is mounted on a mandrel and several of these loaded mandrels are inserted into the autoclave, with their axes parallel to one another. The mandrels are usually part of the autoclave itself because the dye solution travels through the perforated hollow centers on its way to or from the dye packages. Frequently the direction in which the dye is pumped is alternated; inside to outside, outside to inside, and so on. As might be deduced, the dye pressure depends on the steam pressure in the autoclave, as well as on the density of the packages. Low density packages tend to have larger passageways through them than more dense ones. Thus, the package structure affects the dye pressure needed. The yarn package transport system for these products should be designed with the capacity and arrangement of the autoclave in mind.

9.6.3 Preservation of yarn tails on packages

Cones and cheeses are usually made with yarn tails from the inner and outer layers of the package secured at some agreed upon position on the package centers. The purpose of this is to enable the head of one package to be tied to the tail of another. Thus, when the first is exhausted, yarn is automatically taken from the next, and so on. Packages of this sort are frequently used in creels of machines in which many short chains of packages supply whatever equipment the customer is operating. Within these chains, the packages are tied head to tail. This permits the labor of tying the ends to be deferred by the operator because the packages actually supplying the machine act as reservoirs; it makes possible the continuous operation of the yarn using machine. It is commercially important that the tails always are present in the form specified by the user. Winding machines need careful adjustment to produce the desired tails reliably. Even if the packages are used in-house, the receiving department should be treated as a customer.

9.6.4 Shipping

It might seem so obvious that it needs no statement, and yet mills lose thousands of dollars by errors in shipping. In business, there is a time and efficiency factor in the goodwill generated. If the goods do not arrive on time, no matter that they are perfectly satisfactory and reasonably priced, the shipments might be returned. This brings in no revenue to the spinner and only produces extra costs that have to be subtracted from any profit. If the goods are shipped to the wrong place, or the wrong items are shipped, the effects are equally disastrous. It is imperative that the shipping operation be efficient and effective.

The relatively new idea of just-in-time (JIT) shipping is one where incremental orders are transmitted electronically, from user to supplier, as required; the supplier ships goods in timely quantities to keep the user's operation going without large inventories. Inventories would otherwise consume working capital and JIT reduces interest charges and fees. However, there is a downside to the scheme. A sales system has inertia; some of it is due to the inventory stored in various parts of the supply line. JIT seeks to reduce this cushion of stock; but in times of sudden demand, the lack of a cushion can make severe demands on the primary producer, both in the shipping and the production departments. Rather than lose business, many primary producers keep an inventory to meet the need, but it involves risk and cost. The cost tends to be passed down the line because, if one business fails for these reasons, competition is reduced and prices tend to rise.

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