CHAPTER NINE

Spinning

The majority of jute yarns are spun from finisher drawing sliver and spinning from rove is confined chiefly to the finer counts of yarn (173 tex, 5 lb/sp or less). The advantage of using crimped sliver is an economic one, for the cans of finisher drawing sliver hold sufficient material for 25–30 hr spinning compared with about 5 hr supply on a bobbin of rove. As a result of this increased package size, less labour is required for material handling. The move towards sliver spinning has been accompanied by the use of longer drafts at the spinning frame with the accompanying reduction in the number of deliveries required to supply the spinning frames.

The essential features of the spinning process are drafting, twisting, and winding-on. Spinning frames are made in several different sizes, designated by the distance between adjacent spindles, i.e. the pitch. Only a small part of the entire count range is produced on a given pitch of frame but, no matter what the size of the frame, the mechanisms for twisting and winding-on function in the same manner although some differences exist in the methods adopted for controlling fibre motion during drafting.

DRAFTING

All jute spinning frames have two sets of rollers extending along the whole length of the machine—the retaining rollers and the drawing rollers. Each of these sets consist of a positively driven member and a pressing member, between which the fibres are gripped. The draft operates in the usual way by attenuating the material and reducing its count.

The different types of spinning frames can be classified according to their method of draft control.

(1) Breast plate.
(2) Breast plate and intermediate rollers.
(3) Apron and intermediate roller.
(4) Double apron.

(5) Grooved intermediate rollers.
(6) Gill-pins.

The first type is confined to rove-spinning and the remainder to sliver spinning. The drafting mechanisms of the various types are illustrated in Figure 9.1.

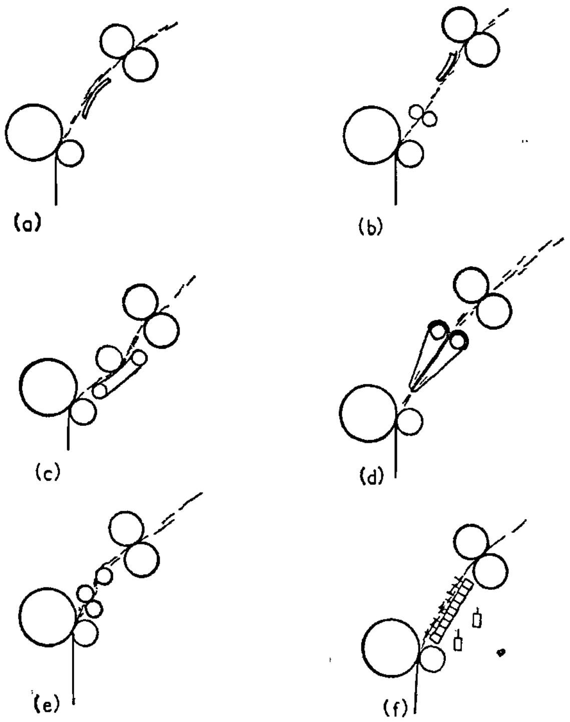


Figure 9.1. Methods of fibre control on jute spinning frames

(1) *Breast plate* (*Figure 9.1*(*a*))

The reach of the frame is, as usual, slightly longer than the length of the longest fibres in the material. Situated between the retaining and drawing rollers is a smooth metal plate called the breast plate. This plate projects forward slightly from the line joining the nips of the two sets of rollers in order that it may play its proper part in the control of short fibre movement. The twist in the roving, it will be recalled, is of such a magnitude that some degree of cohesion is imparted to the strand but at the same time inter-fibre movement is not impeded. When the rove passes down the breast plate towards the drafting nip its leading fibres are caught between the drafting and pressing rollers and pulled from the rove. This has the effect of reducing the count of the rove and, in so doing, the twist angle becomes progressively less and less in relation to the rove count, e.g. the rove may enter the drafting field weighing 84 lb/sp and having 0·75 t.p.i. but by the time a few fibres have been drafted from it the count may only be 50 lb/sp, reducing the twist factor from 6·9 to 5·3. Consequently the inward-directed forces arising from the twist are less. Under these circumstances less restraint is applied to the fibres and hence some degree of draft control is lost. The function of the breast plate is to determine where the rove will begin drafting. This it does by virtue of its position. Because of drafting a slight tension develops in the rove which presses the material more firmly on to the plate. The tension below the plate is greater than that on or above the plate and since inter-fibre movement occurs at the point subjected to the greatest tension, it is here that drafting takes place. By altering the position of the plate relative to both sets of rollers the tension in the rove can be increased or decreased; an increase restricting drafting until just before the drawing nip, a decrease allowing earlier drafting. The draft control from the combination of breast plate position and rove twist is not of a high order and the setting of the plate does not appear to be critical. It is customary to site it in such a manner that the rove is just beginning to untwist as it approaches the foot of the plate.

Immediately beneath the breast plate there is a small conductor for leading the fibres right into the drafting nip. It, too, can be adjusted inwards and outwards.

(2) *Breast plate and intermediate rollers*

This is one of the commonest methods adopted for draft control in jute spinning at the present time. The frame is designed for use with crimped finisher drawing sliver and is illustrated in Figure 9.1(b). In many ways, its design and operation are similar to those of the type just described for rove spinning with the exception, of course, that the material enters the drafting field without any twist in it. The breast plate in this case is a small semicircular plate, concave outwards, which can be swung on its own axis and moved bodily inwards or outwards. The sliver passes down behind the plate and then enters a short channel at the foot of which there is a pair of intermediate rollers, the lower one being positively driven and the upper deriving its motion from the lower of the pair. Both rollers are deeply fluted, the upper having a groove cut in its surface to allow the sliver to pass through. The upper roller is self-weighted and as the sliver passes underneath a gentle restraining force is applied, insufficient to stop drafting but great enough to prevent much premature drafting of the short fibres. After leaving this pair of rollers the sliver enters a small conductor and then passes directly into the drafting nip. On this type of frame the siting of the various members sets up a tension in the sliver when it is being drafted; a tension which causes the material to bear more heavily on the breast plate and consequently increases its resistance to short fibre movement. Thus drafting, with the exception of a small amount of long fibre movement, does not take place until the sliver is between the nip of the intermediate rollers.

(3) *Apron and intermediate roller*

In this type of draft control, Figure 9.1(c), the breast plate has been discarded in favour of an endless rubber apron. The fibres leave the nip of the retaining rollers and then pass on to the surface of a rubber apron. As they move down this, they meet an intermediate roller which is pressing gently into the apron—this helps to stop uncontrolled fibre movement. Below the apron is the usual conductor just before the drafting nip.

(4) *Double apron (Figure 9.1 (d))*

This type is a more recent development of the one just described, in which the intermediate roller has been replaced by a second rubber apron. The sliver passes down between the aprons and the fibres are gripped continuously. The lower apron is driven by a grooved wheel at its upper end, and its lower end is made to turn sharply round a small adjustable plate. The upper apron is driven by contact with the lower and similarly passes round a small plate at its lower end. In this way both aprons can be brought very close to the drawing nip and a positive grip maintained on the short fibres as late as possible.

(5) *Grooved intermediate rollers*

This type of control, Figure 9.1(e), is confined to some large pitch frames used for heavy yarns. The sliver passes down over a series of smooth-surfaced intermediate rollers, each of which has a deep groove cut in its face. The siting of the lower rollers can be adjusted to give a greater or lesser tension in the sliver. In the same manner as type (2), the upper members of the intermediate pairs are self-weighted.

(6) *Gill-pins*

The gill-spinning frame is very similar to the spiral gill-drawing frames described earlier, with the difference that the faller bed is inclined at approximately 45 degrees. To suit the nature of the material at this stage in the process the gill-pins are fine and densely set. The spirals are usually $\frac{1}{4}$ in. pitch and triple screw. This type of frame is limited in its speed capabilities by the faller drops per minute just as the drawing frames are, about 500 per minute being considered the maximum. However with the speed limitations imposed by the flyer design and the quality of the yarn (discussed later) it is seldom that the frame works at the maximum faller-bar speed.

These, then, are the types of draft control found on jute spinning frames. As the variation in the count of short lengths of yarn (the 'thicks and thins') is largely decided by the regularity of the finisher drawing sliver and the manner in which the spinning draft is applied, it is desirable that the draft control mechanism should operate as efficiently as possible. Spinning draft is changed by means of a change pinion and, in the usual manner for jute machinery, when the draft is altered it is the feed speed which changes, the delivery speed remaining constant. Indeed, on the spinning frame this is essential, for any change in the front roller speed causes a change in the twist in the yarn. It is at the spinning frame that draft changes are made to produce yarns to suit sales requirements and therefore it is essential that the correct draft be selected. The draft imposed upon the material must be such that the yarn is spun to the correct count; for this reason a careful assessment must be made of two factors which affect yarn count. These are moisture regain and twist take-up.

Finisher drawing sliver usually has a moisture regain of about 26 per cent and from this material a yarn must be spun which will have the correct count when it is dispatched. During spinning some 25 per cent of the sliver moisture will be evaporated and during the subsequent processes of winding and in storage a further 15–25 per cent will be lost. The yarn must be taken off the frame at a count slightly above the required level to allow for these post-spinning moisture losses. For this reason the draft must be *reduced* by a certain amount. The exact amount of the decrease depends upon the moisture level before, during, and after spinning, but it is customary to arrange for the yarn to have the correct count at 14 per cent moisture regain.

Twist take-up will be dealt with more fully later, suffice it at this stage to say that take-up increases the yarn count and therefore the draft must be *increased* to allow for this. The amount of take-up depends on the degree of twist but for normal twist factors it is between 2 and $2\frac{1}{2}$ per cent.

The method of calculating the required spinning draft is as follows

$$\frac{S}{Y} \times \frac{100+R_y+O}{100+R_s+O} \times \frac{100+T}{100} = D$$

where S is the sliver count, Y the yarn count at R_y per cent regain, R_y the yarn regain at which the yarn will be of the correct count (per cent), R_s the finisher drawing sliver regain (per cent), O the oil content (per cent) (on dry fibre basis), T the twist take-up (per cent), D the spinning draft.

For example, 150 lb/sp finisher drawing sliver, with a regain of 25 per cent is to be spun into 8 lb/sp yarn which will have the correct count at 14 per cent regain. The twist take-up is 2 per cent, and the oil content is 6 per cent. What spinning draft is required? What will the yarn count at the frame be if the regain of newly spun yarn is 19 per cent?

Spinning draft

$$\frac{150}{8} \times \frac{120}{131} \times \frac{102}{100} = 17{\cdot}5$$

Count at 19 per cent regain

$$\frac{150}{17{\cdot}5} \times \frac{125}{131} \times \frac{102}{100} = 8{\cdot}34 \text{ lb/sp}$$

It is customary to check the count of the yarn at the spinning frames as this is the last point where corrective action can be taken if required. Testing is done by taking hanks off a number of bobbins and weighing. For jute yarn testing, the standard reel for winding test-hanks is 90 in. in circumference, 40 turns of the reel making 100 yd. It sometimes happens that over a period of time the count drifts up or down, but unless one is sure that this drift is genuinely due to a change in the *fibre* content of the yarn, no draft pinion change should be made. If, as may happen, such a drift is due to moisture regain changes then a draft change would lead to the wrong count of yarn being spun For this reason the moisture regain should always be checked when a count test is made; more will be said about this in a later chapter, but an example may help to show how this occurs.

Suppose that the yarn in the previous example is being spun, but because of an unusually low relative humidity in the spinning department, the yarn regain falls to 16 per cent at the spinning frame.

New count at frame

$$\frac{150}{17{\cdot}5}\times\frac{122}{131}\times\frac{102}{100} = 8{\cdot}14 \text{ lb/sp}$$

If the draft pinion in use was a 36 tooth, then in order to bring the yarn back on count a pinion change might be made.

New pinion required

$$\frac{8{\cdot}14}{8{\cdot}34}\times 36 = 35 \text{ tooth}$$

The new draft with a 35 tooth pinion would be

$$17{\cdot}5\times\frac{35}{36} = 17{\cdot}0$$

The new yarn count at 14 per cent regain would now be

$$\frac{150}{17{\cdot}0}\times\frac{120}{131}\times\frac{102}{100} = 8{\cdot}24 \text{ lb/sp}$$

Clearly, in this example the yarn count has been made 'off standard' because of a wrong decision. A draft change was made because of an alteration in the yarn moisture.

TWISTING

Jute spinning frames insert the twist by means of overhung flyers suspended above the bobbins. There is no positive drive to the bobbins as there is on the roving frame and the bobbins are made to rotate by the yarn pulling them round. Figure 9.2 shows the twisting arrangement adopted. The flyers are carried on ball-bearing wharves mounted on the front of the frame at about waist-height. The part of the wharf projecting above the mounting assembly is called the 'cap' and plays an important part in the actual operation of the frame, as will be seen later. The wharf is driven by a cotton or nylon tape from the main cylinder of the machine, that part where the tape runs being crowned

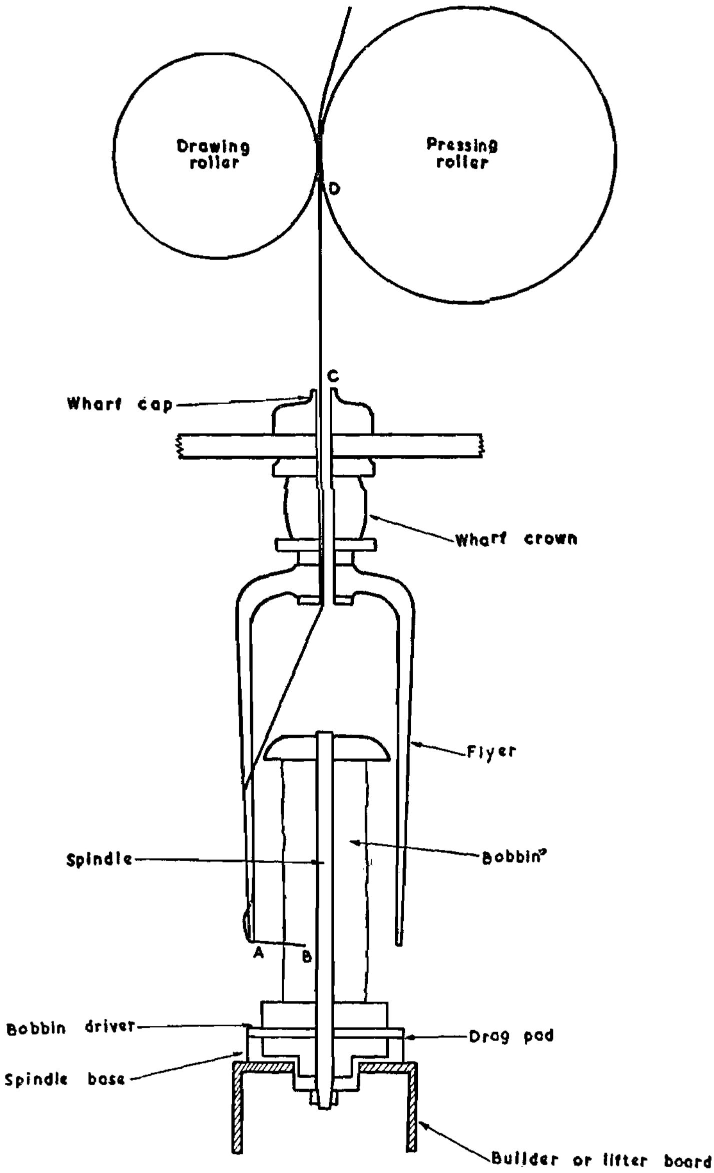


Figure 9.2. Twisting and winding-on section of a jute spinning frame

so that the tape does not give an erratic drive by wandering up and down the bearing surface.

The yarn passes down from the drafting nip to the top of the wharf cap where it enters a central hole and continues down through the wharf. At the exit of the hole a ceramic disk is cemented to protect the metal from the abrasive action of the yarn. The flyer legs are screwed on to the wharf so that they may be replaced if necessary. The legs themselves are tapered towards their tips to reduce centrifugal 'throw-out'. The flyer legs have a small 'eye' at the foot through which the yarn passes on to the bobbin. As the flyers are designed to run at high speeds they must be dynamically balanced otherwise any eccentricity would ultimately damage the whole assembly and could cause a serious accident.

The simplest relationship between flyer speed, delivery speed, and twist is

$$t = \frac{n}{v}$$

where t is the turns of twist per unit length, n the flyer speed, and v the delivery speed. This equation, however, must be modified in the light of twist take-up. If a ribbon of untwisted fibres is rotated about its own axis and twist inserted then it inevitably becomes shorter as the fibres assume a spiral formation. The amount by which the structure reduces in length is known as the 'take-up' and is expressed as a percentage. Thus

$$\frac{\text{untwisted length} - \text{twisted length} \times 100}{\text{untwisted length}}$$

The exact amount of take-up depends upon the twist angle in the yarn; the greater this angle the more take-up there is. Figure 9.3

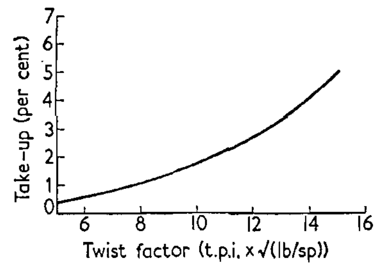


Figure 9.3. Effect of twist factor on twist take-up

shows the relationship between twist angle, as expressed by the twist factor, and take-up for jute yarns. It will be seen that for the common range of twist factors the take-up is of the order of 2 or $2\frac{1}{2}$ per cent. Just as the count is increased by take-up so the twist in the yarn is increased by take-up and therefore the equation above should be altered to

$$t = \frac{n\,(100+T)}{100\,v}$$

where t, n, and v have the same meanings as previously and T is the percentage take-up.

Even using this equation does not, however, give the full picture of yarn twist. If a yarn is examined closely it will be found that the number of turns of twist varies from point to point along the length. This arises chiefly from the fact that the yarn mass itself fluctuates from point to point. Yarn twist is inserted by rotating the lower end of the yarn about the upper end and the twist actually ascends from below into the upper portions of the yarn and in this way runs up towards the drawing nip. The twist is transmitted by the lower fibres taking up a spiral formation and forcing those above them to conform to the same configuration. The fewer and less rigid the fibres the easier is it for the lower ones to force the upper ones to take up the same twist angle as themselves. Notice again that it is the twist angle which is the same along the length of the yarn. Because the twist angle is constant (or in more practical terms, the twist factor is constant) those parts of the yarn that are thin have more turns per unit length than those that are thick.

Common twist factors in use are shown in Table 9.1.

TABLE 9.1

	lb/sp and turns/in.	*tex and turns/cm*
Sacking weft	10·0	23·0
Hessian weft	10·5	24·3
Hessian warp	11·5	26·2
Carpet yarns	12·5	29·0
Sacking warp	13·0	30·2

WINDING-ON

As the action of the builder is the simpler of the two winding motions it will be dealt with first. The bobbins rotate around central dead spindles which are set vertically in the builder. As the builder moves up and down the bobbins alternately rise into and withdraw from the flyers and this reciprocating movement, combined with the rotation of the flyers about the bobbins, winds the yarn on the bobbin in a continuous spiral. Notice that when the builder is at the top of its traverse the yarn is winding on at the bottom of the bobbin and *vice versa*.

The builder is suspended on short lengths of chain which are attached to pulleys keyed to a shaft running along the whole length of the frame. Brackets from the builder carry sleeves which run up and down on columns to give steadiness and stability to the motion. The traversing movement is obtained from a lever at one end of the frame which is made to rise and fall by a heart cam underneath it. Figure 9.4 illustrates the principal parts of the builder motion. The length of the traverse depends on the throw of the cam, the length of the lever following the cam, and the diameters of the pulleys marked A and B in the Figure. There are turnbuckles in the linkage connecting the lever arm to the pulley shaft so that the position of the builder

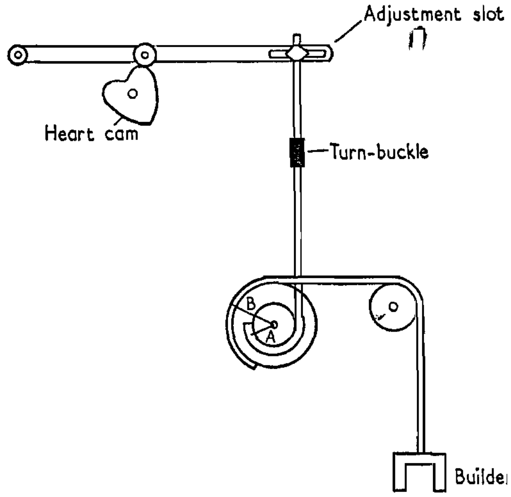


Figure 9.4. Spinning frame builder motion

relative to the flyers and bobbins can be adjusted. The builder should change direction just at that moment when the yarn is winding on at the flange of the bobbin. If the builder is too high or too low in relation to the bobbins then the yarn will be built up unevenly on the

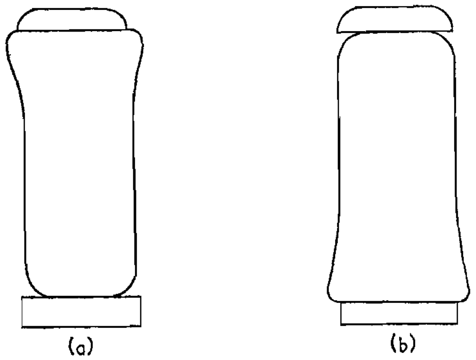


Figure 9.5. Bad bobbin building due to faulty positioning of the builder: (a) *Builder too low;* (b) *builder too high*

bobbin. Figure 9.5 shows the shape of the bobbin when the builder is not adjusted properly. Bobbin building like this is undesirable as it affects the spinning tension adversely, as will be seen later.

In Chapter 8 it was shown that in order to achieve correct winding-on the following equation had to be fulfilled

$$(n-b)\,\pi d = v$$

where n is the flyer r.p.m., b the bobbin r.p.m., d the bobbin diameter, and v the delivery speed. The implication of this relationship is that as the bobbin fills, its revolution rate must increase in order that $\pi(n-b)$ will decrease as d becomes greater. On the roving frame the bobbins were driven through direct gearing at a speed which was varied by the cones and differential. But as the bobbins on a spinning frame are not driven how is this increase in bobbin revolution rate attained? In fact, it is attained automatically by the bobbins themselves as a result of the manner in which they are rotated by the yarn. Figure 9.2 shows how the bobbin rests on a metal carrier which is mounted on a 'dead' spindle on the builder. The upper part of the carrier is a hollow sleeve, which is a loose fit on the dead spindle, and the lower part a flange just slightly larger than the bobbin base. Two small pegs project from the flange of the carrier and when the bobbin is slipped on to the carrier these pegs fit into recesses cut into the underside of the bobbin base. By means of these pegs there is a loose but positive drive between the carrier and the bobbin and they rotate as a pair about the central dead spindle.

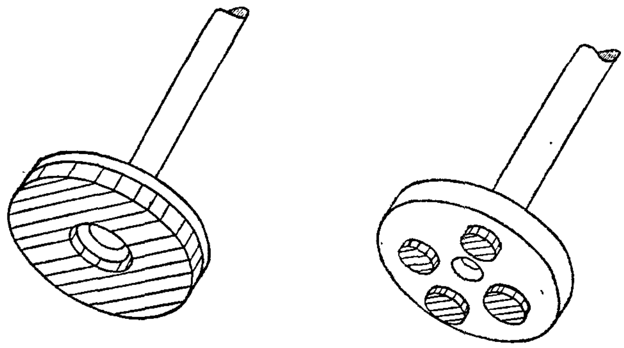


Figure 9.6. Bobbin carrier friction pads

Figure 9.6 shows the underside of two bobbin carriers. One has a complete ring of felt attached to it (shaded in the Figure) and the other has four small felt pads instead of the ring. Whether the solid ring or the pads are used the principle of operation is the same. When the carrier is in position on the builder the felt pads bear against a smooth plate encircling the dead spindle and when the carrier is rotated these felts set up a drag by virtue of the friction between them and the bearing plate on the builder. During the spin it is the yarn which pulls the bobbin and the carrier round and two equal opposite forces act— a tension in the yarn pulling the bobbin round and a drag tending to prevent the bobbin moving. Because of their function these felt pads are known as 'drag-pads'. These contra-acting forces are turning-forces or torques and their magnitude is found from the product of the force and its moment about the central point. For instance if the bobbin radius at some instant during the spin is 1·25 in. and the tension in the yarn turning the bobbin round is 0·9 lb, then the torque that is rotating the bobbin is

$$1{\cdot}25 \times 0{\cdot}9 = 1{\cdot}125 \text{ in.lb}$$

Similarly, if the frictional force of the drag-pads is assumed to be concentrated at the mid-point of the pads at a distance r from the centre of rotation and have a magnitude p, the torque opposing motion is rp.

While the bobbin is rotating, these two torques are equal. Hence,

$$rp = RT$$

where r and p have the meaning given above, R is the radius of the bobbin, and T is the tension in the yarn between the eye of the flyer and the surface of the bobbin.

In order that the bobbin keep rotating, energy must be supplied to the system. This energy comes from the flyer, but of course is ultimately derived from the frame motor. As the bobbin fills up, more energy is required to turn it since it not only is becoming heavier but is also rotating at a higher speed. The torque RT steadily increases throughout the spin but as the bobbin radius increases at a much

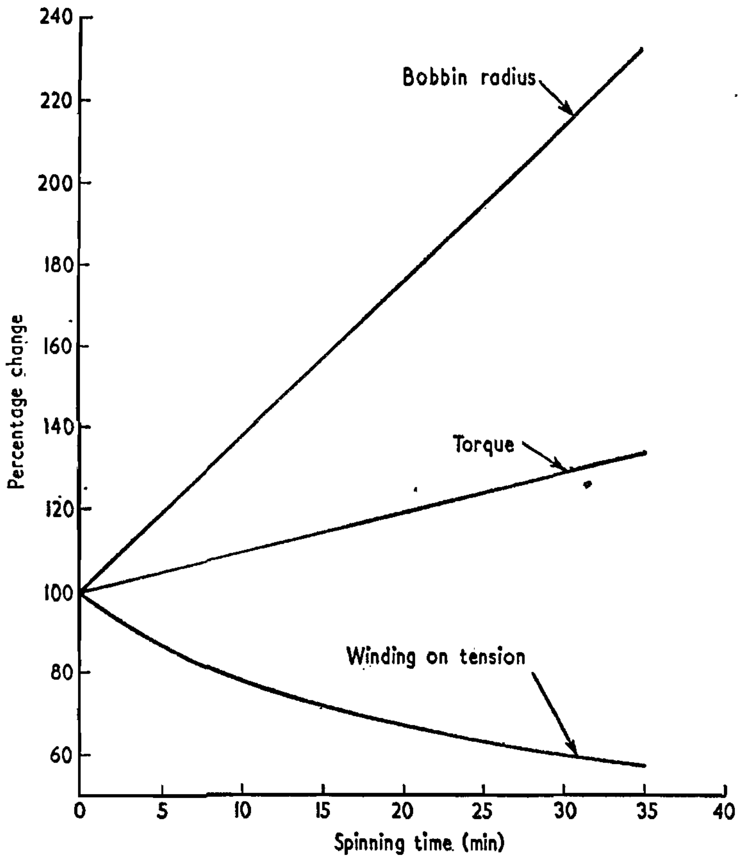


Figure 9.7. Changes in torque and tension during spinning

faster rate than does the torque, the yarn tension, T, becomes smaller as the bobbin builds. Figure 9.7 shows this effect; for convenience each of the variables has been expressed as a percentage, the starting values being taken as 100 per cent in all cases. It will be seen that although the torque required to keep the bobbin turning grows steadily, the yarn tension falls throughout the spin, always remembering that

$$\text{tension} = \frac{\text{torque}}{\text{radius}}$$

It was said above that before the bobbin will rotate continuously, energy must be supplied and that this was done through the flyer pulling the yarn round. If therefore the yarn breaks, then this supply of energy is immediately lost and the frictional torque of the drag-pads brings the carrier and the bobbin to a halt. The yarn will break if the tension in it is greater than the strength of the weakest point. Yarns break frequently, therefore, if either the yarn strength is low or the tension is high. Yarn strength is very largely a matter of the grade of fibre being used and so to avoid an excessive number of spinning breaks the tension should be as low as practicable. Spinning tension, like so many other factors in jute processing, is a balance between two extremes. The upper level of tension is determined by the ability of the yarn to spin successfully; if this level is exceeded then a large number of breaks will occur, obviously this level is related closely to yarn count and strength. The lower level is set by the phenomenon known as 'ballooning'. Ballooning occurs when the tension in the yarn is insufficient to hold it against the flyer leg and the centrifugal force of rotation throws the yarn off the leg in a wide balloon. When this happens the yarn strikes the adjacent flyer and breaks. Since the heavier the yarn the more tendency there is to ballooning, it is necessary to apply greater tension to keep the yarn on the flyer leg; fortunately the heavier yarns can withstand the greater axial tension that is required. On the four-pad type of carrier the pads are put in the outer position when heavy yarns are being spun for this very reason. On the other hand, when a light count is being produced they are placed in their inner position, so that the frictional torque is at its lowest value.

Frictional torque at the drag-pads depends upon such factors as the weight of the assembly, the clearance between the carrier sleeve and the spindle, etc., which are set by the machinery designer and, as such, are outside the control of the user. There are, however, two important features that the user can control—the amount of friction between the pads and the builder bearer plate, and the effective friction radius.

The friction radius can be taken, without serious error, as half-way between the inner and outer edges of the pad and, as in a simple lever, the greater this distance is from the centre of rotation the greater will be the frictional torque and, consequently, the higher the yarn tension. On the full-pad type the friction radius can be altered only by reducing the radius of the pad in contact with the builder; two methods are available for this. Firstly, a smaller drag-pad may be put on or, secondly, a smaller builder bearer plate may be substituted. This latter method is used by one machinery maker for varying the tension to suit the count of yarn being spun or, alternatively, to alter the tension while the frame is in motion, see Figure 9.8. The bearer plate is

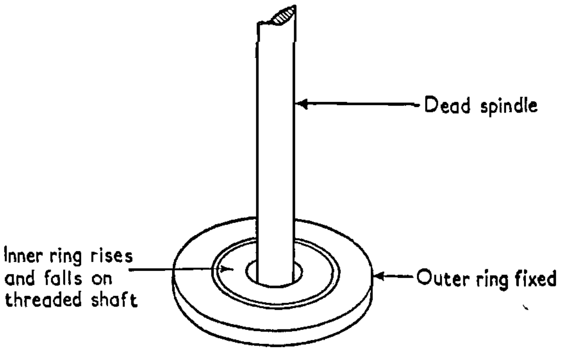


Figure 9.8. Two-position builder friction plate

made in two concentric parts, the inner one of which is mounted on a short threaded spindle. By means of a handle attached to the spindle and projecting from the front of the builder, the central ring may be raised or lowered at will. When it is raised it is just above the level of the outer ring and the felt drag-pad bears only on the inner ring. Consequently, the friction radius is small and the spinning tension low. When the inner ring is lowered the friction radius is greater and the frictional torque is increased. This method of operation allows the frictional torque to be varied throughout a spin and the system is used in an attempt to keep the spinning tension fairly level during the spin. It will be recalled that with a fixed frictional radius spinning tension was highest at the start of each new bobbin and fell gradually throughout the spin; if this two-ring system is used then it is possible to work with a lower frictional torque (and spinning tension) at the start of each bobbin, and as the bobbin diameter grows, the frictional torque can be increased by lowering the inner ring.

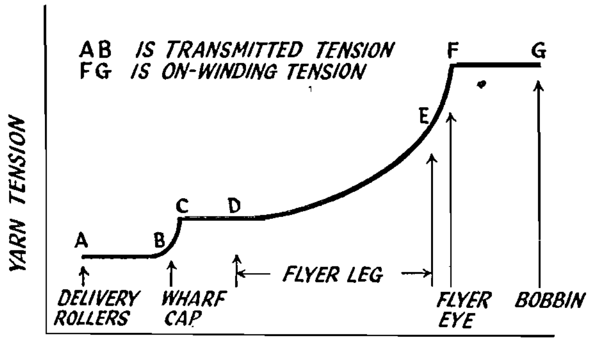
The four-pad type gives another method by which the frictional radius can be altered. It should be noted, however, that this cannot be done during the spin but only when the bobbins are not in use. Each small pad is mounted upon a short spring arm which can be put into one of three positions—inner, middle, or outer. When the pads are in their innermost position the frictional radius is small and consequently the spinning tension is low; when the pads are at the outer position, spinning tension is high. To suit the requirements of the yarn as far as ballooning and axial tension are concerned, the pads are placed at the inside position when light counts are being spun and at the outside when the heavy end of the count range for the frame is being produced.

Thus the manufacturer can, within the limits of the system on his frames, alter the general level of tension by means of these devices that alter the friction radius. There is another important factor over which he can exert some control. This is the amount of friction developed between the drag-pad and the bearing plate on the builder. Most drag-pads are made of felt, but for situations where an extra low tension is required, such as spinning the fine counts, these may be replaced by pads made from cork, compressed fibre, or other material. If the friction of the material used for the pad is high then this automatically leads to a high frictional torque. A low friction material leads to low frictional torque and its corollary, low spinning tension. The friction of a felt pad can become greater if it becomes contaminated with grease or dirt. The carrier sleeve/dead spindle bearing must be greased and for this reason a small grease-cup is formed at the upper end of the dead spindle. Each fresh charge of grease melts as the carrier rotates around the spindle and generates heat, and the grease runs down the spindle. After a time (or with excessive greasing) the grease finds its way on to the drag-pads and in so doing increases the friction between them and the bearing plate. For this reason, greasing should be carried out carefully, and periodically the drag-pads need to be cleaned with solvent.

With well-maintained felt pads the coefficient of friction can be as low as 0·6, leading to an average tension in the yarn between the flyer eye and the bobbin of about 1¼ lb. If, however, the pads become contaminated with grease and dirt the coefficient of friction may rise as high as 0·9, under which circumstances the tension will be around 1¾ lb.

So far, spinning tension has been considered in general terms but it is now necessary to discuss it in greater detail as it is one of the prime factors in determining how well the frame will perform and what its production capabilities will be. Spinning tension and yarn breaks are closely related and since the repairing of yarn breaks is the chief duty of the spinner, their number will determine, to a very large extent, the workload of the spinner and the labour requirements at the spinning stage. Spinning tension arises from the method adopted for winding-on in jute frames. It was shown earlier in this chapter how the frictional torque steadily grew as the bobbin filled up but, because of the faster radial increase of the bobbin, the spinning tension fell during the course of each doff. Spinning tension, however, is not of the same magnitude in all parts of the yarn from the bobbin surface up to the drafting nip.

Two levels of tension are found, on-winding tension and transmitted tension. On-winding tension is the tension developed in that part of the yarn between the flyer eye and the surface of the bobbin. Transmitted tension is the tension in that part of the yarn above the wharf-cap. The transmitted tension is *always* lower than the on-winding tension. The way that the yarn tension varies from the



AB: Transmitted tension
BC: Tension in wharf cap
DF: Tension on flyer leg
FG: On-winding tension

Figure 9.9. Relative tension levels between the delivery nip and the bobbin

drafting nip down to the bobbin is shown in Figure 9.9. The gradual reduction in tension as one progresses back up the yarn from the bobbin is due to the well known capstan effect. A ship can be moored to a jetty merely by wrapping its rope a number of times around a capstan or bollard, no knot being required to keep the boat from drifting away as the friction between the rope and the bollard is sufficient to keep the vessel secure. On the spinning frame, the on-winding tension can be regarded as equivalent to the tension between the vessel and the bollard and the transmitted tension equivalent to the free end of rope lying on the quay-side. The level of the on-winding tension is determined solely by the rotational torque required to overcome the frictional torque of the drag-pads; the transmitted tension depends upon on-winding tension *and* the friction between the yarn and the flyer leg and the length of yarn in contact with it. The length of yarn in contact with the leg depends upon the number of times it is wrapped around it in its downward passage from the top of the leg to the flyer eye and the size of the other small angles where it bears against the ceramic disk at the foot of the hole through the wharf and against the flyer eye. The relationship between the on-winding tension and the transmitted tension is given by

$$T_t = T_o \exp(\mu\theta)$$

where T_t is the transmitted tension, T_o the on-winding tension, μ the coefficient of friction of jute yarn on steel, and θ the total angle of wrap on the flyer leg and any other bearing surfaces.

Since T_o is fixed by the frictional torque at the drag-pads and μ is constant, or nearly so, for all normal jute yarns it follows that the only way in which T_t, the transmitted tension, can be altered is by changing the angle of wrap on the flyer leg. Plate V shows three methods by which the yarn can be led from the top of the flyer to the eye. In practice, only the straight-through and the once-round thread-up is used, for if the yarn is wrapped twice round the leg the transmitted tension is so low that ballooning usually occurs. On a 4¼ in. pitch frame, the average on-winding tension is commonly of the order 1¼ lb and the transmitted tensions for straight thread-up, once round, and twice round the leg are about 0·5, 0·25, and 0·15 lb. It will be appreciated that if the straight thread-up is used the yarn will be subjected to a higher tension throughout its passage from the drafting nip to the flyer eye; this may give rise to a slight increase in spinning breaks. It will usually be found that when the heavy counts are being spun the spinners use the straight thread-up so that the transmitted tension will be sufficiently high to prevent ballooning.

On the 4¼ in. frame, a popular choice for hessian yarns, the on-winding tension at the start of the spin is of the order 1·75 lb and drops to about 1·0 lb at the end, although wide variations in these values are found. The transmitted tension usually begins around 0·3–0·4 lb then falls steadily to 0·15–0·20 lb. In spite of all that has been said so far about the influence of spinning tension on the number of end-breaks that occur, it might be thought that these levels of tension are far below the average strengths of jute yarns. It is not, however, the *average* strength that is important in this respect but the *minimum* strength. For 8 lb/sp yarn this may be around 2 or 3 lb—still apparently well above the spinning tension level and the reason for the correlation between breaks and tension is not brought to light until one examines the tension by means of high-sensitivity instruments which have a rapid response to sudden tension pulses of extremely short duration. Then it is found that while the general level of tension, on-winding and transmitted, is set basically by the frictional torque at the carrier base and the angle of wrap round the flyer leg, there are irregular, sudden tension pulses of extremely short duration which are many times as great as the average level. These are the cause of yarn breaks in spinning.

Basically, they are all connected with bobbin rotation. The bobbin sits upon a carrier which, in turn, is set with a loose fit on the dead spindle. In addition, the surface of the bobbin is not smooth and the effective bobbin radius is changing in an irregular manner as the yarn builds momentarily on top of a yarn in the previous layer then at the next instant falls into a groove between two coils of yarn; with this continual change in radius it follows that the torque supplied to the bobbin is altering from moment to moment. Under these circumstances it would be rather surprising if the bobbin and the carrier rotated smoothly round the spindle. In fact, the motion of the bobbin is subject to a series of sudden accelerations and decelerations which cause the tension in the yarn to be jerky and irregular. Any defect in the spindle/carrier/bobbin assembly is liable to accentuate these irregularities in rotation and consequently leads to higher and more frequent tension pulses in the yarn, with the certainty that more ends will break as a result.

One defect that is inherent in the design of the spindle and the way the spinning frame operates is that the spindle can only be supported at one end. When the bobbin is at the bottom of its traverse the yarn is winding on at the top of the bobbin and is, as it were, 'pulling' the bobbin sideways at the top and exerting a force which tends to 'bend' the spindle. The spindle, of course, does not deflect but it does vibrate more violently than when the yarn is winding on at the foot of the bobbin and the leverage from the winding point to the attachment of the spindle is short. Plate VI shows a high-speed record of the spindle vibration with a short piece of the transmitted tension record attached. The trace refers to one complete builder cycle and the width of the band gives a measure of the degree of spindle vibration; it will be seen that more vibration occurred in the middle of the trace when the spindle was withdrawn from the flyers. The tension trace shows how the tension in the yarn rose as the spindle vibrated more violently.

Another cause of tension pulses is the jerk the flyers receive each time the joint in the driving tape comes on to the wharf; no matter how small and neat the join, this always happens. This jerk imparts a sudden pulse to the tension in the yarn as Plate VII shows; each vertical line arising from the sudden change in the flyer velocity as the joint of the tape comes round. These peaks are of the order of 1·5 lb, roughly 5 times as great as the average transmitted tension.

If the spindle is not exactly central with reference to the flyers, or if it is not vertical and straight, then the rotation will be more irregular than necessary and consequently not only will there be more tension pulses than normal but they will also be more vigorous and yarn breaks will be increased. Yet another cause of irregular spinning tensions is bad bobbin building; if the builder is not aligned properly with reference to the flyers the bobbins will be under-built at one end and over-built at the other. This is undesirable since the narrower bobbin radius will bring about a rise in the average tension and also cause more tension pulses, for the bobbin surface at these points is always more irregular than normal. Needless to say, if the drag-pads are greasy or contaminated in any way they will have a greater tendency towards stick-slip rotation with the consequent irregular tension it sets up.

Figure 9.10 shows a selection of spinning tension traces taken of the transmitted tension on a $4\frac{1}{4}$ in. pitch frame; it should be noted that these traces, because of the response of the instrument, only show the general levels of tension and do not reveal the short-duration pulses that have been discussed above. However, if the general level of tension

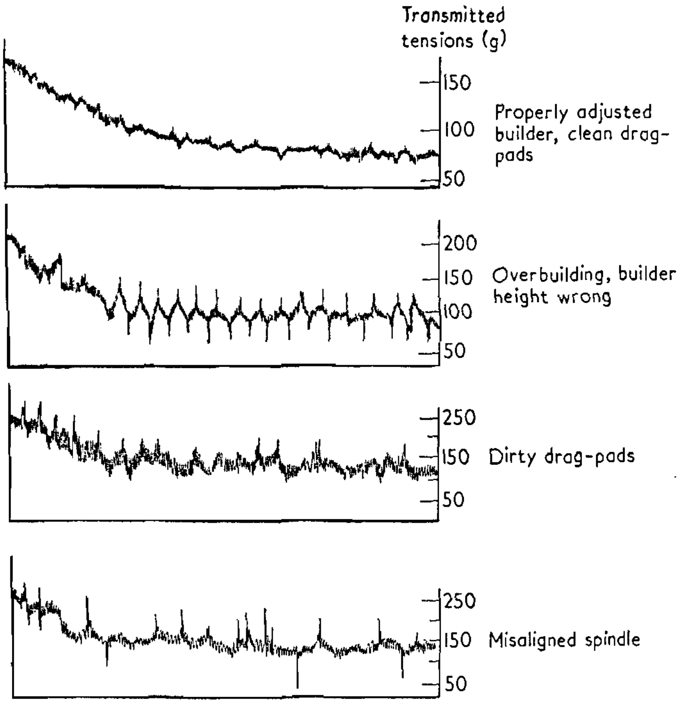


Figure 9.10. Spinning tension records. 4¼ in. frame, 276 tex yarn, 4,000 r.p.m.

is high or irregular, then the rapid tension pulses will be even higher and more frequent.

Spinning tension and frame speed are two closely related features. It has been known from the earliest days of spinning that if the frame speed is increased more yarn breaks occur; the form of the variation of breaks with speed is shown in Figure 9.11. When tests were made of the average tension in the yarn at different frame speeds, however, no change in the general tension level could be seen and it was only when the tension pulses were examined that the reason behind the increased number of yarn breaks was found. Table 9.2 shows the results of one such test. Clearly, at the higher frame speeds many more tension pulses occur.

At flyer speeds of 4,250 r.p.m. the tension peaks of 300 g are about 4 times as frequent as at 2,160 r.p.m. and peaks as high as 650 g are found. When one remembers that these records were taken above the

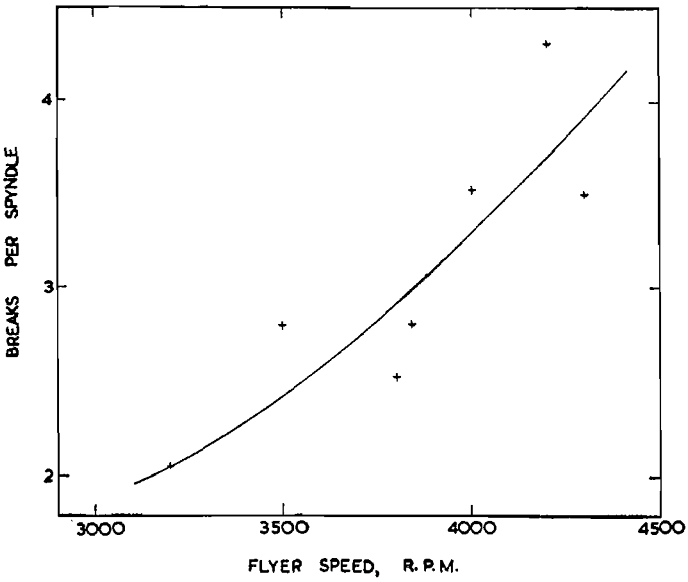


Figure 9.11. Effect of flyer speed on spinning breaks, 276 tex hessian warp

wharf cap it will be appreciated that the *on-winding* tension pulses are of quite a high magnitude (occasional ones being as high as 5–6 lb). Tension pulses of this order are much greater than the weakest parts of the yarn can stand and whenever a pulse and a weak spot coincide the yarn will break.

Under European conditions one spinner can attend to about 200 spindles when hessian yarns are being produced at between 3,700 and 4,000 r.p.m., but greater or lesser spindle allocations are found

TABLE 9.2. FREQUENCY OF TENSION PULSES ON A $4\frac{1}{2}$ IN. FRAME

Transmitted tension (g)	*Pulses per minute*	
	4,250 r.p.m.	*2,160 r.p.m.*
300	3,960	860
400	256	10
500	12	0
600	1·8	0
650	0·6	0

depending on the grade of fibre being worked. The spinning breakage rate varies widely from mill to mill since quality, frame maintenance, and tension levels differ, but a general indication of the breaks per 100 spindles per hour when spinning 260–300 tex yarns at about 4,000 r.p.m. is

Hessian warp	20–45
Hessian weft	30–55
Carpet or linoleum yarns	20–30

Virtually all spinning breaks are caused by the spinning tension exceeding the yarn strength, the exceptions being caused by the yarn striking an adjacent flyer when it balloons off a flyer leg or when one end breaks and becomes tangled with its neighbour, causing it to fall. The number of yarn breaks during spinning has been shown to be closely associated with spinning tension and yarn quality. If the number of end-breaks is large then a greater work-load is thrown on the spinner and it will become impossible for the operative to repair all the breaks as they occur. Consequently there will be some ends permanently down on the frame. The number of spindles that are idle as a result of end-breaks depends not only upon the frequency of the breaks but upon the skill and diligence of the spinner. It is common experience that a skilful spinner can cope with a reasonable number of end-breaks without having too many ends idle, 2 or 3 per cent of the total spindles being a typical figure for average break rates, but a poorer spinner may have 7 or 8 per cent of the ends idle under similar conditions. Thus the skill of the spinner can have a great influence upon the output from a frame.

The rate at which the ends break is not constant throughout the spin, being greater at the start when the spinning tension is high, but, in addition, there is another effect seen at the very start of the bobbin, as the following figures show.

1st builder cycle (approx. $1\frac{1}{2}$ min)	20 per cent of all breaks
Remainder of first 5 min	10 per cent of all breaks
Remainder of bobbin	70 per cent of all breaks

Extensive tests on 8 lb/sp hessian warp and weft yarn have shown that 20 per cent of all the yarn end-breaks occur during the first cycle of the builder when the yarn is winding on to the bare core of the bobbin or one layer of jute. At this time there is no resilience to the bobbin surface and consequently any sudden acceleration or deceleration of the bobbin results in a very high tension peak; later in the spin there is a pad of jute to help to absorb some of the impulsive loads that are thown on to the yarn. Again some 10 per cent of the breaks occur during the rest of the first 5 min of the spin, a time when the spinning tension is high. These high break-rates throw a heavy load on the spinner at the start of each doff and it is always found that the number of idle spindles is greater at the start of the bobbin than during the remainder. Another source of high starting breaks is the careless use of the starting handle of the frame. If the operative starts the frame with a sudden jerk then a large number of ends will certainly fall and, for this reason, the frame should always be started gently.

PRODUCTION ASPECTS OF SPINNING

The output from a spinning frame depends upon the yarn count, twist, and flyer speed.

Jute spinning frames are made in several sizes, each to suit a certain range of counts. Table 9.3 shows the operating details of the various sizes of frame.

TABLE 9.3. SPINNING FRAME DATA

Frame pitch (in.)	*Bobbin dia. (in.)*	*Bobbin length (in.)*	*Count range (lb/sp)*	*Flyer speeds (r.p.m.)*	*Wt of yarn on bobbin (lb)*	*Number of spindles*
$3\frac{1}{2}$	$2\frac{3}{16}$	$4\frac{3}{4}$	$3\frac{1}{2}$–6	4000–4200	0·27	110
$4\frac{1}{4}$	$2\frac{11}{16}$	$5\frac{1}{2}$	6–10	3700–4200	0·50	100
$4\frac{1}{2}$	$2\frac{7}{8}$	$6\frac{1}{2}$	10–18	3000–3600	0·65	90
$5\frac{1}{2}$	$3\frac{1}{2}$	$7\frac{1}{4}$	16–30	1900–2500	1·15	80
6	4	8	20–48	1500–2200	1·75	70

These figures are a general guide and it is quite often found that the count range will be extended somewhat to suit the sales requirements in any one mill.

If P is the frame production, v the delivery speed, n the flyer speed, t the yarn twist, k the twist factor, η the frame efficiency, and c the yarn count,

then,

$$P = cv\eta$$

but,

$$v = \frac{n}{t}$$

and,

$$t = \frac{k}{\sqrt{c}}$$

hence,

$$P = \frac{nc^{3/2}\eta}{k}$$

Thus high production will be achieved with high flyer speeds, high counts, high efficiencies, and low twist factors. Of these variables, k and c are fixed by sales requirements and so from the practical point of view it is only necessary to examine n and η.

FLYER SPEED

The speed at which the frame can be run depends firstly on the ability of the yarn to spin successfully without breaking too often, and secondly on the mechanical capabilities of the machine itself. It has already been indicated that as the speed of the frame is increased then more tension pulses arise and consequently more end-breaks occur. The better qualities of yarn are better able to withstand the stresses of high speed and it is always found that the lower the yarn quality the more end-breaks take place.

With the present design of flyer spinning frame there are limitations put upon the upper limits of speed by the performance of the flyers themselves. These are largely connected with the throw-out of the legs due to centrifugal force. Throw-out depends upon several physical factors. For example,

throw-out $\propto$ cross-sectional shear strength of the leg
$\propto$ leg separation
$\propto$ speed^2
$\propto$ leg length^4

It will be seen that the two most important factors are flyer speed and leg length, for example an increase in speed from 3,000 to 4,200 r.p.m. gives twice as much throw-out and changing the leg length from 6 to 7 in. would raise the throw-out by the same amount.

The amount of throw-out assumes very great importance in determining the size of the bobbin that can be used since all flyer legs are inclined inwards so that when the frame is running and throw-out takes place the legs will assume a vertical position. The inward inclination limits the size of the bobbin diameter that can be used—the bobbin diameter must always be slightly less than the leg separation when the flyer is at rest, otherwise the flyer would jam on it each time the frame was stopped. Therefore, if (1) high speeds or (2) long bobbins are to be used then this increases the throw-out which, in turn, limits the maximum bobbin diameter that may be employed. It will be apparent, therefore, that the yarn carrying capacity, package size, and flyer design are interdependent, and similarly delivery speed, bobbin rotation, and the ability of the yarn to withstand spinning tension are interdependent. It would seem that any twisting device that could overcome these restrictions, or at least some of them, might offer a possibility of increased spinning production. Several flyer designs have been patented, the main objective being to limit throw-out and give either higher flyer speeds or larger spinning packages or both. Flyers resembling open-sided cylinders with a complete ring at the foot and flyers made in two wing-like halves have been used with some success, though the solid ring at the foot does interfere slightly with the normal processes of repairing end-breaks and cleaning. As a development from the wing-like flyers, a counterbalanced single-wing flyer has been produced by the Fairbairn Lawson Textile Machinery Co. Ltd called the Falaflyer. In comparative tests between the Falaflyer and more conventional types it has been found that fewer tension peaks occur. For example, when running at 4,000 r.p.m. a conventional flyer gave 785 pulses greater than 320 g above the cap during the first 5 min of the spin. Under the same conditions the Falaflyer gave only 125. The Falaflyer is combined with the double apron draft control unit, Figure 9.1 (d), and a motor-driven traverse on the Falaspin frame which, it is claimed, gives a stronger, more regular yarn with fewer ends down. The shape of the Falaflyer allows a larger bobbin to be used with an increase of 40 per cent in yarn-carrying capacity compared with the conventional size for a 4¼ in. frame.

Another interesting method of simultaneously twisting and winding-up the yarn is found in centrifugal spinning or, as it is more commonly known, 'pot spinning'. Centrifugal spinning has been known from the beginning of the century when Topham produced his first 'pot' for spinning viscose rayon. With the wet-spun viscose there was little difficulty in producing a stable package which could be handled in subsequent processes, but it was not until 1948 that the first commercially available machine was released for use with dry yarn. This machine was the Prince-Smith Centrifugal (P.S.C.) machine for worsted yarn. The general arrangements of the centrifugal spinning system are shown in Figure 9.12. The yarn descends into a rapidly

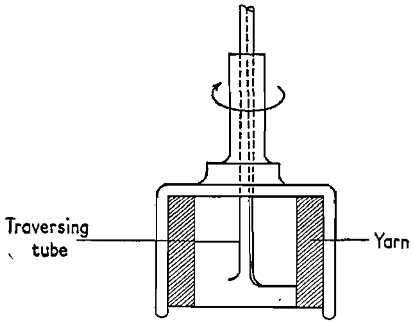


Figure 9.12. Diagrammatic representation of centrifugal spinning

rotating pot and when it comes against the inner surface of the pot it simultaneously becomes twisted and wound-on by centrifugal force. The yarn continues to wind the package from the outside to the inside, then when the packing is full a spring cage or some other device rises into the pot and withdraws the yarn. This type of spinning has great speed potential and while the practical application of the system has not been fully exploited commercially for jute it will be interesting to watch the future developments along these lines.

SPINNING EFFICIENCY

From the viewpoint of production there are several sources of lost time at the spinning frame; doffing, end-breaks, maintenance, lack of orders, etc. This allows one to formulate different levels of efficiency.

(1) Spindle efficiency, the number of spindles that are actually

producing on the frame. Those which are idle because the ends have broken and the spinner has not yet repaired them are deducted from the total number on the frame; usually it is expressed as a percentage, e.g. a spindle efficiency of 96 per cent means that out of every 100 spindles 96 are actually producing and 4 are idle.

(2) Frame efficiency, the actual running time of the frame expressed as a percentage of the total possible running time. Note that this takes account of time lost through doffing *and* spindle efficiency, e.g. a frame with 100 spindles is producing 8 lb/sp yarn at 26 yd/min, the bobbin holds 0·5 lb of yarn and the frame is stopped for doffing for 70 sec, on average there are 2·8 spindles idle because of end-breaks; the frame efficiency is then

0·5 lb of 8 lb/sp yarn	900 yd
Time to spin 900 yd	34·6 min
Doffing time	1·16 min
Total time to fill and doff the bobbins	35·76 min
Number of spindles working effectively	= 100–2·8
	= 97·2

$$\text{Frame efficiency} = \frac{34{\cdot}6 \times 97{\cdot}2}{35{\cdot}76 \times 100} \times 100 \text{ per cent}$$
$$= 94 \text{ per cent}$$

(3) Flat efficiency, this takes account of the frame efficiency *and* lost time through maintenance, spinners' absence, lack of orders, etc. This value for efficiency gives, as it were, a measure of how effectively management is using the productive capacity of the spinning department.

For example, a spinning department of 30 frames has, on average, frame efficiency of 90 per cent and during one particular 40 hr week, 6 hr are spent on maintenance, 1 frame stood for 4 hr because the spinner was ill, and 2 frames were off for 1¼ days through lack of orders. What was the flat efficiency?

Total possible time = 30 × 40 frame hours

Lost time:

Maintenance	6 hr
Spinner's absence	4 hr
Lack of orders (2 × 10)	20 hr
	—
	30 hr

Flat efficiency

$$\frac{(1200-30)\times 90}{1200\times 100}\times 100 = 87{\cdot}6 \text{ per cent}$$

STOP MOTIONS AND PIECING

There is only one stop motion on a jute spinning frame and this is for detecting a broken end of yarn. A light porcelain finger rests against each yarn between the drafting rollers and the wharf cap. When the yarn is running normally the finger is held back but when the yarn has broken it allows the finger to swing forward and, through a system of levers and trip-rods, the front retaining roller springs away from its fellow and the rove or sliver stops passing between them. This front roller is held against the driven retaining roller by means of a heavy counterweight which drops forward when the stop motion operates. This weight not only provides the energy required to separate the two retaining rollers but acts as an indicator and shows the spinner that an end has broken.

To repair the break, the spinner grasps the wharf cap firmly and stops it (this can be done quite safely because the driving-tape to the wharf slips on the polished surface). A special wire hook is then passed down through the hole in the wharf cap and the broken end of yarn on the bobbin drawn up through the cap. The spinner grasps this end in the right hand and quickly places it into the nip of the drafting rollers. Simultaneously, the spinner lets the wharf cap go and the flyer immediately rotates. With the left hand the spinner swiftly pushes the counterweight upwards, making the retaining rollers engage once more and bring down the rove or sliver. As soon as the rove or sliver reaches the drafting zone the broken end of yarn is released and passes through the drafting nip along with the fresh supply of sliver or rove, becoming twisted in with it as soon as it emerges from the nip and comes under the influence of the flyer. In this way a broken end can be joined on to a new piece without a knot—the whole operation being known as piecing or splicing. Inevitably, a splice is about twice the normal thickness of the yarn because the broken end must be twisted in with a new piece if the two are to hold together. This is a defect in the yarn, but one which is unavoidable—all that can be done in this respect is to try to keep the splices as small and neat as possible. As may be imagined, the operation of piecing requires considerable skill and experience before a neat effective splice can be made each time. A good spinner can carry out a splice in ten seconds or even less but a poor spinner may take longer and find that the end breaks when the splice passes down the flyer leg.

A yarn defect, known as 'spinner's double' may arise if the stop motion is not functioning properly. If the supply of material is not cut off quickly enough when an end breaks then a ribbon of drafted, but untwisted, jute is liable to drift across to its neighbour and become twisted with it, producing a double-count portion of yarn which may extend for some distance.