7
Manufacturing techniques

7.1 Overview of production processes

Since the first days of the Industrial Revolution in the mid 1700s, it has always been the case that every technological development has, in and of itself, created a new commercial application. That is to say, a market has been discovered where no market existed before. This is perhaps hardly astonishing, since it is rare for anyone to be able to conceive of a product or service that is entirely without parallel in their own experience. It does, however, demonstrate the importance of technological development for the continuing growth of companies and of their market shares. It might even be true to say that in these cases, the technology drives the market. In the last quarter of the twentieth century, this pattern (that is, the pattern of a new technique creating a new market) was made manifest three times in the field of fancy yarns. These new markets – or new market sectors – have been opened up following the development of the hollow spindle spinning system, the chenille manufacturing system, and the miniturisation of the circular knitting process to create the chainette yarn. It is therefore reasonable to expect it to continue to do so: new mechanisms will be developed, resulting in new costs, new effects, and new markets.

There are, at present, four main methods being used for the production of fancy yarns that involve structural effects: hollow spindle, ring twisting, the 'combined system' and the chenille system. Of these, the ring spindle, hollow spindle and combined system installations produce superficially similar yarns and yarn types, although the structures, and therefore the properties, do in fact differ. The chenille machine, on the other hand, although less versatile than these in that it can only produce a single structure, is unique in that it can produce a chenille yarn rapidly, consistently, and at a lower cost than previously was feasible.

In 1976, the Lezzeni Company in Italy developed a new manufacturing route that combined the hollow spindle system and the ring spindle system, and since that time many other manufacturers have followed suit. In the ensuing period there have also been very considerable advances in the electronic control of spinning systems, as there have been in the electronic control of other manufacturing processes. However, there have been no major developments in the actual spinning processes themselves. The chenille manufacturing system is also relatively recent, at least from the point of view of an industry as old as the textile industry, since it too is a development of the past two or three decades.

The 'combined system', as its name suggests, is a technique using a machine that combines two spinning points, one after the other, in a single passage of the machine. One of the most common combinations is that which combines a hollow spindle with immediate passage of a ring spindle in the reverse twist direction. This produces a somewhat softer yarn, as the binding twists of the hollow spindle are slightly opened out. At the same time, it requires only a single passage of the machine to produce even the most complex effects. This point is becoming a matter of considerable importance in these days of shrinking margins and shorter manufacturers' lead-times.

More recently still, developments in warp and weft knitting have introduced machines that are capable of producing yarn-like products using these methods; for example, the 'chainette' type yarns, the 'tape' yarns and the 'feather' yarns. These yarns are appearing at many levels of the market, in a range of applications, although their primary use thus far has been in knitted apparel. Strictly speaking, these are not spinning techniques at all, and the materials they produce cannot be produced using classical spinning methods, but they do manufacture materials that can be used as yarns.

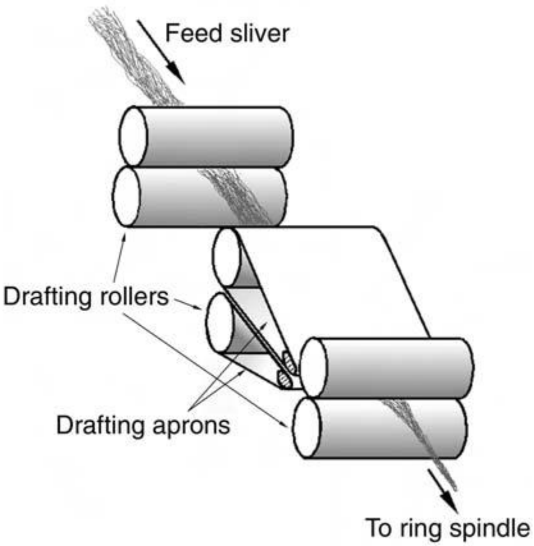
Airjet texturising is being used increasingly for apparel, although much of the production in the recent past was more strongly associated with yarns for automotive and contract furnishing. Viewed purely as a manufacturing technique, airjet texturising has several advantages. The speed of production of which it is capable far outstrips that of conventional systems, and the continuous filament feed produces yarns stronger than those produced using staple fibres, although the entanglement of the filaments in fact weakens the structure in comparison with the material that is fed into the texturising machinery. Furthermore, as development work progresses under the impetus provided by the combination of practical curiosity and potential profits, the technique continues to become more versatile and the resultant yarns more wearable. Already, advances in processing technology have made it possible to produce airjet texturised yarns that have sufficient elasticity to be both useful and comfortable in apparel fabrics. These yarns are used now both in knitting and in weaving. However, the limitation of the technique is that it can only be used to process continuous filament feedstocks.

7.2 Yarn production systems

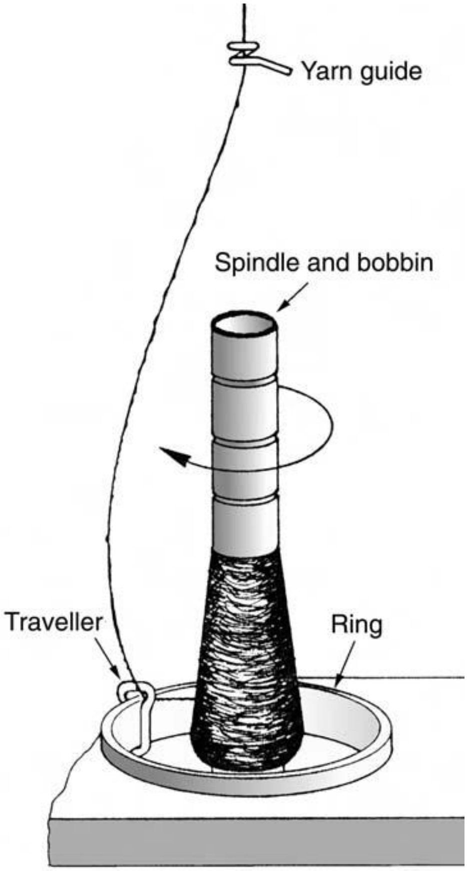
7.2.1 The ring spindle system

Ring spinning, in spite of the encroachment of a variety of new spinning methods in recent years, is still regarded as the ‘standard’ spinning method, and it remains the benchmark against which all other yarn production processes are measured. The main advantages of the system lie in the high degree of fibre control available at all stages of the process, and in the wide range of counts it can produce.

The basic operation of the ring spindle system is shown in Figures 7.1 and 7.2. Figure 7.1 shows the roller drafting system that is used almost universally in ring spinning machines. The feed slivers pass through three pairs of rollers. The two rollers of each pair are pressed together, and the surface speed of the rollers is increased from each pair to the next. The fibres that have been gripped by a faster-moving pair of rollers are drawn past the fibres gripped by the preceding, more slowly-moving pair of rollers. Consequently, the length of the sliver is increased by a factor equal to the ratio of the surface speeds of the two pairs of rollers. This ratio of surface speed is called the mechanical draft. If we ignore any shrinkage of the fibre strand after drafting, the mechanical draft is the same as the actual draft, which is defined as the ratio of the linear density of the feed to that of the delivery. Clearly, the danger here lies in the risk that inappropriate choice of the distance between two pairs of rollers in comparison with the fibre staple length



7.1 Roller drafting.



7.2 Ring spindle.

will result in either broken fibres or in imperfect fibre control. This is one of the primary reasons for the historical specialisation of many spinning mills in the fibre type treated.

The space between any two adjacent pairs of rollers is called a drafting zone. The distance between the nip lines (the notional lines on which the upper and lower rollers of each pair touch each other and 'nip' the sliver) of two adjacent pairs of rollers is called the roller setting. The first pair of rollers that the feed slivers pass through are called the back rollers or feed rollers and the last pair are called front rollers or delivery rollers. Drafting aprons may be included to improve the fibre control within the system. These are covers, which pass over one set of rollers and a pair of smaller ones close to the next set of main rollers, providing support and control of the fibres as they pass from one nip to the next.

The drafted fibre strand is then twisted by the ring spindle, as illustrated in Fig. 7.2.

The yarn leaving the front rollers is threaded through a yarn guide (the lappet), which is located directly above the spindle axis. The yarn then passes under the C-shaped traveller and onto a bobbin. The bobbin is mounted on the spindle and rotates with it. When the bobbin rotates, the tension of the yarn pulls the traveller around the ring. The twist inserted in the yarn can be determined from the spindle speed and the yarn delivery speed by using the following formula:

$$t = \frac{N_s}{V_d} - \frac{1}{\pi D_p} \qquad [7.1]$$

where

t = the turns of twist per unit length of yarn (turns/metre);
N_s = the spindle speed (turns/minute);
V_d = the yarn delivery speed (metres/minute)
D_p = the yarn package diameter.

It is common practice to ignore the second part of the above equation and to simplify the calculation as follows:

$$t = \frac{N_s}{V_d} \qquad [7.2]$$

The small error introduced by this simplification proves to be of little practical significance.

During yarn production, the ring rail on which the ring and traveller are mounted (see Fig. 7.2) moves up and down in order to spread the yarn along the length of the bobbin. This ensures that a proper package can be built. The movement of the ring rail appears to be complicated in practice, but the aim is straightforward: to build a package that is stable, easy to unwind and contains the maximum amount of yarn possible. As the yarn is wound onto the bobbin during production, the bobbin diameter and the height of the package increase steadily.

In the production of a normal yarn, the attenuation of the fibre strand should be achieved with the minimum variation in its linear density. This results in the maximum yarn evenness. Since fibres of different lengths will tend to move differently during drafting, this is not necessarily easy to accomplish. The differing behaviour of fibres that differ in length will cause unevenness in the yarn. Indeed, it was for this reason that the drafting aprons in the front drafting zone were developed, in order to improve the fibre control and therefore to minimise this variation in normal, 'plain' yarn production. During the production of fancy yarns such as slub yarns, these drafting aprons can be removed, and the resulting uneven movement of the fibres can be exploited to create deliberately-introduced random variations in the yarn. This effect may be enhanced by mixing fibres of different lengths to exaggerate these variations in yarn thickness. For example, woollen slubbing can be mixed with worsted top sliver, to create a yarn in which the imperfect fibre control during drafting produces randomly distributed slubs (thick places) of varying dimensions.

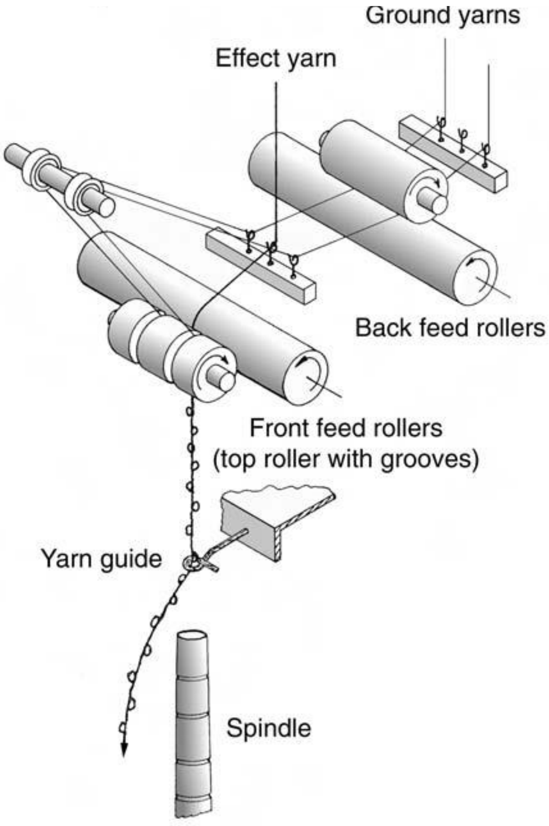
An alternative method is to modify the spinning frame in such a way that the intermittent acceleration of the drafting rollers causes constantly varying degrees of draft to be applied. This method might also be used on the flyer frame to produce a slubbed roving from which a yarn could be spun using constant draft, although it should be borne in mind that the slubs thus produced would be greatly lengthened in the resultant yarn. Further modifications to the drafting system have been developed that make possible the use of differing yarn paths to the spinning head. Each of these can be separately controlled, and each is provided with drafting aprons for better fibre control in order to allow the differential drafting of several slivers or rovings during feeding. Drafting systems of varying complexity have been developed, together with a variety of different methods for controlling the drives (stepper motors, differential clutches and so on). Another popular method is to use an extra feeding device to inject (that is, to feed intermittently) additional material into the drafting zone. This allows the production of flake or flammé yarns (elongated slubs).

Producing fancy yarns on the ring system

Fancy yarns that involve yarn effects contain one or more ground yarns, one or more effect yarns and, in most cases, a binder yarn. These fancy yarns are produced in two or more separate stages, not counting the production of the individual yarns that are combined to make up the final fancy yarn. (Obviously, these individual yarns need to be produced separately before they can be combined to create the fancy yarn.) The ground yarns and the effect yarns are then twisted together to create the fancy effect.

For some fancy doubled yarns, such as marl and spiral yarns, that are structurally relatively straightforward, the additional process of binding is not required. For most other effects such as bouclé, loop and snarl yarns, it is essential to stabilise the yarn by fixing the effect into place with the ground yarns using a binder yarn. This binder is added in a further twisting process. If this stage is not performed, the effect is free to move up and down the core yarns, to snag on machinery during the subsequent processes, or even to unravel itself.

Figure 7.3 shows a typical feeding arrangement when the fancy yarn to be produced is a loop yarn. Two ground yarns must always be used when creating a loop yarn. These two ground yarns are fed by the back feed rollers while the effect yarn is fed by the front feed rollers. As the ground yarns and the effect yarn are fed at different speeds, the ground yarns are



7.3 Feed system for loop yarn formation.

made to pass through the grooves cut in the top front roller, instead of being nipped as they would be if the grooves were not in place. This allows the ground yarns and the effect yarn to converge in the twisting zone after they have emerged from the front rollers. The two ground yarns, kept separated by the two grooves, form a triangle between the front rollers and the twisting point at which they come together. This triangle provides the essential space in which the overfed effect can form the loops. In order to maintain good control of the yarn, the effect yarn (which is overfed, and therefore not under tension between the feed roller and the twisting zone) is fed by the rollers that are closest to the twisting zone; in other words, the front rollers. It is also important that the effect yarn should be fed in such a way that the ground yarns are placed one on each side of it.

The yarn effect is critically dependent on a combination of factors: the overfeed ratio (that is, the ratio of the effect yarn speed to the ground yarn speed), the twist, the groove spacing, and the properties of the component yarns. In order to produce good loop effects, the effect yarn should be stable (that is, it should display low twist-liveliness) and elastic. The loop size can be altered by changing the size of the spinning triangle and the overfeed ratio. The spinning triangle can be changed by altering the spinning tension, the twist level (this is the most economical method) and the top roller groove space. If the twist level of the loop yarn being produced is used to control the size of the loops, it will at the same time affect the slip resistance of the loops. For example, by increasing the twist level, the yarn twisting torque is increased and this causes the twisting point to move towards the front drafting rollers, which in turn reduces the spinning triangle. Because of the higher twist, the loops will have a greater resistance to slippage. However, the yarn will become harder, although it is possible to rectify this later during the binding process.

The feed system for snarl yarn production is the same as it is for producing loop yarns. Indeed, the main difference between the loop yarn and the snarl yarn lies in the properties of the effect yarn. To create a snarl yarn, the effect yarn should have a relatively high level of twist, which will facilitate the formation of the snarl effect. The overfeed ratio is also higher (250% as compared to around 200%).

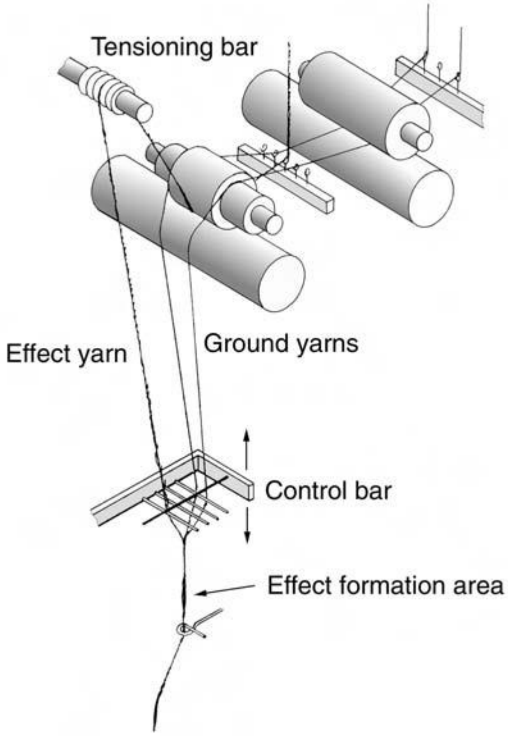
The feed system described for the loop yarn may also be used for other yarn effects where only one ground yarn is needed. Again, the effect yarn is fed by the front rollers while the ground yarn is fed by the back rollers and passes through a groove in the top front roller.

If the effect yarn is considerably thicker than the ground yarns (which may be fine filament yarns, for example), a smooth top roller may be used instead of the grooved roller. In this case, the top roller is lifted by the thicker effect yarn and cannot exert any nip pressure on the ground yarns.

In producing some effects, such as the gimp yarn, the initial twisting process only lays the foundation for the desired effect, and therefore a reverse twisting is required to make the effect visible. For most other effects (loops, snarls or bouclés), the effect yarn or yarns may appear to be twisted in by the ground yarns, but this is not in fact the case. On the contrary, the strands are simply twisted around each other. To prevent the effects sliding along the yarn length during subsequent processing, it is necessary to bind the effects to the ground yarn or yarns by twisting-in one or more binder yarns, using an additional twisting process. In addition, in order to ensure that the effects are made stable enough for subsequent handling, the initial twist level is usually high. This produces a hard, lean and twist-lively yarn. The final twisting is always in the opposite direction to the initial twisting and this is used to set the fancy yarn twist to the correct level to achieve the desired yarn character (which may be, for example, a soft, open look). Around 80 to 85% of fancy yarns require this final twisting process, which adjusts the appearance and structure of the completed yarn while binding all the components together. The twist level for final twisting depends on the yarn count and the desired yarn character (for example, increasing the binding twist will improve the slipfastness of the effect). It is normally between 20% and 40% of the initial twist.

As the binder must wrap around the yarn, it needs to be overfed. The amount of this overfeed depends on the yarn count and the effect being produced. A greater amount of overfeed is needed for thicker yarns and for yarns with more pronounced effects. It is usually around 4–11%. The binder yarn should generally be as inconspicuous as possible and it is usually less than 50% of the total ground yarn thickness. A fine, 'colourless' filament may often be used as the binder in order to reduce its visual impact on the completed yarn. The choice of the binder colour can materially affect the saleability of a yarn for a particular purpose.

For the production of knop yarns (shown in Fig. 7.4), the ground yarn needs to be fed intermittently. The effect yarn and the ground yarns converge below the control bar. The knop effect is formed when the ground yarns stop while the effect yarn continues to be fed, forming a prominent 'bunch' on the yarn surface. To achieve a neat knop, the control bar remains stationary so that the effect yarn is given as little play as possible. During



7.4 Feed system for knop yarn formation.

the formation of the knop, the control bar can be moved up and down to spread the knop over a desired length of the yarn. This produces an elongated knop, which creates an effect often referred to as a 'stripe' yarn. These stripes may be fixed by using a high twist level or may be left 'floating' by using a low twist level. In the latter case, the stripes will then move up and down the yarn during subsequent processing.

Two effect yarns of different colours may be used to wrap around each other alternately. In this case, no ground yarn is used since each yarn in turn takes the place of the ground yarn. The knops of one yarn hide the colour of the other yarn alternately, which produces an effect not dissimilar to space dyeing.

The ring spinning system is still the most flexible yarn production system in terms of both raw material handling and the range of yarn counts produced. Its main drawback lies in the lengthy and costly processes involved in production by this route. When produced using the ring spinning route, most fancy yarns require several twisting processes. The loop yarn, for example, requires a minimum of four component yarns (two ground yarns, one effect yarn and one binder yarn). Each component yarn has to be spun separately. The ground yarns and the effect yarn are then twisted together and this process is followed by the final twisting process required for binding. Thus, even if we do not include the production of the component yarns, two separate stages are involved. Since it is by no means unknown for two fancy yarns to be twisted together to produce other, still more complex effects, the number of twisting processes involved can increase at an alarming rate. In recent years, alternative techniques for making fancy yarns in a single-stage process have emerged and become more popular. The most widely used of these new techniques is the hollow spindle system.

7.2.2 The hollow spindle system

The hollow spindle principle of spinning was first developed by George Mitov at the Institute of Clothing and Textiles in Bulgaria.[8] The process he devised replaced twist in a yarn by wrapping a filament binder around the materials being used. This resulted in a fasciated yarn structure, in which most of the elements lie parallel to one another while the binder imparts the necessary cohesion. This system is suitable for making plain as well as fancy yarns. Its primary selling point for the manufacture of fancy yarns is that most can be made using a single passage of the machine, while, as discussed earlier, a minimum of two passages would be needed for a similar yarn made using the ring system. It should be remembered, however, that although the yarns are superficially similar, and may appear to be structurally similar as well, fancy yarns made using the hollow spindle system are quite different in structure from those made using the conventional ring spinning system, and are likely to differ also in details of appearance and of behaviour during processing. This is demonstrated by the yarn and fabric trials described later in this chapter. Hollow spindle fancy yarns are used mainly in knitted garments or fabrics, although the plain yarns have found many other applications, in carpets and in medical textiles among others.

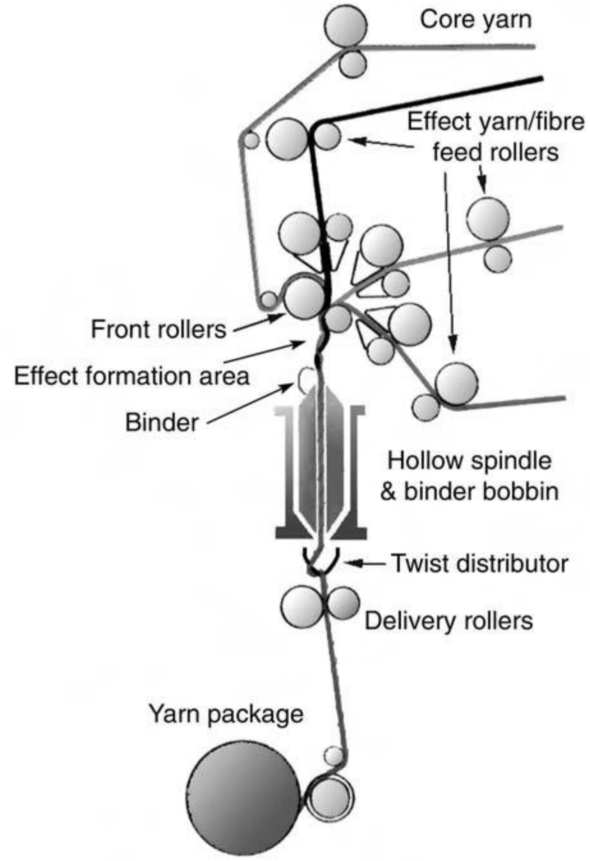
In producing hollow spindle yarns, whether plain or fancy, fewer preparatory processes are required than for ring spinning, for example. In particular, it is no longer necessary to produce a roving as an intermediate process between the sliver and the yarn. This results in lower pre-production costs. Because the binder is usually a filament, the speed of production of that element of the final yarn is much faster than is the case for spun yarns, and consequently the total cost is lower.

In the production of fancy yarns, the hollow spindle technique is used to add the binder immediately the effect is produced, instead of using a second, separate operation. However, it should be recalled that because there is no twist holding the elements of the fancy yarn together, it has no cohesion beyond that imparted by the binder. If the binder breaks, the yarn falls into its separate components more readily and dramatically than does a fancy yarn produced by ring spinning. Furthermore, a filament binder will typically offer relatively little warning of weakness – it is unlikely to show any thin places, for example.

Figure 7.5 shows an example of the hollow spindle system. In this particular example, there are four independent feeding devices, three for effect fibres and one for the core yarns. The effect fibres are fed in the form of staple roving or sliver. After that, they are drafted using roller drafting systems that are similar to those used on ringframes. The effect fibres are combined with the core yarns and then passed through the rotating hollow spindle. A bobbin bearing the binder (usually a filament yarn) is mounted on the hollow spindle and rotates with it. The binder is pulled into the hollow spindle from the top. The rotation of the hollow spindle wraps the binder around the staple strand and the core yarns. The binder then holds the effect and the core yarns in place.

To avoid the possibility of the drafted staple strand disintegrating before it is wrapped by the binder, the spindle usually generates false twist in the staple strand. The staple strand does not therefore pass directly through the hollow spindle. It is first wrapped around a twist regulator, which is usually located at the bottom of the spindle.

A very wide range of fancy effects can be produced using the hollow spindle system. Many of these effects can be controlled by controlling the speeds of each of the different feeding devices (core and effect). It is also possible to use the hollow spindle system to create fancy yarns that include yarns in their effect. Still more effects can be produced by controlling the final yarn delivery speed. Because the effect fibres do not have real twist,



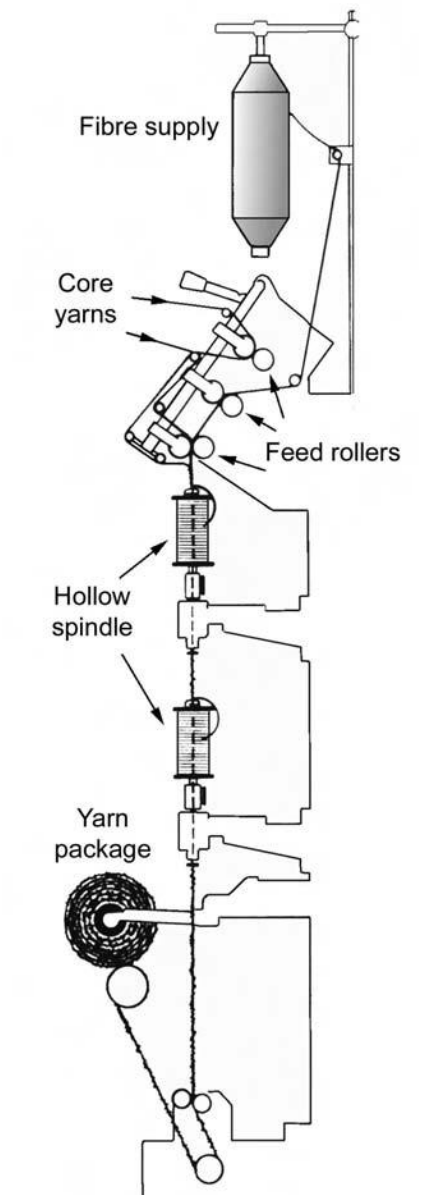
7.5 Hollow spindle system.

hollow spindle yarns differ from ring yarns in both their appearance and their performance characteristics. The former tend to be bulkier and have lower wear resistance.

7.2.3 Combined systems

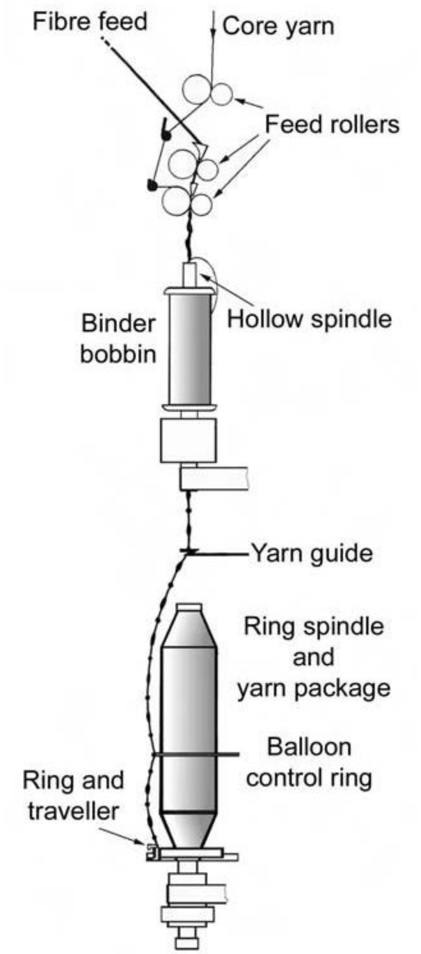
The combined systems were first developed in order to unite the benefits of the ring and hollow spindle systems in a single machine, since it is felt that a yarn with twist has a more stable and reliable structure than one that has a fasciated structure.

Thereafter, it was realised that two hollow spindles could also be mounted in series, and that this would offer a different variety of resultant yarns, and a different range of benefits. This is shown in Fig. 7.6, which depicts two hollow spindles, arranged one above the other to wrap the



7.6 Two-spindle wrap system.

staple strand with two binders which are applied in opposite directions. This technique is used to produce special effect yarns that have a more stable structure, a result of the fact that the effect fibres are trapped by two binders instead of one.



7.7 Combination of ring and hollow spindles.

Figure 7.7 shows the original combined system in which the hollow spindle and ring spindle were combined in a single machine. In this case, the wrapped yarn is being given some true twist by the ring spindle located immediately beneath the hollow spindle. It was felt that the speed of assembly offered by the hollow spindle, enhanced by the true twist inserted by the ring spindle, would be able to create yarns that would be less expensive than true ring spun yarns while still retaining some of the characteristics.

In considering these mechanisms, we should bear in mind that, although only one passage of the machine is required, that single passage can take place no faster than the speed of the slowest process. Furthermore, the machines are complex and time-consuming to set up, as one might expect, since the materials necessary for two machine passages under the ring system must be assembled at one time.

7.2.4 The doubling system

The doubling system is based essentially on the ring spindle. The general arrangement is to provide two or more yarns that can be fed independently at controlled speeds, which may include uniform, fluctuating or intermittent feeds as required. This permits the production of spiral or marl type yarns very simply, but it obviously demands that the feedstock should be in yarn form.

The method allows the production of some of the simpler fancy yarn structures by ordinary spinners who do not specialise in fancy yarn production. Indeed, these yarns can be created by anyone who has access to a doubling frame, and since many weavers and knitters also maintain their own, this enables them, too, to create fancy yarns. In skilled hands, the doubling frame can produce some interesting effects, in particular when it is used to combine two existing fancy yarns to create another.

In garment and fabric knitting, it is possible to produce a marl-like, or heathered effect, by simply feeding two yarns into the knitting machine at the same time. However, although this method does have the advantage of reducing yarn variability, 'multi-ending', as it is termed, does not ensure so stable an effect as that which can be created by first using a doubling frame to produce a doubled yarn and then knitting with that doubled yarn.

It is also possible to produce spiral effects using an ordinary doubling system. This can be achieved by combining two yarns of very different thickness and of opposite twist. If the doubling twist is in the same direction as that of the thicker single yarn twist, the thicker yarn contracts while the thinner yarn expands, resulting in the thinner yarn spiralling around the thicker. If on the other hand the doubling twist is in the opposite direction to that of the thicker single yarn twist, the thicker yarn expands while the thinner yarn contracts, resulting in the thicker yarn spiralling around the thinner yarn. Although their basic structure is identical, these yarns are aesthetically very different and they will be employed in very different ways.

7.2.5 The condenser system

Although it is used particularly for short staple wool and recovered fibres for woollen fabrics, and is not viewed as being a method for the production of very high quality yarns, the condenser spinning method may still be used to produce fancy yarns of a particular type.

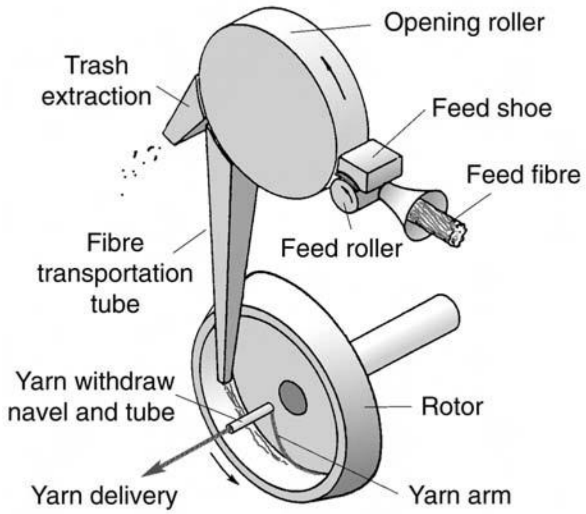
The effect components are introduced into the blend either prior to or during the carding operation. For example, a controlled flow of coloured nepps may be fed to the card just before the condenser; or the nepps may be incorporated into the blend. In the latter case, the blend must therefore already have been opened out, as it is necessary to use an open setting in order to prevent the fibre balls themselves being opened out. The yarns thus produced will have small colour flecks, spread out to a lesser or greater extent, depending upon the closeness of the settings. Longer and larger flake effects can be produced on the condenser system by injecting fibre materials into the condensing zone.

7.2.6 Open end spinning

There are two commonly used open end systems: rotor and friction. The rotor system is mainly used for the production of plain, short staple yarns. The friction system is used mainly to make coarse industrial yarns. However, both systems can also be used for making particular fancy yarns.

The rotor system

In rotor spinning (Fig. 7.8), the fibre material is fed into an opening unit by a feed roller in conjunction with a feed shoe. This feed material is usually a drawn sliver. An opening roller is located inside the opening unit. The surface speed of this opening roller is much faster than the feed roller, and it opens up the fibres to create a very thin and open fibre flow. The fibres are taken off the opening roller by an air stream that has a speed about twice that of the opening roller. The fibres are carried by the air stream



7.8 Rotor spinning system.

through the fibre transportation tube and into the spinning rotor. The surface speed of the rotor is faster again than the exit air speed, so the fibres emerging from the transportation tube are pulled into the rotor. This in turn keeps the fibres aligned in the direction of the fibre flow. The centrifugal force generated by the rotor throws the fibres into the rotor groove. Because of the high surface speed of the rotor, only a very thin layer of fibres, with usually one or two fibres in the cross-section, is deposited in the rotor as the rotor passes the fibre exit point of the transportation tube. Many such layers of fibres are needed to make up the yarn. This doubling up of the fibres in the rotor is called back-doubling, and it contributes to the maintenance of an even linear fibre density.

The centrifugal force inside the rotor throws the tail of the yarn arm against the rotor groove. The yarn arm rotates with the rotor, and each rotation of the yarn arm inserts one twist in the yarn. As the yarn is withdrawn continuously through the navel and tube, the contact point of the yarn arm with the rotor groove must move around the rotor. Because the yarn arm is rotating axially, the fibres in the rotor groove are twisted into the yarn.

There is no need to rotate the yarn package to ensure the insertion of twist, so with less mass to rotate and control, rotor spinning can attain much higher twisting speeds than is possible in ring spinning. Furthermore, since the feed can be in sliver form, the roving process needed in ring spinning is eliminated in rotor spinning, which reduces the production cost still more. The final package can also be much larger, with fewer knots in the product, and in a more suitable form for subsequent processes.

The absence of trash particles on the fibres is more critical for rotor spinning than for ring spinning. This is because the yarn is formed in an enclosed space inside the rotor, which means that trash particles remaining on the fibres can accumulate in the rotor groove. This will lead to a gradual deterioration of yarn quality and, in severe cases, it can result in yarn breakage. In order to reduce the trash particles remaining among the fibres, a trash extraction device is used at the opening roller.

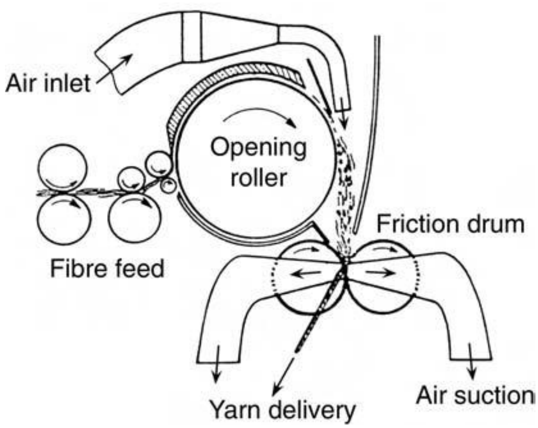
As the twist in the yarn runs into the fibre band in the rotor groove, the inner layers of the yarn tend to have higher levels of twist than do the outer layers. Fibres landing on the rotating fibre band close to the yarn tail, or landing directly on the rotating yarn arm when the yarn arm passes the exit of the transportation tube, tend to wrap around the yarn instead of being twisted into it. These wrapping fibres are characteristic of rotor-spun yarns.

Rotor spun yarns usually have lower strength than ring spun yarns of the same components and count because there is poorer fibre disposition within the yarn, although the rotor spun yarn tends to be more consistent in its strength along its length. This is the result of the combined effects of using an opening roller to open up the fibres, transporting the fibres by airflow, and the low yarn tension during yarn formation. The wrapping fibres also lead to a rougher yarn surface. The back-doubling action gives rotor yarns a better short-term evenness than ring spun yarns.

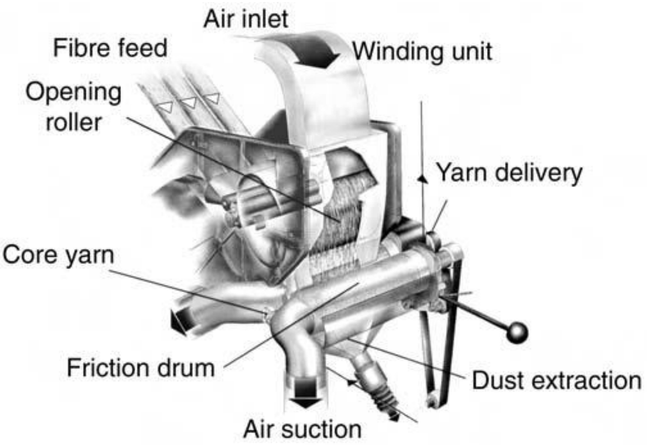
Rotor spinning is used almost exclusively for spinning short staple fibre yarns. Recent developments in electronic control have allowed the development of rotor spinning machinery that is capable of producing slub yarns. These yarns are used in furnishings and drapes, rather than in apparel fabrics, although they are sometimes used in denim fabrics. They are produced by attachments to ordinary open end spinning devices, which usually incorporate an electronically-controlled device to briefly accelerate the drawing-in roller. As a result of the back doubling action inside the rotor, it is not possible to produce slubs shorter than the circumference length of the rotor because any variation in the fibre feed stock is spread over a minimum length of the rotor circumference. There have also been attempts to use injections of pressurised air into the fibre transportation tube to alter the fibre flow and thus introduce variations in the yarn. However, the effects created using this approach are very limited since the fibre flow in the transportation tube is extremely thin and the variation in the yarn caused by changes in the airflow is consequently very small.

The friction system

Friction spinning is an entirely different open end spinning technique. Instead of using a rotor, two friction rollers are used to collect the opened-up fibres and to twist them into the yarn. The principle is shown in Fig. 7.9. Unlike ring or rotor spinning machines that are produced by many manufacturers around the world, friction spinning machines are at present made



7.9 Friction spinning principle.



7.10 DREF 2 friction spinner.

only by Dr. Ernst Fehrer AG of Austria. Figure 7.10 shows the DREF 2 machine. The company also produces the DREF 3 machine, which has an extra drafting unit on the side of the machine in order to feed in drafted staple fibres to form a core component. The most recent offering from DREF is the DREF 2000 machine, which essentially operates on the same principle as the earlier versions.

The fibres are fed in sliver form and are opened by a carding roller. The opened fibres are then blown off the carding roller by an air current and transported to the nip area of two perforated friction drums. The fibres are drawn onto the surfaces of the friction drums by air suction. The two friction drums rotate in the same direction and twist is inserted into the fibre strand because of the friction between the fibre strand and the two drum surfaces. The yarn is withdrawn in the direction parallel to the axis of the friction drums and is delivered to a package-forming unit. A high twisting speed can be achieved even when using a relatively low speed for the friction drums, because the friction drum diameter is so much larger than the yarn diameter.

Because the yarn is withdrawn from the side of the machine, fibres fed from the machine end away from the yarn delivery tend to form the yarn core while fibres fed from the machine end closer to the yarn delivery tend to form the sheath. This characteristic can be conveniently exploited to produce core – sheath yarn structures for particular purposes such as a yarn with the strength of a polyester core and the natural feel of a cotton sheath. Furthermore, additional core components, filaments or drafted staple fibres, can be fed from the side of the machine while the fibres fed from the top of the machine, the normal input, form the sheath.

The fibre configuration in friction spun yarns is very poor. When the fibres come to the friction drum surface, they are obliged to decelerate sharply from a high velocity to become almost stationary. This causes fibre bending and disorientation. Due to the very low tension in the yarn formation zone, fibre binding within the yarn is also poor. As a result, the yarn has a very low tensile strength and in most cases only coarse yarns, of 100 Tex and above, will be produced.

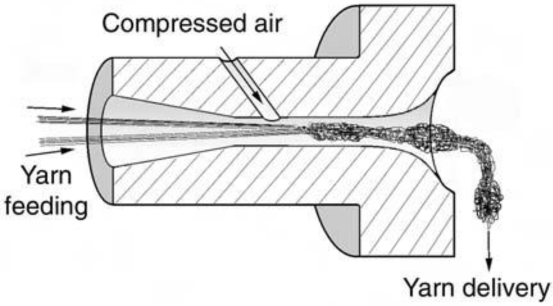
The main application of friction spinning is for the production of industrial yarns and for spinning using recycled fibres. The process can also be used with aramid and glass fibres and with various core components including wires.

Slub yarns, which are potentially important for decorative effects, can be produced on the friction system by changing the feed speed of one or more of the slivers, or by injecting fibres directly into the friction zone. However, the yarn tends to offer low performance in processing and use, as a result of the poor binding of the fibres in the yarn indicated earlier.

7.2.7 Airjet texturing

Also referred to as 'airjet texturising', airjet texturing was introduced by DuPont in the 1950s, and was then known as the Taslan® process. It may be used on all types of synthetic flat filament, and is used for texturing POY (Partially Oriented Yarns) and fully drawn yarns. In some cases, the speed of processing can reach more than 900 metres per minute. Figure 7.11 shows the basic principles of the process.

The flat filaments are wetted, in order to improve process stability by reducing filament to filament friction, and fed into the texturing jet. The material is then blasted with high pressure air or steam that accelerates to supersonic speeds and forces the filaments to buckle and mutually entrap each other in the turbulent airstream. These air jets are enclosed in a 'jet box' which reduces noise and collects the water and spin finish as it is washed off the yarns. Following this, heaters are frequently used to remove the water remaining at the end of the process and to set the bulk



7.11 Airjet texturing.

of the finished yarn. Because the filaments buckle and loop during the texturing process, they need to be overfed as compared to the final delivery speed.

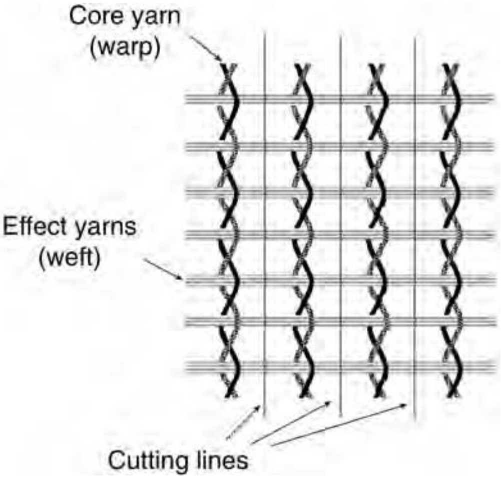
It is possible to use airjet texturing to combine two or more threadlines, which may vary in several ways. This allows the resultant yarn to be 'engineered' in terms of both its composition and its properties, and it opens the way for the production of what appear to be 'fancy yarns'. The basic technique consists of feeding in several 'ends' of flat filament at differing speeds. The yarn created by this process is becoming more frequently used in apparel fabrics as developments in the filament feedstock and the precise texturing techniques result in yarns that are becoming increasingly comfortable in wear, unlike some of the early ones that, through a combination of poor feedstock choice (in terms of both polymer and filament denier) and less sophisticated techniques, produced yarns with no elasticity and relatively poor aesthetic appearance. These new airjet textured yarns are beginning to be used for knitted fabrics, and indeed are even used in fabrics for intimate apparel. All airjet textured yarns have a reduced tensile strength compared with an untextured filament yarn because of the confusion of the filaments.

Fancy yarns – primarily slubs and bouclés – can be made, and if the filaments are chosen carefully, can be very successful, but the market for them, in recent years at least, has been much reduced. However, as recent developments begin to come into production we can expect to see that situation change. In particular, metallic filaments can be processed to create new types of metallic yarns, with varying degrees of lustre and a range of other properties. The vast speeds achievable in airjet texturing (especially in comparison with conventional fancy twisting) offer sufficient commercial incentive to encourage research in producing a range of fancy effects by this means. In addition, work involving new filament profiles and new production techniques will allow more and more variety to be introduced into the yarns created using this process.

7.2.8 Methods of creating chenille yarns

Weaving

A chenille yarn was in times past produced by weaving a leno fabric, which was then cut into narrow warpwise strips. This is illustrated in Fig. 7.12. The yarn so produced had projecting tufts formed by what had originally been the weft yarn of the leno material. This technique has been superseded by a variety of new systems, which create more or less convincing copies of the chenille effect. The old, leno-woven method may still be used in some very specialist applications, but the scarcity and expense of this particular effect



7.12 Chenille yarn production by weaving.

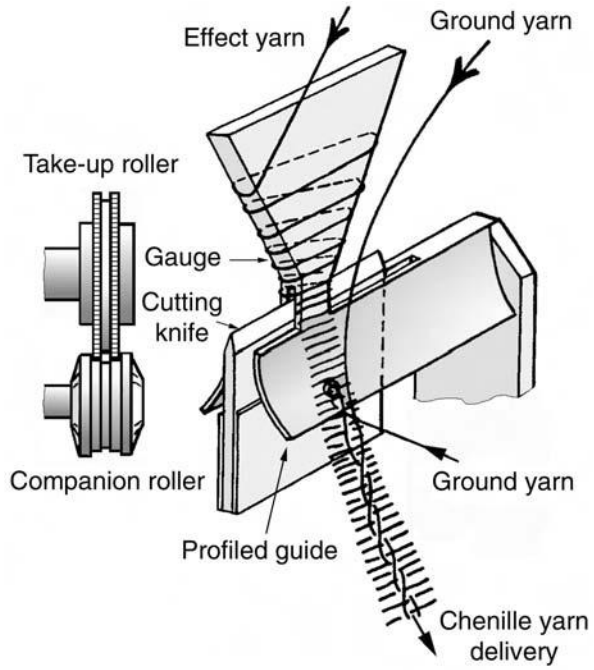
when this was the only method is sufficient testimony to the relative slowness and difficulty of the technique. It is not really a viable alternative if the goal is to create yarns for the mass market.

The chenille system

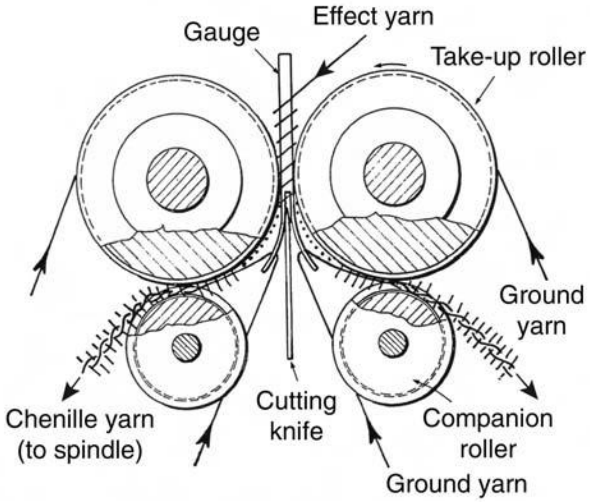
A method of producing a chenille yarn has been developed which produces two ends at each unit. This is illustrated in Figures 7.13 and 7.14. The effect yarns are wrapped around a gauge or former that is triangularly shaped at the top, narrowing towards the base to allow the effect yarn coils to slide downwards onto the cutting knife. The width at the bottom of the gauge determines the effect length, by maintaining the depth of the pile, or 'beard', in the final yarn. Although, for the sake of simplicity, the cutting knife is shown in Figures 7.13 and 7.14 as a straight knife edge, the modern machines all use a circular cutting knife.

On each side of the cutting knife there are two ground yarns, which may be either singles or two-fold yarns. One ground yarn is guided by the take-up roller while the other is guided by the companion roller. The take-up roller is pressed against the profiled guide and intermeshes with the companion roller, allowing the two ground yarns to trap the pile created by the effect yarn in between them, at right angles to the ground yarn axis. The two ground yarns are twisted together, usually by a ring spindle at the lower part of the machine, to produce the final yarn.

In the early years of this technique, several factors militated against the popularity of the yarn. First of all, like all new systems, the technique was not without its problems, and much research and effort was needed to



7.13 Chenille yarn production (1).



7.14 Chenille yarn production (2).

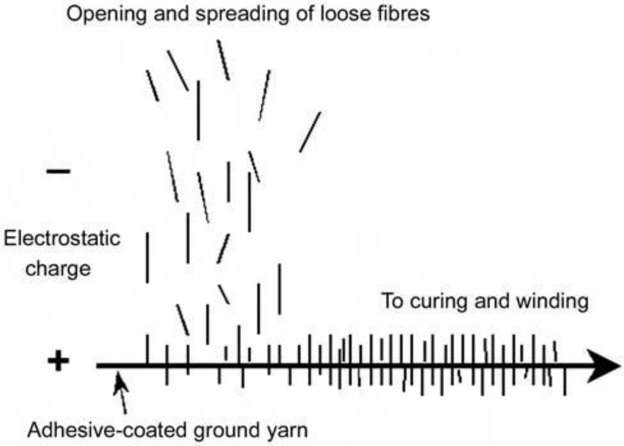
develop the expertise needed to manage the new system. In addition, the chenille effect is one that has distinct phases of popularity (and by contrast unpopularity), and since the machines developed to create chenille type yarns can do nothing else, the purchase of them could be clearly seen to be a gamble. Further, the yarn does have a very distinct weakness – it does not have very good inherent abrasion resistance.

When the yarns are in use, clearly the abrasion resistance of the chenille yarn is crucially important, in particular because the effect sought is always that of the velvety feel of the pile, and the bald look of worn velvet or chenille is not appealing. Any removal of the effect yarn forming the beard, either during further processing or during the eventual end-use, will expose the ground yarns, which in turn will result in this bare appearance. To avoid this undesirable result, several options are available, or a combination of them may be chosen. These include creating a longer beard that will offer greater resistance to being pulled out and will also take longer to abrade: clearly, whether or not this option is selected is dictated mainly by the desired yarn appearance. Other options include the use of longer fibres in the effect yarn and of a higher twist level in the creation of the chenille itself, in order to offer greater resistance to the removal of the effect yarn. Careful choice of the effect and ground yarns to increase the inter-fibre friction may also assist in reducing the rate of loss of the effect.

The use of chenille yarns in domestic furnishing is sufficient proof that great strides have been made in rendering this aesthetically appealing yarn useable in situations where the fabric is subject to considerable abrasion. These important characteristics are also enhanced by the use of higher twist levels, although the addition of a thermoplastic filament to the composition is another development that has significantly reduced the main problem of shedding to which early chenille yarns were prone. The use of thermoplastic fibre, of course, brings its own challenges in production, especially since the relatively low melting point may result in activation of the filament at the wrong time; or alternatively, if the temperature of the thermosetting device is too high, the thermoplastic filament may melt completely and run down the 'beard', settling in beads on the ends of the fibres.

Like velvet and other pile fabrics, the chenille yarn made using this process has what is in effect a nap (see Fig. 7.15 and Plate 1, Example B). This is caused by the interlacing of the pile and the core, and it means that in later treatment of the yarn, the number of winding processes need to be carefully monitored in order to ensure that the nap lies in the same direction on all cones or cheeses in a batch. If this is not done, the fabric in which the yarn is used will show colour differences resulting from the differing reflectances of the nap, which depend upon the angle of the pile and of the light.

7.15 Chenille structure showing nap.



7.16 Flocking process.

Flocking

Chenille effects can also be produced by a flocking process in which a ground yarn coated with adhesive is flocked electrostatically with loose fibres (Fig. 7.16). The loose fibres and the ground yarn are charged with opposite electrostatic charges. As a result of this, the loose fibres are attracted to the ground yarn and are bonded to it by the adhesive. The loose fibres have the same electrostatic charge and they repel each other, ensuring good fibre separation and also forcing them to 'stand' on the ground yarn rather than lie flat on the ground yarn surface. This is a very economical production method, but the yarn has poor abrasion resistance because the anchor of the loose fibres onto the ground yarn is small and these loose fibres can very easily be worn off, leaving the ground yarn bare.

Mock chenille

A mock chenille effect can be produced by plying two gimp or bouclé or loop yarns with dense effects; for example, two loop yarns with large numbers of small loops. The yarn may not look like a chenille, but when it is made into fabric, the large number of small loops in the fabric results in a fabric surface that resembles a chenille effect.

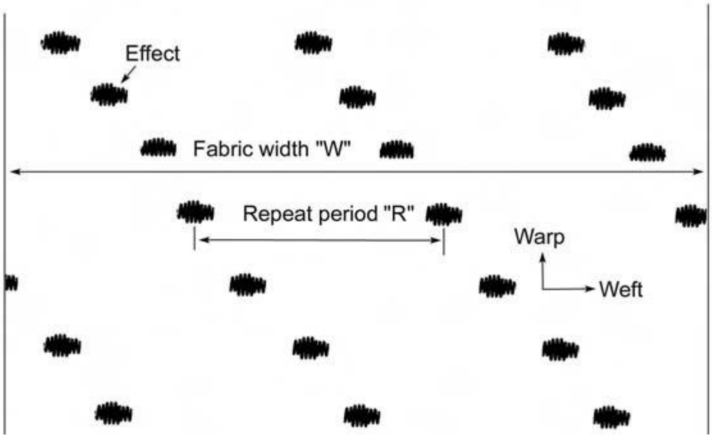
7.2.9 Dyeing

Fancy coloured yarns may be produced by such techniques as space dyeing or ombré dyeing. Cross dyeing effects and dye-injected rovings or slivers all contribute to a range of fancy effects, and all offer original creative opportunities to the designer. The printing of patterns onto comber sliver or other fibre materials is another variation on this technique.

In addition, continuing research in wool treatments has allowed the development of dye resist techniques that may also be of value in this field.

7.2.10 The phenomenon of 'striping'

Machines that create intermittent fancy effects need to include some form of randomisation mechanism to eliminate any possibility of 'striping' effects. This 'striping' occurs if the effect introduced in a yarn, of whatever nature – colour, volume, texture – has a 'period of repetition' that can be expressed as a multiple of the width of the fabric in which it is used. It is manifested in the form of warpwise or angled stripes in the fabric as the effect repeats. Since this effect can be seen even when the multiple is not a whole number, it follows that patterning of some form will appear whenever there is any type of repeating variation. Assuming the fabric width is *W* and the repeat period is *R*, if *R/W* (when *R* is larger than *W*, which is more likely to be the case) or *W/R* (when *W* is larger than *R*) is a whole number, warpwise stripes will appear in the fabric. If *R/W* or *W/R* is a whole number plus a fraction, an angled pattern will appear in the fabric. In Fig. 7.17, *W/R* is just less than 3 and the effects will appear slightly to the right in successive weft lines in relation to those that appear in the weft line just



7.17 Striping or patterning in a fabric.

above. This results in the angled pattern shown in Fig. 7.17. If the period of repetition is altered in relation to the width of the fabric, the angle of the stripe will change, but it will always be present to some degree.

The human brain is especially skilled at pattern recognition, so even if such a pattern is not exact, it will normally be possible to discern it. In weaving, the use of multiple cheeses for weft input allows the patterning in woven fabrics to be attenuated, and if the period of repetition is long enough in relation to the expected uses of the fabric, this form of patterning may not present too serious a problem. Clearly, however, it is greatly to be preferred that there should be no patterning at all. In early machines that were developed for the production of fancy doubled yarns, this potential difficulty was addressed by a range of mechanical techniques.

More recently, with the development of microprocessor-controlled equipment for the design and production of fancy doubled yarns, it has become possible to create yarns with intermittent effects that occur randomly, or randomly within certain boundaries. In fact in strict mathematical terms, this randomness is only ‘pseudo-randomness’, in that the algorithms employed will always produce the same results from the same starting-point. However, since the results show neither pattern nor period, there will be no regularity or even approximate regularity for the eye to detect. The work already undertaken to deal with this question, and to create machines that employ these techniques, has become much more important since it has become possible to produce the intermittent effects, and especially as these intermittent effects have become more striking. In particular, the ‘button’ and ‘flammé’ yarns that can be produced on modern, electronically-controlled hollow spindle machines are sufficiently dramatic for any regular repeating pattern in the yarn to become very obvious in the fabric. These novelties have brought with them the new challenge of avoiding or eliminating patterning and striping effects, and have demonstrated yet again the usefulness of applying a mathematical understanding to ordinary events.

Striping does not pose a risk only to makers and users of fancy yarns. On the contrary, their awareness of the unfortunate effect produced by striping in fabrics has given the manufacturers of many different types of textile processing machinery much cause for thought over the years. It is not merely the deliberately introduced intermittent effect that can create striping, the risk of striping is found in the package dyeing of yarns as well, since the differing pressures at different points in a cross-wound package may influence the dye take-up shown by the yarn at these different levels. However, in the future it may become possible for this characteristic, hitherto seen as an undesirable artefact of the manufacturing process, to be harnessed in new ways to produce new and intriguing effects.

7.3 Yarn and fabric trials

In order to demonstrate some of the basic effects of changing process parameters on the yarn and fabric appearance, a number of fancy yarns were produced under laboratory conditions and then woven and knitted into fabrics. This section presents a comparison of those yarns and fabrics.

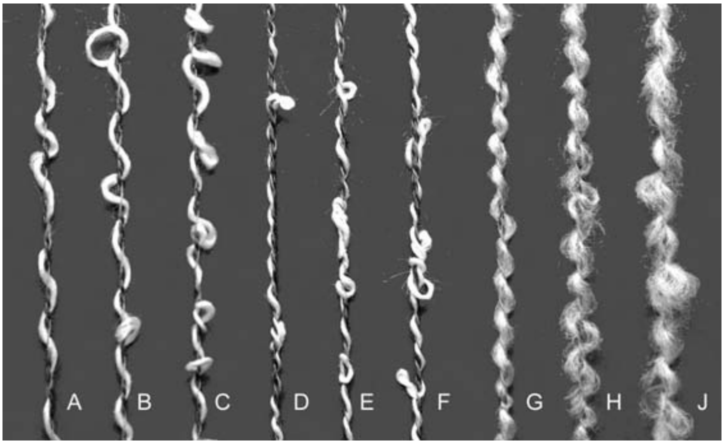
7.3.1 Production details

Two sets of yarns were made, the first using a Calvani Fancyjet-6 ring twister and the second using a Gemill & Dunsmore hollow spindle machine. Obviously, the hollow spindle apparatus created a yarn in a single passage of the machine, whereas the ring twister required two separate passages of the machine. The first assembles the core and effect components, while the second applies a binder in the reverse twist direction, and in doing so also 'opens out' the twist applied in the first process and creates the final balanced yarn. For both machines, the same core yarns, binder yarn and effect yarn were used. Three overfeed ratios – 140%, 180% and 220% – were used on each machine. In addition, three fibre-effect yarns were made on the hollow spindle machine using the same overfeed ratios in order to offer clear demonstrations of the special characteristics of a fibre effect in comparison with a yarn effect.

In general, the successful production of the anticipated effect involved substantial experimental efforts, which were mainly concerned with two factors. These were the spacing of the two core yarns and the twist level. With inappropriate spacing and twist, there were frequent breakages of the ground yarns and even, occasionally, of the effect yarn. It was also noted that there was a higher number of breakages when starting from an empty bobbin. Furthermore, the effects tended to be unstable, especially when the machine was first started with each new set-up. This is clearly due to the higher tension and the tension variations involved when starting from an empty bobbin. Little difficulty was encountered with the hollow spindle machine in the production of yarn effects, but in producing the fibre effect yarns, some roller lapping occurred at the higher overfeed ratios. This could be resolved by reducing the delivery speed.

7.3.2 Yarn samples

The nine yarn samples are shown in Fig. 7.18. Yarns A, B and C were produced on the Calvani ring twister using overfeed ratios (of effect yarn to core yarn) of 140%, 180% and 220% respectively. Yarns D, E and F were produced on the hollow spindle machine with the same component yarns, using a wrapping density similar to the twist used on the Calvani twister



7.18 Trial yarn samples.

and with the same corresponding overfeed ratios. Yarns G, H and J were produced on the hollow spindle machine with the same core and binder yarns, but the effect was produced from a roving, again using overfeed ratios of 140%, 180% and 220% respectively.

For the yarn effects (examples A to F), there are obvious increases in the frequency, or density, of the effect as the overfeed ratio increases, but the increases in the size of the effects are much less noticeable, except in the changes from yarn A to yarn B.

There are also clear differences between the ring yarns and the hollow spindle yarns of the same overfeed ratio. The hollow spindle yarns are much more compact than the ring yarns. This is the result of the binding process that is necessary for the ring yarns. As the binding process uses a twist that is opposite in direction to that of the initial twist, the effect yarn twist became much lower in the final yarn created on the ring twister, thus creating a bulkier and softer appearance. The higher degree of snarling in the hollow spindle yarns is also due to the high twist level of the effect yarn. The high snarling tendency was also noted in the ring yarns after the first 'assembly' stage, prior to the final binding process.

For the fibre effect yarns G, H and J, the size of the effect increases with the overfeed ratio while the frequency or density of the effect seems to be only a function of the binder wrapping density.

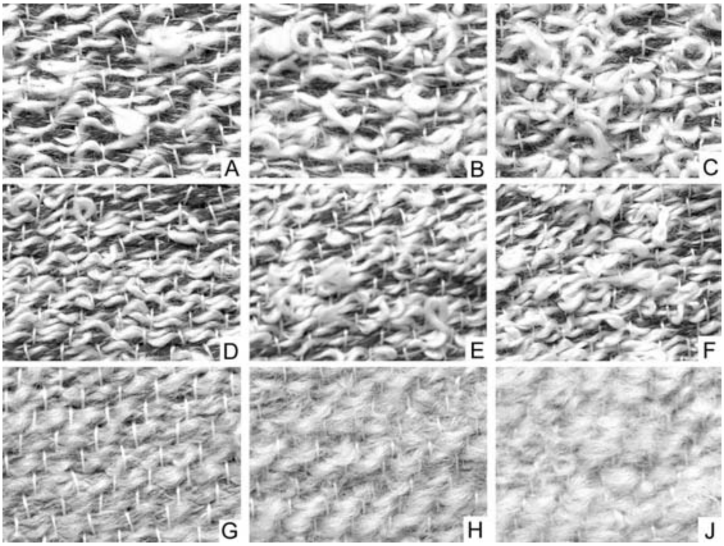
7.3.3 Fabric samples

Woven

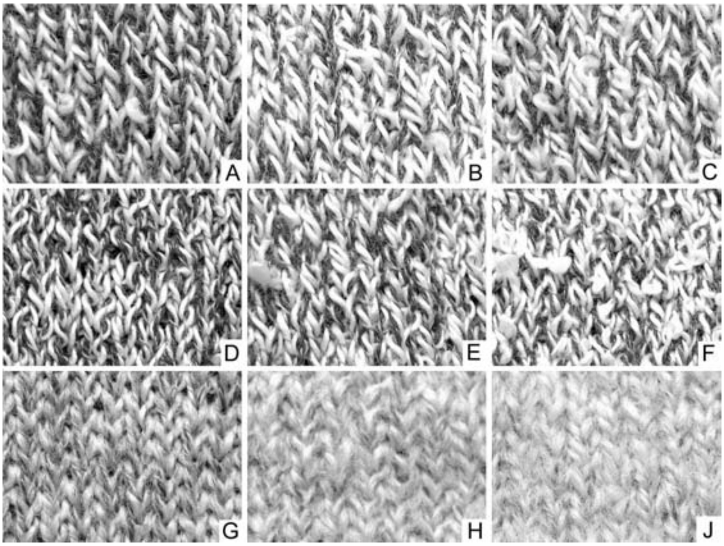
The nine yarns described in the above section were woven on a Bonas SUPERTEX narrow fabrics rapier loom. A standard yarn was used as the warp in all cases while the fancy yarns were used for the weft. In order to emphasize the fancy effect, a weft-faced 3 for 1 twill weave was used. The fabrics are depicted in Fig. 7.19. The appearance of the fabrics is dominated by the effect yarn, even when the overfeed ratio is only 140%. The increase of the surface effect with the overfeed ratio is quite as expected.

Knitted

The nine yarns were also knitted into fabrics using a Dubied flat V-bed hand knitting machine with a gauge of 4.5 (see Fig. 7.20). A plain, single jersey structure was used to reduce the sometimes confusing visual effect of a combination of fabric and yarn structures, since the object of these trials was to provide clear, simple examples demonstrating fancy effects in their simplest application. Even though the knitted fabrics were made completely from the fancy yarns, the effects in the fabrics appear less dramatic than those on the woven fabrics. It would have been more effective, aesthetically, to combine the fancy yarns with some standard yarns in the fabric and to introduce contrasting appearances by using the different yarns. This, in fact, is a widely used practice in the industry, since it allows designers to maximise the visual effect of the sometimes expensive fancy yarns while at the same time reducing the financial impact of their use. It must also be pointed out that the fabrics shown here are all in greige state and, as such, the structures are uneven in appearance.



7.19 Trial woven fabrics.



7.20 Trial knitted fabrics.

7.4 Future developments

There will no doubt be continuing development of new machines and faster processes – or at least, so one might hope and expect. Quite apart from anything else, we have already commented that the greatest surges in market interest over the past two decades have always been associated with the evolution of new machines and new production processes.

It is possible that upper limits for production speed have already been reached for some of the current processes, and that further advances will lie in the field of innovative production techniques that may, in and of themselves, produce new yarn types and combinations. The hollow spindle and the chenille manufacturing techniques are both developments of the past few decades, and the latter system has made the production of this particular yarn very much less expensive than once it was. The development of the small circular knitting machines to produce 'chainette' and 'tape' yarns, or of braiding and warp knitting for the same purposes, has been continuing quietly for some time.

The major achievements of the past two decades have rested, to a significant degree, on the increasing use of electronic controls for the machinery. In particular, increasing electronic control has resulted in the development of computer-aided management and diagnostic systems that increase the data available to the production department. Thereafter, this data may be linked to a company-wide stock tracking and management system. The hope is that such innovations will permit the streamlining of the production process, which in turn will limit machine downtime and thus improve profitability. However, in the developed world at least, it should be borne in mind that even the most up-to-date computer-aided production will not make the production of commodity goods economically viable in countries where both wages and social costs are high. The production of fancy yarns or equivalent high value, high margin items seems likely to be the best route to business growth in such areas.

Further developments could also lie in the application of new materials science to the conventional spinning systems, to improve the performance and durability of machine parts, to reduce end breaks or to increase production speeds.