12. Spinning

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Learning objectives

On completion of this topic you should be able to:

- Describe the preparation of the materials required for the three spinning systems
- Explain the purpose and device used for drawing to form a roving
- Outline the principles of ring spinning, in particular the functions of the key parts of a spinning frame
- Explain the purpose of the traveller and the parameters that control its performance
- Describe what an end-break is, and why it occurs
- Outline the process of package formation
- Compare the essential features of worsted, semiworsted and woollen ring spinning frames
- Explain the role of the false twist device in woollen spinning
- List the features provided with modern ring spinning machines

Key terms and concepts

Woollen, worsted, semiworsted spinning, drawing, drafting, roving, ring spinning, false twist, traveller, bobbin, balloon, end breaks, package build, roller drafting, Sirospun, compact spinning, spinning triangle, Solospun

Introduction to the topic

While the term *spinning* is commonly used to describe the entire yarn-making process, in this topic the more specific meaning applied, i.e. the formation of yarn by drafting, the insertion of twist and forming a package.

The ultimate aim of spinning is to produce a coherent and cohesive strand of fibres (i.e. a yarn) of the required linear density (count) and which has good evenness, tensile properties and a minimum number of faults.

Spinning can be divided into three basic operations:

- Attenuation (drafting) of the roving (worsted), sliver (semiworsted) or slubbing (woollen) to the required linear density
- Imparting cohesion to the fibrous strand, usually by the insertion of twist
- Winding the yarn onto an appropriate package.

Spinning machines can be divided into two main groups:

1. Intermittent (e.g. mule)
2. Continuous (ring, flyer, cap, open-end, self-twist, etc..)

Today the worsted mule (http://www.cottontimes.co.uk/cromptono.htm) is almost only found in museums, cap spinning is limited to a few specialist spinners mostly spinning very fine yarns, and flyer spinners are sometimes used for coarse count yarns, such as for hand knitting.

Ring spinning using a traveller to guide the yarn onto the package was invented by Addison and Stevens in the USA in 1829. It has developed into the most successful form of spinning and is widely used for spinning cotton, worsted, woollen, flax, spun silk and manmade fibres. Because of its versatility in terms of yarn linear density and fibre type and also the superior quality and character of the yarn it produces, conventional ring spinning remains by far the most popular system for spinning wool. This is especially true for fine wools. This topic will therefore focus on the ring spinning route, and recent adaptations to this method.

The references for this topic are Lawrence (2002), Hunter (2002) and Oxtoby (1987).

12.1 Preparation for spinning

The amount of preparation for spinning depends on the processing route:

Woollen

The slubbing produced by a woollen card is ready for spinning, and no further preparation is required.

Semiworsted

The sliver, which has received several gillings (usually three) after carding, is ready for spinning and no further preparation is required. However, eliminating intermediate stages such as the roving requires high drafts, precise drafting and also good fibre control. Alternatively, rovings may be used for fine yarn production, with similar preparation as for worsted yarns (see below).

Worsted

The raw material for worsted spinning is a top, a highly uniform sliver prepared by topmaking, which is a sequence of carding, gilling and combing steps. The top must be further processed in the worsted spinning plant before spinning can commence.

It is not possible to spin relatively fine, even yarns in the semiworsted process because the steps that eliminate the beneficial effects of sliver feed reversal and doubling are limited. The worsted process uses a sequence of steps, called *drawing*, to gradually reduce the linear density of a sliver by a drafting action. At the same time, the movement and alignment of fibres and the sliver linear density and evenness must be controlled.

A top has typically 25,000 fibres in its cross-section, a roving around 800 fibres and a singles yarn, 35 fibres. Drawing, which combines both drafting and doubling actions, enables a roving (twisted or twistless) to be produced from a top. In this form, the efficient spinning of a yarn of the desired linear density and quality is possible.

12.2 Worsted drawing

Gilling

The top delivered from a top-making plant requires further mechanical treatment in order to produce a quality worsted yarn. This preparation stage is drawing, with the objectives:

- Reduction in the linear density (weight) of the top sliver
- Blending and regularising the sliver
- Fibre straightening.

Drawing (i.e. doubling plus drafting) consists of three or four gilling processes, the first two with autolevellers to enhance sliver evenness. The pinning on the fallers becomes progressively finer with each process. The more gradually the sliver weight is reduced, the better the resulting yarn. In order to improve production rates 2, 3 or 4 head deliveries are used.

Typical gilling conditions for three-gill sequence are shown in Table 12.1

Table 12.1 Gilling conditions in worsted spinning. Source: Wood, 2006.

Gilling	Doubling	Draft ratio	Output linear density
1	8	8	~ 16 ktex
2	4	8	~ 8 ktex
3	3	6.5	~ 3.5 ktex

Roving

A roving frame is used when the number of fibres in the cross-section is such that fibre control in drafting cannot be achieved with pins. The input sliver has 5 – 10 times less fibres in the cross section than the starting top.

The roving process is the final step before spinning. The objectives are:

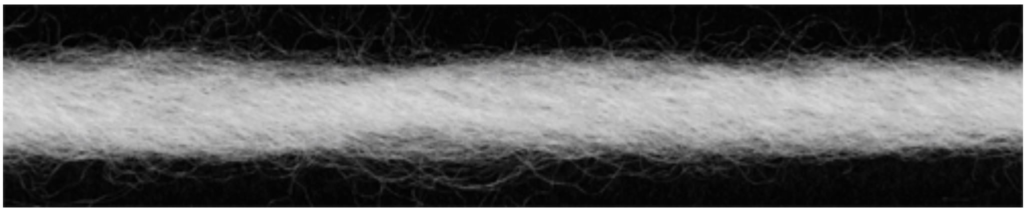
- Reduction in the linear density of the sliver
- Blending and regularising the sliver
- Improvement of strength and cohesion
- Package formation.

The sliver produced by the final gilling of the drawing process is drafted by a factor of 8-20 between two pairs of rollers, using double aprons for fibre control. The resulting strand of fibres is extremely delicate and needs to be consolidated to improve its strength and cohesion.

This is done either by (a) passing the strand between oscillating rubbers or (b) inserting some twist. Sufficient strength is required for both winding on and winding off the delivery package. Two rovings are wound on to each take-up bobbin to save creel space during spinning. One bobbin serves two spindles, with a roving for each.

A section of roving is shown in Figure 12.1.

Figure 12.1 Roving. Source: Wood, 2006.



Rub roving

This is the most common method of roving formation for fine, cohesive wools. The strand of fibres produced in drafting is passed between a pair of oscillating leather aprons. These roll the fibres, thereby consolidating them in the strand and increasing the inter-fibre friction. The resultant roving is wound on to a barrel, with normally two rovings side by side. Modern machines run at 200 metres per minute, and often have automatic doffing facilities. Horizontal and vertical frames operate on the same principle.

Figure 12.2 shows the double apron drafting section of a Schlumberger roving frame, and the rubbing section is shown in Figure 12.3. The roving rubbing is achieved by a pair of grooved rubber aprons. It is possible to set the oscillating frequency of the upper apron at 5, 6 or more rubs per metre.

Figure 12.2 Double apron drafting section of roving frame. Source: NCS Schlumberger (a).

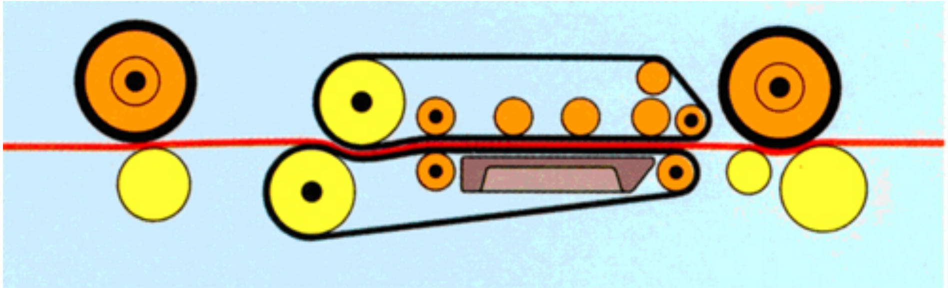


Figure 12.3 Rubbing section of roving frame. Source: NCS Schlumberger (a).

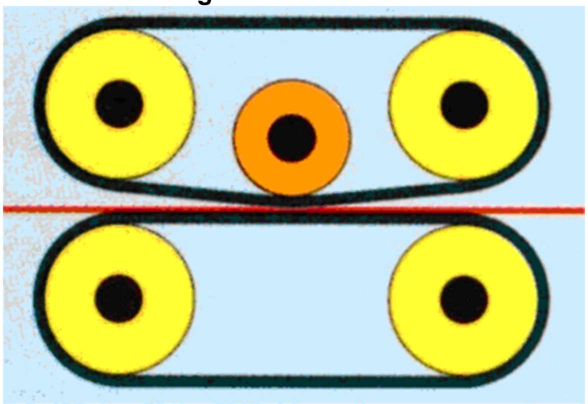
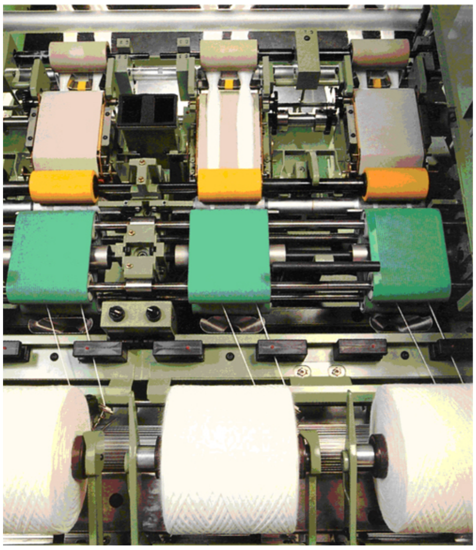


Figure 12.4 shows the layout of a horizontal roving frame, with the drafting section opened up to display the pair of slivers in position.

Figure 12.4 Vertical roving frame (Schlumberger) showing the drafting section (top), rubbing section (middle) and package formation (bottom). Source: NCS Schlumberger (a).

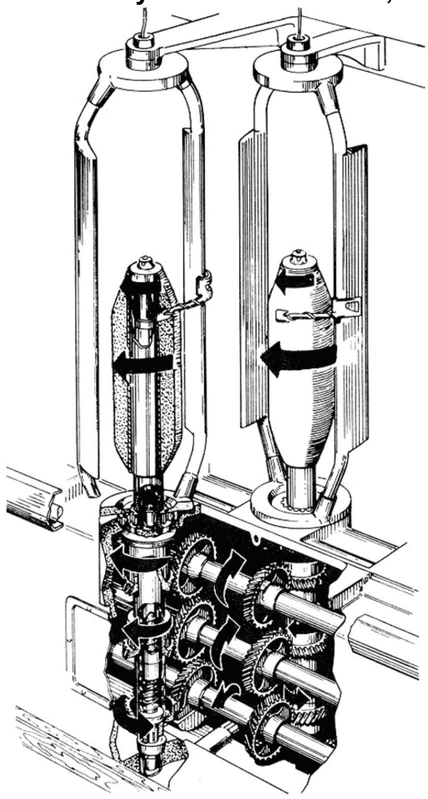


Twisted roving

The sliver is usually drafted first, using an apron drafting system. The strand of fibres thus produced is passed down the inside of an arm of a positively driven rotating flyer on a cone roving machine (Figure 12.5). This causes the fibres to be twisted together and the resulting compaction of the strand gives it cohesion. The roving produced is wound onto a positively driven bobbin. The level of twist inserted is usually quite low.

Because it is required to rotate large flyers, this method of producing rovings is much slower than the rub roving method. Maximum achievable speeds are around 100 metres per minute. However, because the bobbin is positively driven and the roving does not have to pull the bobbin around, a large package can be formed. The spindles may rotate at around 1,800 rpm or higher.

Figure 12.5 Twist roving on a cone roving machine, showing the positive drives to the spindle and flyer. Source: Wood, 2006.



12.3 The principles of ring spinning

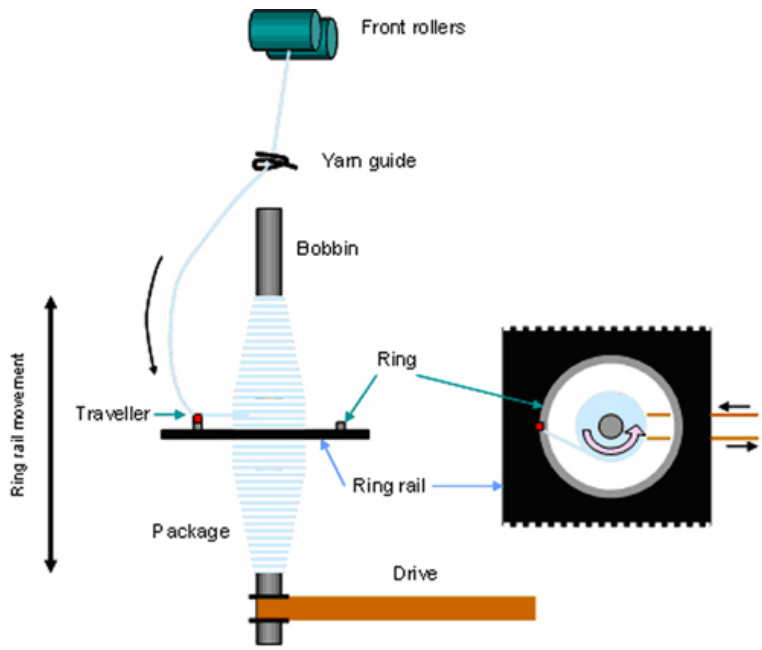
The input into a ring frame can be any of the following:

- Twisted (flyer) rovings – worsted and semiworsted system
- Twistless (rubbed) rovings – worsted and semiworsted system
- Sliver – semiworsted system
- Slubbings – woollen system

Double apron drafting, with drafts typically around 20, is generally used in modern ring frames, except in low draft woollen spinning and some of the high draft spinning systems.

Figure 12.6 shows the essential features of a single spindle which is one production unit of a ring spinning frame.

Figure 12.6 A single spindle of a ring spinning frame. Source: Wood, 2006.

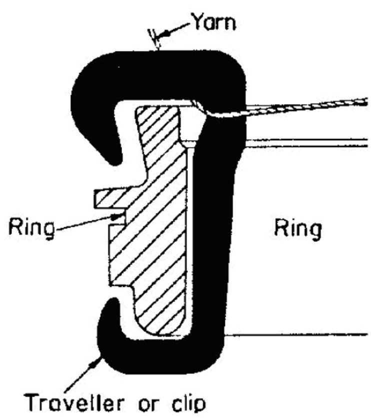


The spindle is driven by a tape or belt, making the yarn tube or bobbin rotate at speeds of up to 17,000 rpm. Surrounding each spindle is a flanged metal ring fastened in a ring plate. During the operation of the frame the ring plate traverses up and down to distribute the yarn on the bobbin.

In the upper flange of each ring is a small metal or synthetic clip called a traveller (Figure 12.7), which is free to rotate around the ring. The yarn coming from the front rollers is threaded through this traveller and fastened to the bobbin. Winding-on of the yarn is accomplished by the travelling lagging behind the spindle and bobbin, the yarn thus being drawn on to the bobbin; i.e. the traveller guides the yarn on to the bobbin. The level of twist inserted in the yarn is governed by a combination of the surface speed of the front rollers and the rotational speed of the spindle.

To reduce friction between traveller and ring, oil is continually applied to the ring as a lubricant.

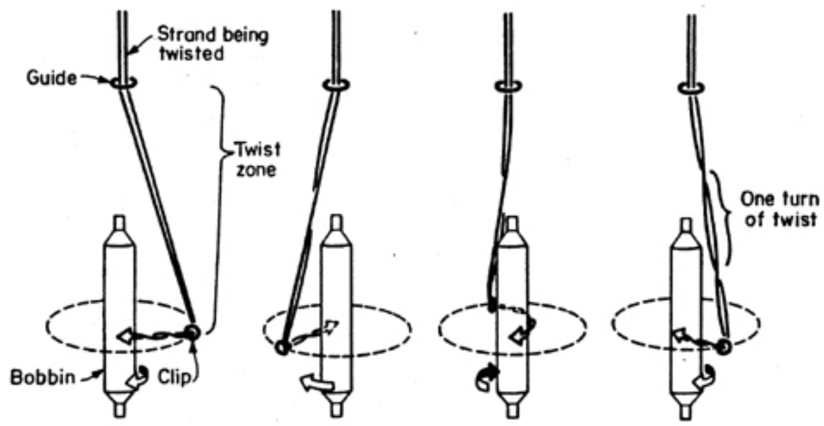
Figure 12.7 Traveller on ring. Source: Wood, 2006.



Ring spinning frames are used for worsted, semiworsted and woollen yarns, the major differences being the sizes of packages and travellers, the diameter of the ring and the drafting rollers.

Figure 12.8 shows the mechanism by which twist inserted as the traveller moves around the ring. One cycle of the traveller on the ring inserts one turn of twist in the strand.

Figure 12.8 Inserting one turn of twist. Source: Wood, 2006.

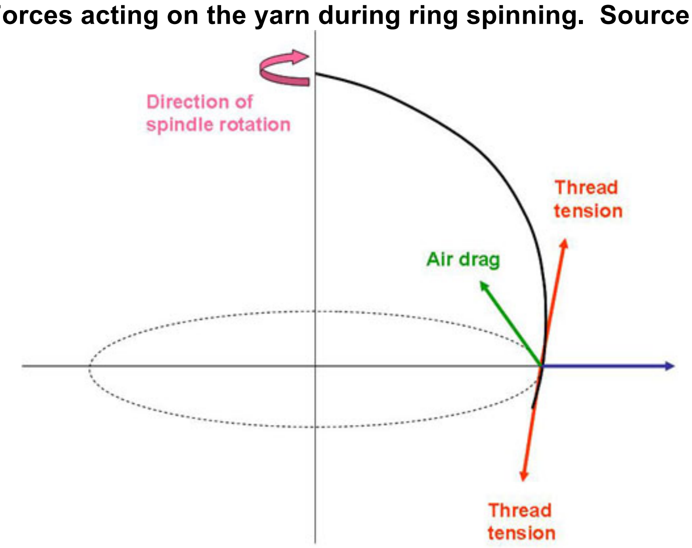


The tension applied to the yarn is affected by the air resistance on the yarn, the friction of the ring and traveller and the centrifugal force set up as the 'balloon' of yarn and the traveller revolve (Figure 12.9). (The balloon is the curved section of yarn between the guide and the traveller). These in turn are influenced in varying amounts by:

a) the mass and shape of the traveller
b) the yarn count and twist
c) the diameter of the ring in relation to the diameter of the bobbin
d) the speed of the bobbin, which impacts on the speed of the traveller.

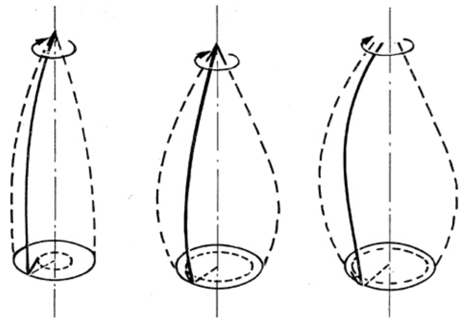
The usual method of altering the tension or drag is to change the size (mass) of the traveller. A heavier traveller imposes a greater tension while a light traveller causes more ballooning. In general, heavier travellers are used for heavier counts and usually the maximum traveller mass is used which is consistent with good spinning performance, i.e. an acceptable rate of end-breakages. As a last resort it may be necessary to reduce the spindle speed to control the end-breakage rate.

Figure 12.9 Forces acting on the yarn during ring spinning. Source: Wood, 2006.



The speed of the traveller is the limiting factor in ring spinning, with a maximum traveller speed of around 45 m/s. Smaller ring sizes enable high spindle speeds to be achieved whilst keeping traveller speed below the maximum. Spindle speeds range from 2000 - 17,000 rpm while ring sizes go from around 45 mm to 300 mm. Figure 12.10 shows the effect of ring size on the shape of the balloon. The balloon profile becomes larger and bulges out more at the base as the tension decreases.

Figure 12.10 Balloon shapes under various ring spinning conditions. Source: Wood, 2006.



Separating plates between each spindle prevent each yarn balloon from fouling the neighbouring spindle positions.

Traveller and spindle speeds

To maximise production, it is usual to try to run the spinning frame as fast as possible without an excessive number of end breaks occurring. The maximum spindle speed is generally determined by the end break rate, the number of operators manning the frames and the speed and dexterity of the operators in making a good *piecening* in a yarn after an end break.

The spindle speeds can be readily checked by a stroboscope, a light source which flashes at regular short intervals. When the frequency of the stroboscope light equals the rotational frequency of a spindle, the spindle appears stationary. Any slight deviations from the stroboscope frequency appear as slow rotations of the spindle. Using the stroboscope, significant deviations (~ 7 – 10%) from the required spindle speed, which might arise from belt slippage, can be identified and eliminated.

The traveller guides the yarn on to the tube and traverses up and down with the ring rail as well as moving at high speed around the ring. The travellers are typically ear-shaped and are made of steel, nylon, nylon with glass or carbon fibre and nylon with steel inserts in contact with the yarn.

The usual method of altering the tension or drag in ring spinning is by changing the size or weight of the travellers. A heavier traveller imposes a greater tension, while a light traveller allows more ballooning of the yarn to occur. Most traveller weights vary between 7 and 70 mg. The choice of traveller depends on the spindle speed (n rpm), the ring diameter (d mm), the yarn count, the yarn type and yarn strength.

The value of the product *nd* can be used as a guide to the spinning performance of a yarn, with excessive heating of the ring and traveller (which reduces traveller life) being the limiting factor. The traveller has a maximum speed of about 40 metres per second (or 140 km/h). A typical value of the product *nd* for nylon travellers is around 7×10^5.

A speed limitation arises due to the count of the yarn. When spinning yarns heavier than 200 tex from wool or wool-rich blends wear of the yarn on the traveller may occur. The yarn gradually wears a deep groove, and long before a traveller breaks this groove causes a much hairier (rougher) yarn to be produced, with possibly more end breaks.

It is usual to try to run the spinning frame as fast as possible without an excessive number of end breaks occurring. For example, if the spindles are running at 5000 rpm and the yarn is leaving the delivery rollers at 20 metres per minute then it will have 5000/20 or 250 turns per metre of twist inserted. If a high twist yarn of, say, 500 tpm is required then only 5000/500 or 10 metres per minute of yarn will be produced.

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Spinning end breaks

As the yarn is wound onto the bobbin it is under tension. A component of this tension is the force required to move the traveller against the friction between the ring and the traveller. The centripetal force of the balloon rotation also contributes to the tension, and air resistance, yarn count and twist also have an effect. If the tension on a strand exceeds its breaking strength, an end break will inevitably occur.

The important factors influencing end breaks are:

1. the number of fibres in the strand
2. the propagation of twist up the strand to this point
3. the mean tension and tension fluctuations on the strand.

The weakest part of forming a yarn will be at the point where the twist is inserted. In ring spinning this point is just below the front drafting rollers (the so-called 'spinning triangle'), and most breakages occur here. No twist exists for fibre cohesion at this point, so when the number of fibres becomes too low to support the tension on the strand of fibres, the end breaks.

Obviously, the more fibres in the cross-section of the strand, the more the yarn will be able to withstand the tension applied. Problems will arise when the number of fibres in the cross-section of the strand varies significantly or the peak value of the tension fluctuation is too high. The number of fibres is determined by the laws of probability, so that even if the number of fibres in the yarn cross-section is 35, the actual number will be lower than this 50% of the time.

The variation of the number of fibres in the cross-section causes thin and thick places in the fibre strand. As these pass through the twist insertion point, the thin places are more easily twisted than the thick places; hence thin parts will tend to have more twist than the thicker parts. A very thin part of the ribbon will become over twisted and weak, and this will make the yarn susceptible to peak tension fluctuations.

The tension on the yarn is greatest when the winding circumference is smallest. This leads to the common practice of slow start up speeds for spinning frames.

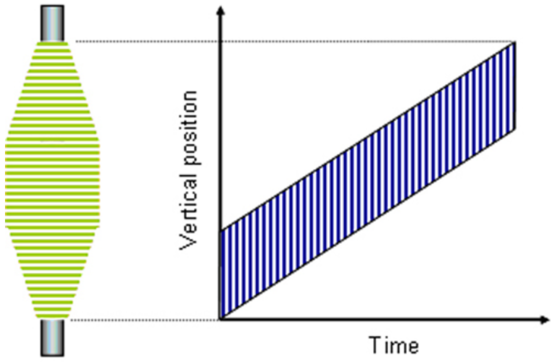
Package build

Variable speed drives are often used on ring frames to counteract the effect on tension of a varying winding-on diameter, especially when a new set of tubes is being started. A slow speed is needed when the package is small and the tension is highest, and is then gradually raised to its maximum value. As the package increases in size the speed of the spindle is kept almost constant, and then is gradually reduced until the package is complete.

The drives can also be used to control the speed of the spindle throughout the up and down cycle of the ring rail, with the highest speed at the bottom of the cycle where the package (or cop) has its maximum diameter. The lowest speed occurs at the top of the cycle where the yarn is being wound onto the diameter of the empty tube.

When the twisted yarn passes down on to the package it is necessary to wind the yarn on in an orderly manner so that it forms a package which can withstand handling and which will unwind without become entangled. This is achieved by controlling upward and downward traverses of the ring rail. A common form of traverse is shown in Figure 12.11, along with the shape of the package produced. This shape of package is called a *cop*. Here the yarn moves down slowly and up quickly to provide locking coils and to avoid sloughing-off when the yarn is subsequently unwound.

Figure 12.11 Ring rail traverse and package shape for cop build. Source: Wood, 2006.



Spinning frame features

Modern ring frames have a number of features which enhance their performance. Some of these features are standard on almost all machines, while others are optional extras.

1) Variable speed motors can counteract the tension changes of varying winding-on diameters. When a new bobbin is started a slow speed is required because when the bobbin is narrowest the tension is highest
2) By restricting the maximum balloon radius using a control ring, the air drag and centrifugal force is reduced on the balloon. Hence the tension in the yarn is reduced. With finer yarn counts the maximum balloon diameter is reduced and it may be less than the spinning ring diameter. Under such conditions the effectiveness of control rings ceases
3) Improved design of both rings and travellers, together with improved ring lubrication, permit higher spindle speeds
4) Nylon travellers also enable higher spindle speeds
5) Other aids such as the 'Pneumafil' system which uses suction to remove broken ends and facilitate piecening, help to improve production efficiency
6) A stop motion device where electronic sensors detect end breaks
7) Suction and/or blowing heads move back and forth along the machine removing dust and fly
8) Automatic doffing systems are available to save labour costs. These may doff the frame in one unit or remove full spindles from a group of spindles only. The empty tubes are automatically loaded from a magazine by a conveyor, while the bobbins are transported to a container or the next stage (winding).

Advantages and disadvantages of ring spinning

The most expensive process in yarn production is the insertion of twist into a strand of fibres. This is due to the fact that at each spindle position both the strand mass per unit length and the strand velocity are very small. As a result, the production at each spindle is severely limited. The capital cost, power cost and labour cost per spindle have been reduced as far as possible by the spinning machinery manufacturers, but they still remain very high in relation to the production rate. This follows directly from the method used both to insert twist and to wind the yarn onto a package.

Generally, ring and traveller systems have the following technical advantages and disadvantages:

Advantages

- Offer a wide spinning count range (5 – 300 tex)
- Can process most natural and man-made fibres, and blends
- Produce yarns with tensile strength and handling aesthetics suitable for the majority of fabric end uses.

Disadvantages

- Even with ideal situation of no end breaks, spinning is still discontinuous because it has to be stopped for doffing
- To attain high twisting rates (and hence high production speed) the yarn package must be reduced in size, resulting in more frequent stoppages for doffing
- The maximum speed is restricted by the frictional contact of ring and traveller, and the yarn tension
- Bobbin size is restricted by ring diameter
- Yarn has to be re-wound to larger size packages.

12.4 Ring spinning machines

While the same principles hold for worsted, semiworsted and woollen spinning, there are major differences in the machines used in the three systems. These differences are summarised in Table 12.2. Wide ranges within each spinning system are evident in the draft levels, ring diameters and spindle speeds. These may be varied depending mostly on the twist and count of the yarn being produced.

Table 12.2 Comparison of spinning machines (typical). Source: Wood, 2006.

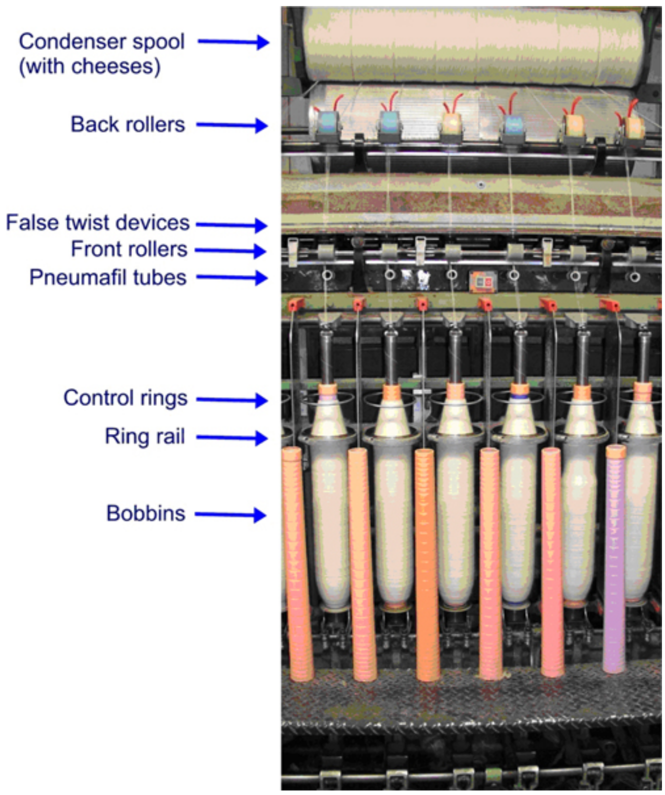
	Worsted	Semiworsted	Woollen
Input material	Roving	Sliver	Slubbing
Drafting system	Rollers and aprons	Rollers and aprons	Rollers
Level of draft	15 – 30	80 – 120	1.2 – 1.3
Diameter of ring (mm)	45 – 65	75 – 180	100 – 300
Spindle speed (rpm)	7,000 – 17,000	3,000 – 6,000	2,500 – 4,000

Woollen ring spinning

A woollen ring spinning frame, as shown in Figure 12.12, comprises:

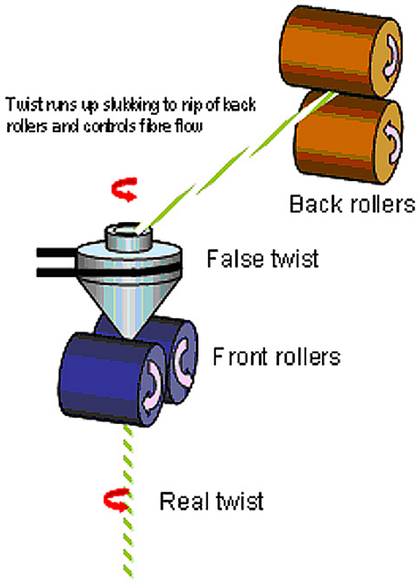
- an overhead creel to hold the spools, with positive let-off drum feed
- a drafting system incorporating a false-twist device, and
- collapsed-balloon spindles.

Figure 12.12 Spindles on a woollen ring spinning frame. Source: Wood, 2006.



Drafting and the false twist device
The drafting of the slubbings is in the range 20-30%, which is exceptionally low in comparison with the drafts used in worsted and semiworsted spinning. Drafting of delicate woollen slubbings is only feasible because they are given cohesion by the application of false twist. The false-twist device (Figure 12.13) rotates at about half the speed of the spindle and inserts about 80 – 160 turns per metre of twist in the strand.

Figure 12.13 False twist device. Source: Wood, 2006.

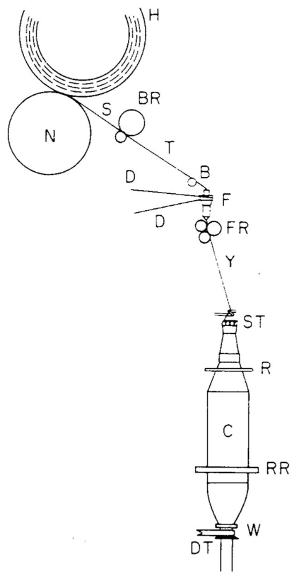


The count and quality of the yarn produced by a woollen frame are largely determined by the quality of the slubbings supplied. Small corrections to the count of the yarn can be made by adjusting the draft. Drafting is controlled by the speed of rotation of the false-twist unit, which increases the inter-fibre friction and thereby provides greater fibre control during drafting. It reduces the strand irregularity by preferentially drafting thick places with low twist since twist generally runs into thinner places thereby increasing the inter-fibre cohesion there.

A speed that is too high on the false-twist unit causes the fibres to bind and this inhibits drafting. On the other hand, fibre control is lost when the speed is too low and the number of end-breaks increases. Longer fibres need less drafting twist than short fibres.

Operation of the spinning frame
The operation of the ring spinning frame is as follows (Figure 12.14).

Figure 12.14 Spindle parts on woollen spinning frame. Source: Wood, 2006.



Slubbing from each of the cheeses is unwound by frictional contact between the cheeses H and the drum N. Each slubbing end S is taken through the nip of the back rollers BR. The thread T then passes through the false twisting device F which is close to the nip of the front rollers FR.

There are many variations of the path of the yarn Y from the nip of the front roller until the yarn is placed on the yarn package C via the traveller. The traveller slides on the inside of the ring RR and rotates around the rotating spindle. Friction between the traveller and ring as well as drag on the yarn causes the traveller to lag behind the spindle. The difference in speed between the spindle and traveller causes the yarn to wind onto the package.

The spindle is driven by the driving belt DT connected to the spindle wharve W. A suction tube is positioned just below the front rollers of each spindle to collect a broken end and send it to a cabinet for collection (and subsequent recycling back to the card hopper). This helps to keep the spinning frame clean, prevents fibres from lapping around the front roller and makes it easier to join (*piecen*) a broken end.

During ring spinning a balloon is formed, due to the action of the centrifugal force. Woollen ring frames have relatively large rings in comparison with worsted spinning in order to obtain an adequate length of yarn on the yarn packages. But when larger rings are used and acceptable spindle speeds are maintained, yarn tension is increased due to the larger diameter of the balloon and a higher chance of end breaks is the result.

One or two balloon control rings R may be used to restrain the size of the yarn balloon. Almost invariably there are also separating plates to restrain the balloon. The spindle top (or *crown*) ST may have a ‘finger’ attached to it which entraps the yarn and brings the top of the balloon down to near the top of the spindle. Alternatively, the spindle top may be shaped with notches so that the balloon is completely collapsed, except in the region of the traveller. The yarn, instead of ballooning, coils around the spindle and also around the yarn tube near the top. The yarn then travels out to the traveller before it is wound onto the yarn package.

With this ‘collapsed balloon’ spinning it is most desirable that the yarn guide (or lappet or ‘pigtail’) be maintained at a certain distance above the spindle top ST. The notched spindle top inserts twist in the yarn – by driving twist up to the nip of the front rollers where the thread of fibres is twistless and weakest, the rate of end breaks is reduced at higher spindle speeds.

Notable recent developments in the ring spinning of woollen yarns mostly involve automation, i.e.:

- Automatic doffing of full packages, fitting of new tubes, replacing slubbing packages, and joining of slubbings. Automatic doffing reduces labour and improves productivity
- End-break detectors and monitors allow ‘rogue’ spindles to be identified
- Information on traveller, roller and spindle speeds enables yarn production and twist to be determined by monitoring systems
- Adjustment of the various spinning operations and parameters at an electronic console.

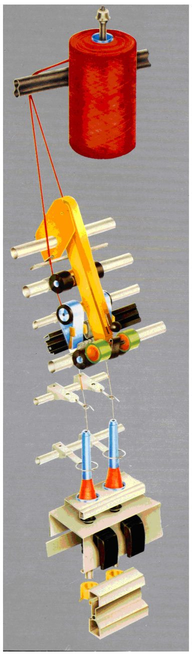
Worsted spinning frame

Figure 12.15 shows a typical worsted spinning frame with:

- A pair of rovings wound off the package
- Drafting zone with a combination of aprons and rollers
- Spindles including control rings.

The sizes of the travellers, rings and packages are much smaller than those on a typical woollen spinning frame, reflecting the finer counts of yarn produced on such machines.

Figure 12.15 Worsted spindles. Source: Cognetex.



Semiworsted spinning frame

For most semiworsted yarns spinning takes place directly after the third gilling step. However, for fine yarns it is necessary to produce a finer sliver than can be produced on a gillbox. In these cases a roving frame is used prior to spinning. As an alternative, a two-zone drafting system may be used on a spinning frame to provide the high drafts required.

Figure 12.16 shows the drafting section of a semiworsted spinning frame used for the production of carpet yarn. The top drafting rollers have been raised to reveal the slivers in position for drafting.

Figure 12.16 Drafting section of semiworsted spinning frame. Source: Houget Duesberg Boson.

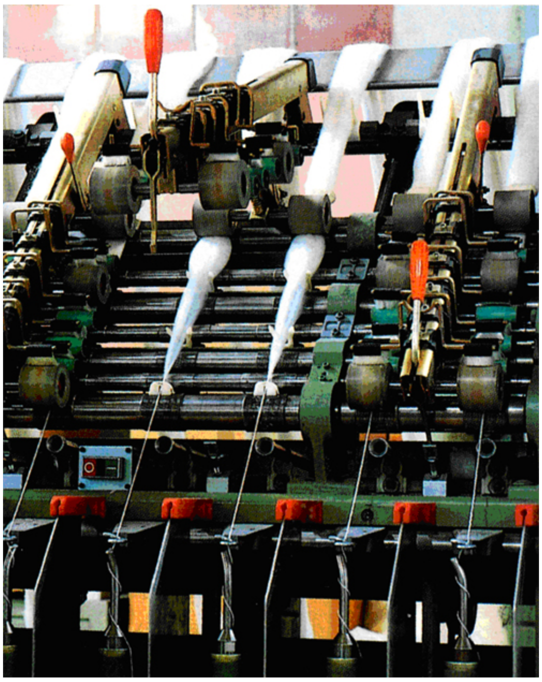
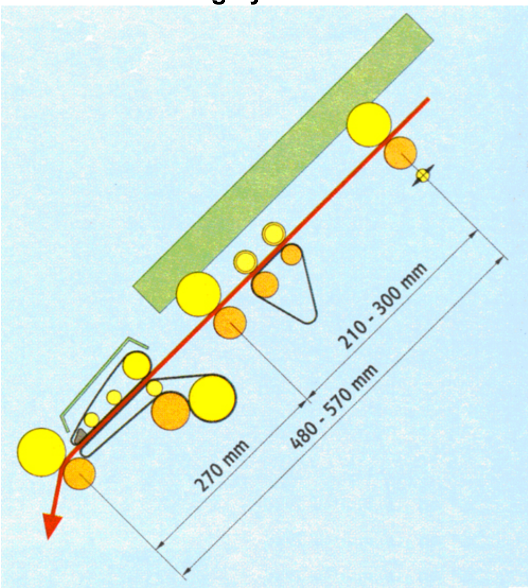


Figure 12.17 shows a relatively complex, double zone drafting device.

Figure 12.17 Double zone drafting system. Source: NCS Schlumberger (b).



The ratch (the distance between the back and front drafting rollers) should be set such that no fibre has both ends nipped at the same time. Fibres a little shorter than the ratch will pass easily from the back nip to the front nip. Short fibres are not nipped at all for a significant period of their passage across the drafting zone. Such "floating fibres" tend to be carried in groups towards the front rollers, creating thick and thin places in the yarn. The function of the drafting aprons and the intermediate rollers is to control the movement of the floating fibres and hence promote evenness.

Lighter counts of semiworsted yarn (e.g. for face-to-face carpets) can be spun using a double-zone drafting system where a roller drafting system, perhaps with a short apron, is followed by a conventional double-apron system. The first zone applies a draft up to 8 and the draft in the second zone may be up to 25, giving a total maximum draft of 200. Floating fibres in the first zone are controlled by soft "Sampre" rollers which apply light pressure to the sliver.

Irrespective of whether single or double zone drafting is used, the general principle followed is to operate the card and gillboxes at standard settings and to adjust the draft at the spinning frame to achieve the required yarn count.

Modern ring frames have DC drives for each element, controlled by a microprocessor. This eliminates the need for change wheels as all settings are made from a panel located on the headstock (drive unit).

Spinning machinery optimised for the counts to be spun should be used. For heavy count carpet yarns, larger packages are used to minimise the proportion of time required for doffing. For fine counts small packages are used to maximise spindle speeds and number of spindles per frame. Ring diameters range from 75 mm to 180 mm.

See the Appendix for a comparison of the properties of the yarn produced by the woollen, semiworsted and worsted processing routes.

12.5 Innovations in the spinning of wool yarns

Considerable efforts in spinning machinery development have been directed towards eliminating two-folding in the production in weaving yarns, with the objective being to produce as fine a yarn as possible that can be woven without resorting either to two-plying or sizing (Hunter 2002; Lawrence 2003). The three main approaches have been (1) two-strand spinning (Sirospun), (2) compact (condensed) spinning, and (3) Solospun.

Sirospun

Sirospun (http://www.tft.csiro.au/achievements/sirospun.html) was developed to address the demand for lighter-weight wool yarns and fabrics. It is a commercially-successful example of two-strand (or twin-spun) spinning, where a pair of rovings is fed separately to the same double apron drafting system (Figure 12.18).

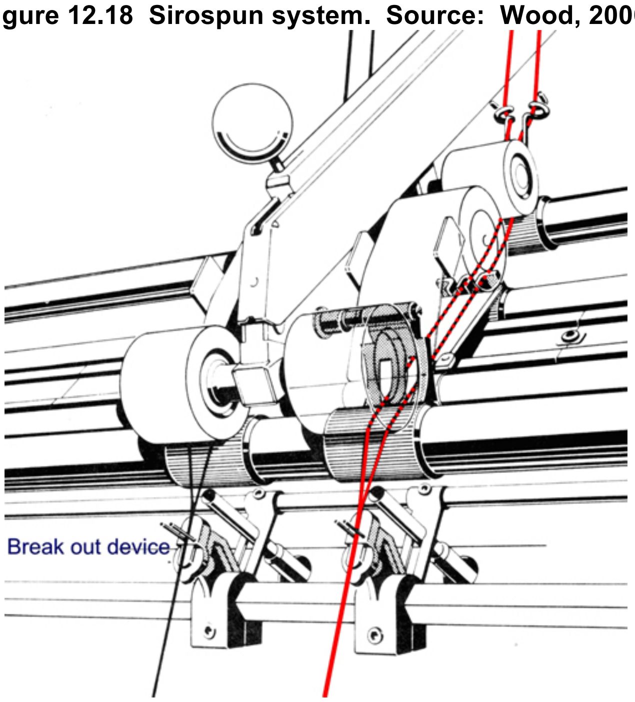
The principle is that if two drafted strands of fibres are spaced apart but twisted together in spinning, then a number of fibre trapping mechanisms operate to bind the surface fibres together and thus enable the yarn to withstand the abrasive action experienced in weaving.

Each strand receives some twist before they are combined at the convergence point after the front rollers. The Sirospun attachments can be fitted to most conventional double apron worsted spinning frames. The fitting involves a simple modification to the drafting unit of each spindle. This modification enables a spindle to draft two rovings into two separate strands and then twist them together.

Sirospun uses a break out device to ensure that no single yarn is produced. A similar technology, Duospun uses suctioning and automatic re-piecening to prevent spinning when one end breaks.

The yarn has unidirectional twist and the fibres are not trapped as well as in two-folding. However, with sufficient twist, fibre length and a similar number of fibres to the two-fold yarn, the weaving performance is satisfactory. Sirospun reduces spinning costs by an average of around 55%, but increases weaving costs because of slightly higher rates of yarn breakage.

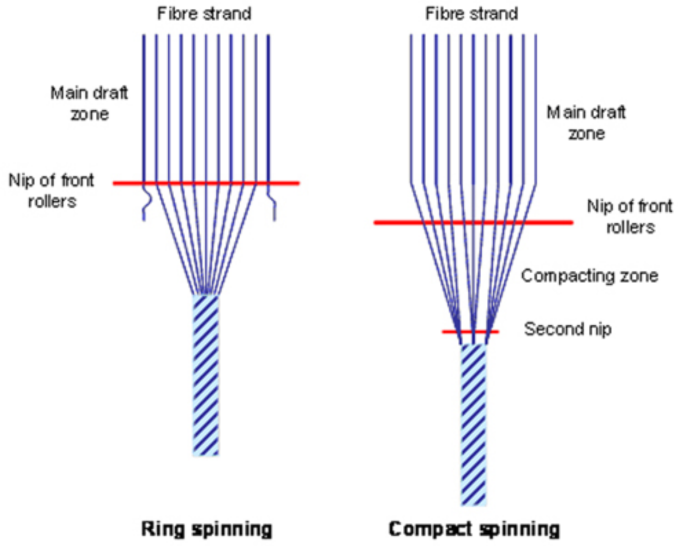
Figure 12.18 Sirospun system. Source: Wood, 2006.



Compact spinning

Compact (http://bala.bravehost.com/Modern%20Developments.html) (or condensed) spinning system (Figure 12.19) aims to alter the geometry of the so-called 'spinning triangle'. This is the zone occupied by the fibres between the nip of the front roller of a spinning frame and the point at which twist is inserted. The aim is provide more effective binding of surface fibres into the body of the yarn.

Figure 12.19 Comparison of the spinning triangles in ring spinning and compact spinning. Source: Wood, 2006.



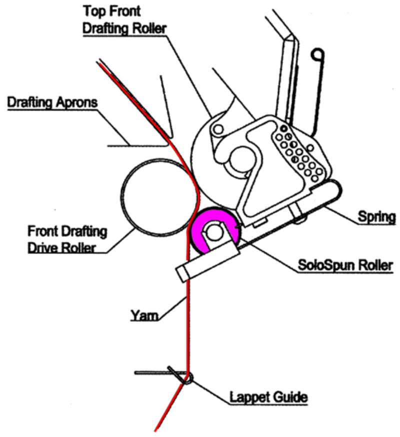
Compact spinning devices (http://www.fibtex.lodz.pl/43_09_30.pdf) narrow (or condense) the spinning triangle at the exit of the front rollers. They give better control of the fibres and facilitate their integration (binding) into the yarn, thus eliminating peripheral fibres. This is achieved by introducing an intermediate zone between the front roller delivery and the yarn formation (twist insertion) point. In this zone the widths of the fibrous ribbon and spinning triangle are reduced, giving improved spinning efficiencies, fibre alignment, smoothness, hairiness, tensile properties and compactness in the yarn. The condensing systems used to accomplish this usually involve pneumatics (vacuum) applied to a perforated front roller or apron.

Commercially available systems are supplied by Suessen (http://www.suessen.com/htmls/felite1.htm), Rieter, Cognetex (http://www.fuster.com/pdf/cognetex/com4wool_eng_ita.pdf) and Zinser (http://www.zinser-texma.com).

Solospun

Solospun (http://www.solospun.woolmark.com/) is another recent technology to produce a 'weavable singles' yarn. It acts on the normal single strand of fibres, unlike Sirospun.
It is a joint development of WRONZ/Canesis, CSIRO and IWS and simply entails clipping a pair of grooved plastic rollers to the drafting arms of a worsted spinning frame (Figure 12.20).

Figure 12.20 Solospun attachment. Source: Wood, 2006.



These rollers divide the fibre ribbons emerging from the front rollers into separate streams and do not permit twist to reach the front roller nip. This allows the fibres (in substrands) to twist and recombine in such a way as to increase the localised twist (cohesion) and compactness of the substrands and yarn, as well as the fibre integration into the yarn.

Relatively even yarns of 25 – 50 tex can be spun, and compared to two-fold yarns, yarn production costs savings are estimated to be between 15 – 40%. The key advantages of Solospun over Sirospun are:

- Improved spinning performance
- No need for two strands
- Can operate at lower twist levels and with fewer fibres than the normal two-fold equivalent.

Appendix – Comparison of Spinning Systems.

	Woollen	Semi-worsted	Worsted
Wool requirements:	can handle all wool types, but more suitable for shorter wools rather than very long	wools should be sound, staple length 75-125 mm, and low vegetable matter content	requires wools which for their diameter are longer, better style and sounder
	usually a wide range of blend components	usually a limited range of components in blend	uses similar wools rather than a mixture of types
	all fibre diameters used, from very fine to very coarse	mainly medium fineness wools; 27 - 35 μm	mainly fine wools; less than 30 μm, usually less than 24 μm
	can use reprocessed wools of all types	not suitable for short reprocessed wools	wastes never used
	blend cost generally lowest	blend cost higher than woollen	blend cost highest
Complexity of the processing system	the shortest route with fewest steps, large woollen card has low production rate	a compact, high production system, cheaper to operate than worsted system	the most complex route; largest number of steps; card similar to semi-worsted card
	card removes some VM but cannot tolerate high levels of vegetable matter	limited ability to remove vegetable matter and short fibres	vegetable matter and short fibres removed by combing
	carding is very critical because it sets the yarn count, and is the final opportunity for blending	carding is less critical because of substantial blending and drafting in subsequent steps	carding is less critical because of substantial blending and drafting in subsequent steps
Properties of yarn:	minimal alignment of fibres, many may be hooked	reasonable degree of fibre alignment	fibre alignment very high, giving most even yarn
	yarn is hairy - many fibre ends protrude from surface	less fibre ends and loops protrude from surface	few fibre ends and loops protrude, so least hairy
	yarn is bulky, soft and resilient	medium bulk and resilience	low bulk, and firm handle
	tends to be weakest with breaking strength of 3-5 g/tex	typical breaking strength 5-7 g/tex	tends to be strongest yarn; breaking strength 7-9 g/tex
	require at least around 110 fibres in yarn cross-section	require at least around 90 fibres in yarn cross-section	require at least around 40 fibres in yarn cross-section
End product uses:	suitable for all purposes: apparel, carpets, furnishings.	carpets and knitwear mainly	high quality weaving and knitting yarns for quality apparel
	yarn structure often not apparent in finished product	yarn structure may or may not be clearly visible	yarn structure is usually well-defined in product

Readings

The following readings are available on CD

1. Anon, 1955, ‘The Scientist Looks at the Wool Industry: Worsted spinning,’ *Wool Science Review*, vol. 14(3).
2. Anon, 1957, ‘The Scientist Looks at the Wool Industry: Woollen ring frame spinning,’ *Wool Science Review*, vol. 17(3).
3. CSIRO Textile and Fibre Technology, Wool For Spinners, Wool for Spinners, Message from Sirolan-Yarnspec.
4. Oxenham, W. 2003, ‘Developments in spinning,’ *Textile World,* Technology: Spinning.

Movies

The following movies are available on CD:

- Canesis Network Ltd Semi-worsted spinning.
- Canesis Network Ltd Woollen Spinning.
- Canesis Network Ltd Worsted Spinning.

Activities

Available on WebCT

Multi-Choice Questions

Submit answers via WebCT

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Assignment Questions

Choose ONE question from ONE of the topics as your assignment. Short answer questions appear on WebCT. Submit your answer via WebCT

Summary

Summary Slides are available on CD

While the term ‘spinning’ is commonly used to describe the entire yarn-making process, in this topic the more specific meaning applied, i.e. the formation of yarn by drafting, the insertion of twist and forming a package. The ultimate aim of spinning is to produce a coherent and cohesive strand of fibres (i.e. a yarn) of the required linear density (count) and which has good evenness, tensile properties and a minimum number of faults.

Because of its versatility in terms of yarn linear density and fibre type, and also the superior quality and character of the yarn it produces, conventional ring spinning is the most popular system for spinning wool into woollen, worsted and semiworsted yarn. This topic will therefore focus on the principles and technologies for the ring spinning route, and recent adaptations to this method. For worsted yarn spinning, the preparation steps of gilling and roving must also be considered.

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Hunter, L. 2002, Mechanical Processing for Yarn Production, in: *Wool: Science and Technology*, W.S. Simpson and G.H. Crawshaw, (eds), Textile Institute, Woodhead Publishing Ltd, CRC Press, ISBN 1 85573 574 1.
Lawrence, C.A. 2003, Carding Theory, in: *Fundamentals of Spun Yarn Technology*, CRC Press, ISBN 1-56676-821-7.
NCS Schlumberger (a), FM 8 Horizontal Rubbing Frames, product marketing brochure, NCS Schlumberger, France.
NCS Schlumberger (b), CF50 Ring Spinning Frames, product marketing brochure, NCS Schlumberger, France.
Oxtoby, E. 1987, *Spun Yarn Technology*, Butterworths, ISBN 0-408-01464-4.

Glossary of terms

Apron	Small, continuous belt used for (a) rubbing of rovings, and (b) controlling fibres in drafting zone
Balloon	The curved path of a yarn between the yarn guide and traveller in a spinning frame
Bobbin (or tube)	A cylindrical or slightly tapered former, for holding slubbings, top, rovings or yarn
Compact (or condensed) spinning	The drafted strand is compacted in an extra zone before twist is inserted, enabling a smoother, less hairy yarn to be produced
Creel	A device for holding packages of slubbing, sliver, roving or yarn in position, and delivery ends to a process (gilling, combing, spinning, tufting)
Doffing	Removing full yarn packages on a spinning frame and replacing them with empty tubes
Doubling	Feeding two or more ends of sliver into a drafting device in parallel to facilitate mixing
Draft	The ratio of the front roller surface speed to the back roller surface speed
Drafting (attenuation)	The process of reducing the linear density of a sliver or roving, often using two pairs of rollers rotating at different speeds (roller drafting)
Drawing	A sliver operation which combines doubling and drafting
End break	A stoppage in spinning where one end breaks due to excessive tension etc., and requires attention of the operator to *piecen*
False twist	Insertion of temporary twist in a slubbing to provide it with sufficient strength for drafting and twist insertion in woollen spinning
Floating fibres	Fibres in a sliver or roving in a drafting zone that are not in contact with either pairs of rollers
Headstock	The drive unit of a spinning frame, where speeds can be set
Mule spinning	An intermittent method of spinning where the formation of yarn (drafting and twisting) is undertaken in one operation, and winding to the package is undertaken in another. Drafts of 1.2 – 1.6 are used

Package build	The formation of a yarn package of the required shape
Piecening (or piecen)	The joining of two strands of fibre in yarn manufacture, either manually or automatically, usually by overlapping the ends
Pneumafil tube	Suction tube for removing broken end from the spindle area of a woollen spinning frame
Ratch	The distance between the front and back rollers in a drafting device
Ring	Provides the circular path for the traveller in a ring spinning frame
Ring spinning	A method of spinning in which twist in inserted in a yarn using a rotating traveller
Roving	A relatively fine, even strand of fibres drafted from a sliver, and it is the input material to worsted ring spinning
Semiworsted spinning	Yarn manufacture route involving carding gilling and ring spinning in which the fibres are substantially parallel and are not combed
Sirospun	A modification to a worsted ring spinning frame that enables two rovings to be drafted in parallel, then twisted together. It is an example of twin-spun (or two-strand) spinning which eliminates the need for a twisting step
Sliver	A thick, continuous strand of staple fibres, without twist
Slubbing	The untwisted strands from a woollen card that have been consolidated by the rubbing action of the condenser
Solospun	An adaptation to a worsted ring spinning frame to enable a weavable singles yarn to be produced
Spindle	The rotating shaft drives the bobbin in a spinning frame
Spinning frame	A machine for making yarn comprising many spindles, each with a bobbin, ring and traveller
Spinning triangle	The zone immediately in front of the front rollers of a ring spinning frame where the twist is inserted into the strand of fibres
Traveller	A small plastic or metal clip that moves around the ring of a spinning frame and guides the yarn onto the bobbin
Woollen spinning	Yarn manufacture route involving the spinning of condensed slubbings produced by a woollen card
Worsted spinning	Yarn manufacture route involving the spinning of fine, even yarns following carding, gilling combing and drawing steps