WOOLLEN SPINNING

Woollen spinning cycle

The classic product is based a well established technology, reflected in the following spinning cycle:

Stage 1	PREPARATION	opening, blending and cleaning the material
Stage 2	CARDING	processing of the blend and production of the roving fineness
Stage 3	SPINNING	transformation of the roving into yarn

In spinning, the classic drawing, twisting and winding operations can be carried out both by continuous ring spinning machines and by discontinuous selfacting machines.
It is also possible to use spinning-twisting machines to produce fancy yarns in a single operation.

Preparation

Introduction

Crucial in order to obtain a homogeneous, strong and even yarn is optimal blending of its component fibres. If this applies when processing lots of a single material, then efficient blending becomes even more important in the woollen spinning cycle, in which the fibres' adherence to the fundamental parameters determining spinnability can vary considerably. Blends generally present the following characteristics:

- a very high number of components (even in excess of 10), present in highly variable proportions (sometimes even very small percentages, below 5%)
- fibres presenting highly dissimilar characteristics, particularly as regards their length (there are situations in which 25 mm waste are blended with synthetic fibres over 80 mm in length)
- widely varying colours, sometimes not constant from the start to the end of a single lot
- presence of foreign matters and impurities, sometimes originating from packing, or, more often, attributable to the origin of the material, (for example in the case of regenerated fibres, waste, processing waste)
- the need to use high-performance additives, to promote fibre cohesion and to facilitate their sliding over one another, as well as their processability on machines.

A blending and preparation system may or may not be based on the number of components in the blend, and it is this which determines the type of spinning process to be carried out on the raw stock.

Preparation system based on the number of components (instant)

A series of bale pluckers – their number corresponds to the number of components to be blended – that are also equipped with weighing devices work parallel with one another, unloading the required proportion of each of the various types of fibre on to a transverse vertical apron (Figure 69).

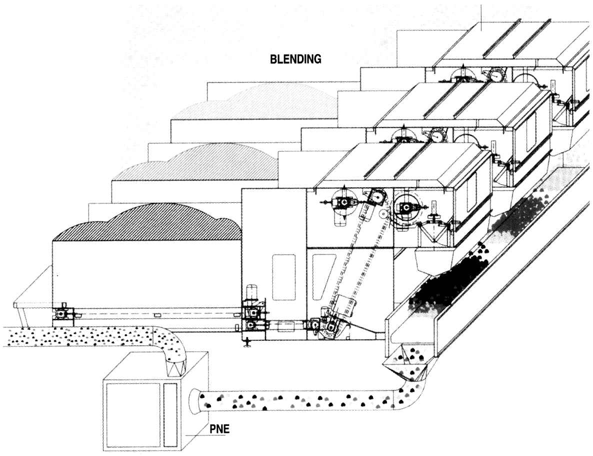

Fig. 69 Bale pluckers working parallel with one another

The fibres are collected, through a contemporaneous stratification process, which guarantees the production of blends that immediately present the composition required of the end product.
In the subsequent stages, the material is opened, oiled and, if requested, stored.
Clearly, a process of this kind, simple and inexpensive, is preferable for the production of lots that do not vary much, given that there is a limit to the number of components that can be handled by the system, which is not required to perform thorough blending. Instant preparation is often preferred by producers of nonwovens, precisely because it is best suited to materials that are relatively standardised, as regards both colour and composition.

Preparation system based on the number of components (global)

In this case, preparation involves a series of sequential operations, some of which can be repeated, perhaps several times, according to the characteristics of the materials and the level of quality required. As a result it is a more sophisticated and complex process than the previous one, but also more versatile.
The classic cycle is as follows:

1. bale plucking
2. dedusting
3. fibre opening
4. oiling
5. stratification and blending
6. plucking with blending apron
7. storage and supplying the carding room

The stages that tend to be repeated are, above all, opening, oiling and blending, although once oiling has been carried out, the dedusting stage is excluded from the cycle as it would not be efficient on oil-impregnated material.
A complex preparation line of this kind is suitable for the processing even of small and highly variable lots and is thus described in more detail below.

Bale plucking

The bale plucker is the first machine in the cycle, as it carries out a preliminary plucking and partial blending of the fibres. The bales, which are compressed when they reach the spinning mill, are first removed from their protective wrapping and then placed on the conveyor that feeds the bale plucker, which separates the fibres, returning them to their open-tuft state and thereby ensuring even feeding of all the subsequent machines. Furthermore, depending on the operating width (this generally ranges from 2 m to 5 m), the machine can be loaded with parallel rows of bales; alternation of the various components will result in a preliminary blending, which will be improved and rendered even more thorough in the subsequent stages.
The working of this machine (see earlier Figure 69) is based on a principle of opening, obtained through a vertical apron made up of wooden steel-spiked staves.
The table hooks the fibres and, blending them, raises them upwards to a point where a cylinder knocks off any excess material. An unloading cylinder, located behind the blending apron, frees the fibres from the spikes of the apron, and sends them to the hopper.

Dedusting

From the bale plucker the fibres are pneumatically conveyed to the blowroom, which opens the tufts and removes all types of dust and impurities.
The material is fed, via an entry hopper, into the blowroom, in which there operates a cylindrical drum with a diameter of around 600 mm. (the drum can sometimes be cone-shaped). Its surface is covered with blunt steel spikes (Figure 70).
These spikes are arranged helically to favour, together with the suction effect, the progress of the material. The rotation of the cylinder has two effects: the material is opened thanks to the action of the spikes on the fibrous mass (this opening is often increased by also lining with spikes the inside of the carter with which the moving fibres inevitably come into contact) and dedusting thanks to the cylinder repeatedly and violently striking against an underlying grid.

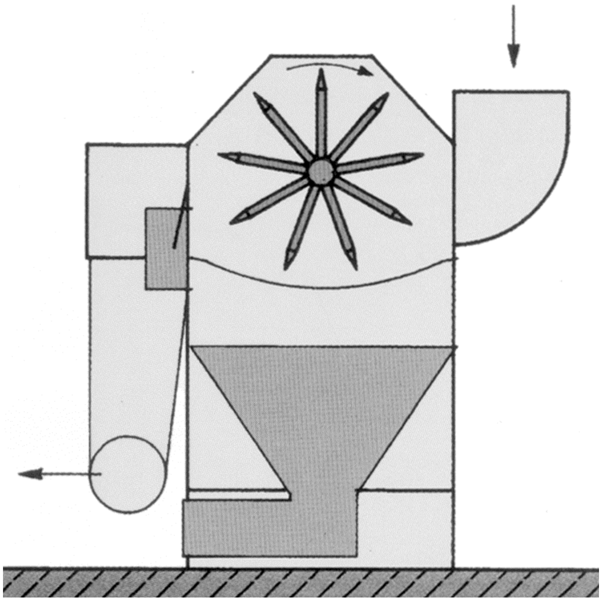

Fig. 70 Blowroom

The whole machine is subject to suction and the dust is collected in special filters; the material, on the other hand, undergoing contemporaneously, the rotary action of the cylinder and suction along the operating width, effects a helical movement around the drum and exits from the side opposite to that on which it entered. It is then transferred by the delivery hopper into the transportation conduit.

Opening

This stage is usually carried out by an opening willow in the case of shorter fibres and by a willow in the case of longer ones.
In the opening willow the fibres, evenly and constantly fed to the conveyor, are drawn inside the machine by two licker-in cylinders, which have grooved surfaces to help them to retain the material. From this cylinder nip area the fibrous mass is violently taken up by a drum that rotates rapidly in a clockwise direction. This drum is covered with wooden staves that have sharp steel spikes (Figure 71).

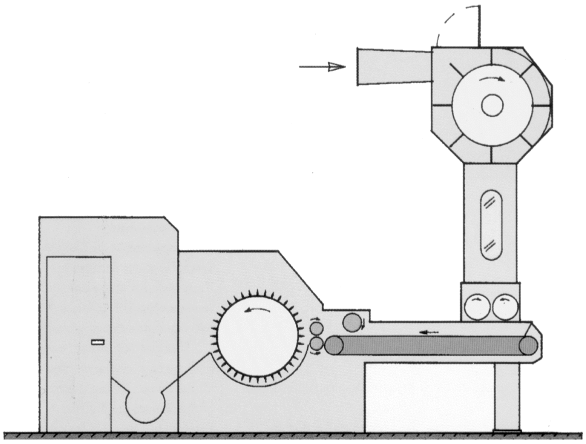

Fig. 71 Opening willow

The action of the drum spikes and the large difference between the peripheral speed of the surface of the drum and that of the feeder cylinders result in opening of the material.
In the opening willow, the material passes from the feeding conveyor to the feeding cylinders (Figure 72). The surface of the machine's main drum, like the worker cylinders and card strippers, is covered in rigid, curved spikes, which exert a strong opening and blending action. The material is detached from the drums spikes by an unloading cylinder.

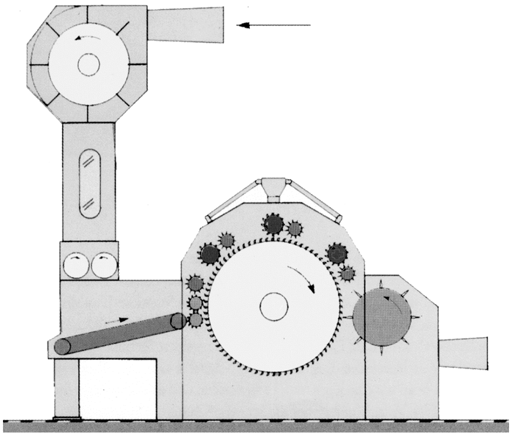

Fig. 72 Carding willow

Oiling

Oiling of the fibre blend is fundamentally important, because it increases the coefficient of friction between the fibres (which is particularly low in the case of short fibres). This favours the cohesion of the card web and of the rovings; it also help to reduce the coefficient of friction between the material and the machine's metallic clothings. The oiling emulsion is generally made up of oiling agent, emulsifier, softener, anti-static agent, condensing agent, additives and water. Naturally, the proportions in which these products are present in the emulsion varies considerably according to the type of material to be processed and its requirements. The emulsion usually accounts for at least 5-6% of the total weight of the blend, while its upper limit is impossible to establish, as it depends too much on the type of fibre being processed.

The emulsion is prepared in a steel tank. From here, it is pumped to the oiling chamber, which distributes it continuously onto the fibres (Figure 73).

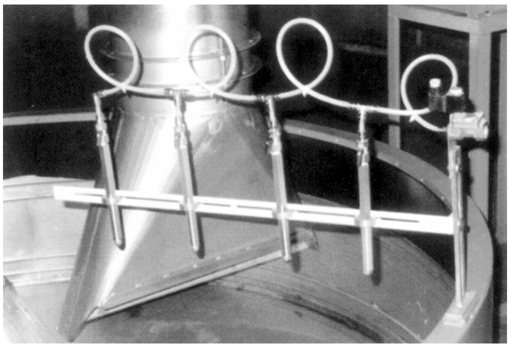

Fig. 73 Oiling in a rotating tank

The fibrous material is deposited on a circular plate which rotates slowly, so that all the fibres are passed under the spraying device, made up of a series of nozzles.
Safety systems cut off the supply of emulsion in the absence of fibres, while the speed of rotation can be adjusted according to the amount of fibre being processed.
A central cone prevents the impregnated fibres from becoming mixed up with still-to-be-treated ones while a control sensor, an oscillating rod whose end registers the volume of material present, regulates the quantity of fibre undergoing oiling, stopping the machine if too much material is present. A fan picks up pneumatically the impregnated fibres, to be conveyed to the next stage.

Blending

After oiling the fibre is sent to the blending rooms, where, traditionally, the material is laid down horizontally and carefully broken down into many thin layers, in such a way as to optimise blending with the subsequent vertical plucking. Mobile conveyor belts are often used in place of traditional pneumatic transportation of the fibres. Indeed, for the blending of heterogeneous fibres, the box filling system with blowing of the material has an undesired separating effect that is attributable to the different dynamic behaviour of the fibres, in turn determined by their volume. More modern systems effect mechanical stratification, without the application of air, thereby making it possible to apply the emulsion during the loading of the box, while the fibres are being deposited in layers (Figure 74).

Fig. 74 Stratification in the cell without air

Plucking with blending apron

Once it has been laid horizontally in layers, the material has to be plucked in the direction perpendicular to that in which it was laid down. This allows optimal blending.
This plucking operation is carried out using a fixed or a mobile blending apron.
The blending apron is a conveyor belt that has spikes on its surface, and is angled not completely vertically, but in such a way as to form, thanks to its inclination, an angle slightly greater than 90° with the horizontal fibre. Given its size, the conveyor practically intersects the section of the chamber, thus the fibres become attached to the spikes of the upwards-moving apron; then, once they have reached the top, they are detached by a doffing cylinder and collected in the unloading device.
Telescopic tubes connect the blending apron, which runs on tracks throughout the inside of the box, to the pneumatic transportation system, which feeds the material to subsequent processes (Figure 75).
Other tracks, outside the chambers and perpendicular to the previous ones, allow the blending apron to be moved, as necessary, between adjacent chambers.

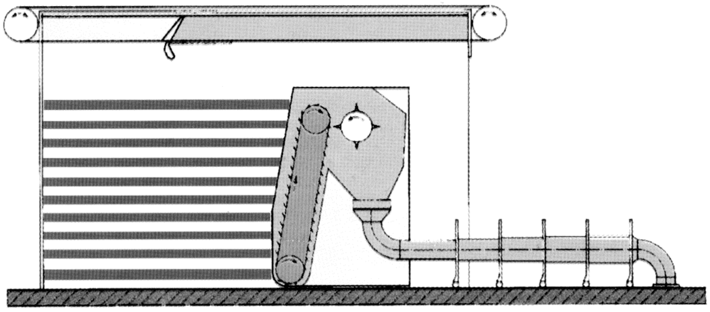

Fig. 75 Cell with channel filling and mobile blending apron emptying

In the fixed blending apron picking system (Figure 76), the cells have a moving base that transports the fibre to the blending apron, located on the room entry side, while on the other side, a retaining wall advances to prevent material from slipping backwards.

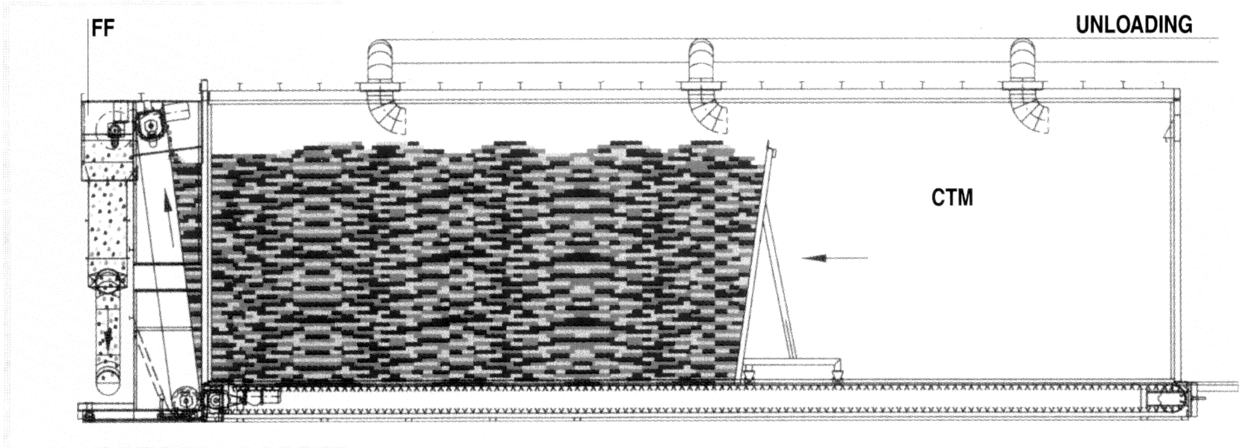

Fig. 76 Cell emptying with a fixed blending apron system

Storage and carding room supplying

Leaving the blending chambers, the fibre can once again be put through the opening machines, or if it needs further homogenisation (this applies particularly if one of the components is present in only a very small proportion), submitted to a second or even third blending and relative picking. Finally, the material is transferred to storage cells, ready to be fed, from special hoppers, to the carding room equipment loader .
The storage cells (Figure 77) are equipped with a fixed blending apron whose plucking system is driven by special photocells that control the level of material present inside the hopper.

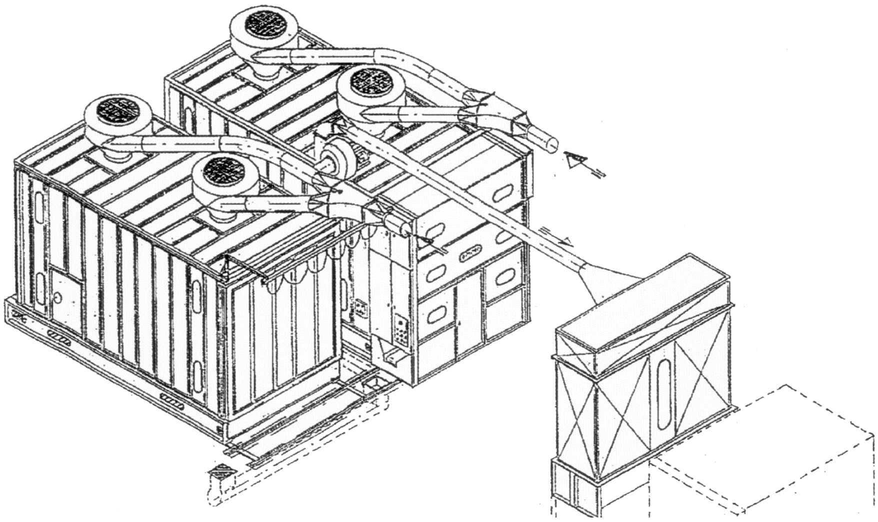

Fig. 77 Storage cells

The volumetric hoppers, in turn, ensuring (through a control system based on photocells and timers) constant discharging of fibres into the loaders, guarantee the carding room equipment autonomous operation.

Automation and safety

In an automatic preparation cycle, the only intervention on the part of the operator is to supply the bale plucker with bales, while the prepared material, delivered by the storage boxes, is fed directly to the hoppers that supply the carding room equipment loaders, thereby creating a direct link with the carding room.
The machines are connected up by a pneumatic transportation system that renders processing productive and safe.
Automation has led to an improvement in blend quality, without depriving the system of any of its flexibility, allowing the repetition of cycles on the different machines, and their exclusion, and thus guaranteeing optimal processing of the most varied and the most homogeneous materials.
There have also been considerable improvements in terms of the healthiness of the working environment, with marked reductions in dust concentrations, and in the area of accident prevention.
Figure 78 illustrates a preparation system.

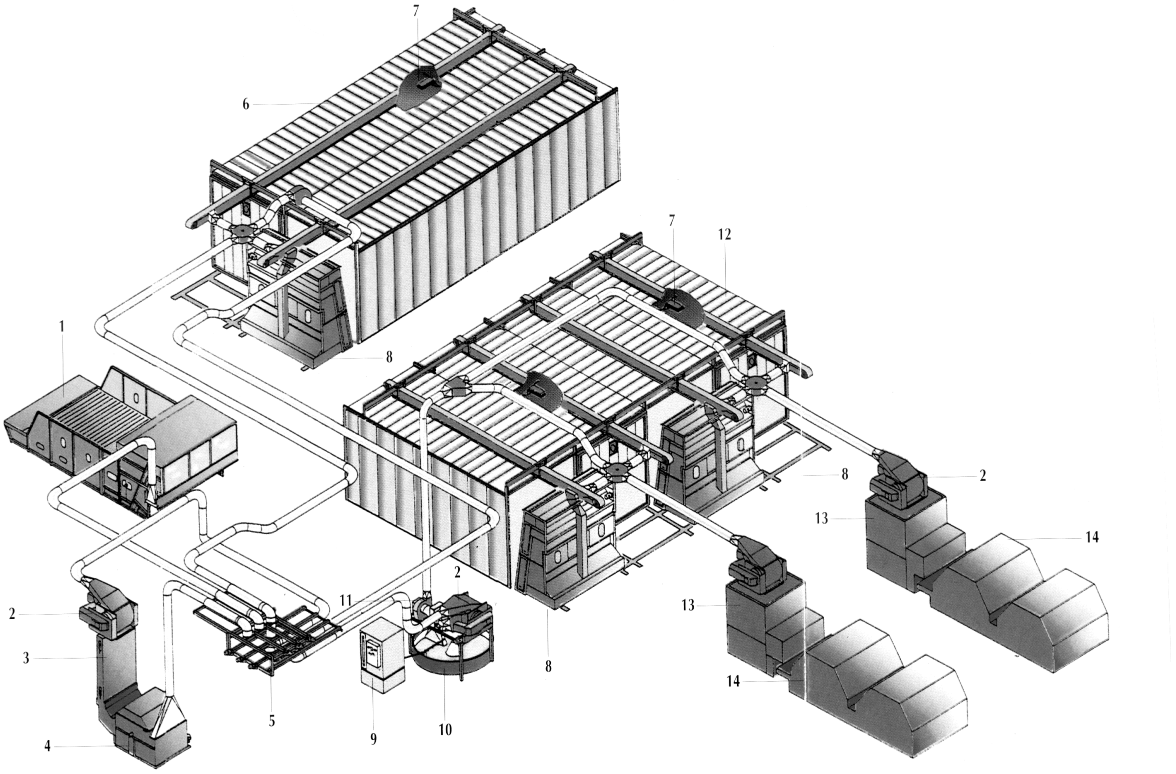

Fig. 78 Complete preparation cycle

1 Bale plucker
2 Condenser
3 Vibrating wall
4 Fibre opening
5 Exchanger
6 Blending chamber
7 Deposition device
8 Mobile blending apron
9 Oiling pump
10 Oiling tank
11 Fan
12 Storage chamber
13 Card loader
14 Card

Carding

Carding functions

Carding fulfils a series of precise objectives, serving:

- to open the blend fibres fully and definitively
- to arrange (as far as their length allows) the fibres parallel with one another
- to remove impurities
- to blend the raw material further
- to reduce the blend to a web of fibres and to divide it up into rovings of the required count, suitable for feeding to the spinning machines.

Carding plays a crucial role in all spinning cycles, and its role is never more central than in the woollen spinning cycle, in which it incorporates different functions, all essential in order to obtain the level of quality required of the product.

Basically, passing the material over the card undoes tangles of fibres and therefore makes it possible to remove all kinds of impurity. This is achieved thanks to the action of the spikes covering the surfaces of cylinders that rotate around parallel axes.

The equipment also fulfils another function, which is both delicate and fundamental: it has to guarantee the accuracy and evenness of the web count and subsequently of the roving count. Indeed, the definitive spinning machines that operate within the woollen spinning cycle can impart only a very low draft, which means that there is practically no possibility, at this stage, of intervening to correct the yarn count.

The carding room equipment thus performs the same operations already carried out in the preparation stage, this time more thoroughly, supplying the divider with rovings of the right count.

Operation of the card

The card used in woollen spinning is traditionally the sort with cylinders (covered with clothings that are angled to varying degrees), which rotate at different speeds, effecting the three cardinal actions: carding, stripping and raising. Appropriately combined, these three actions allow opening of the tufts, continuous detachment of the fibres from the card clothing, which would otherwise soon become clogged up, and delivery of the material from the machine at the end of a processing cycle.

The type of the clothing and the direction and peripheral speed of the cylinder characterise unambiguously the operating principles of the machine.

Modern cards are fed by automatic loaders that, connected up with storage boxes containing the ready prepared fibre blend, deposit the required quantity of material onto an endless belt or a conveyor (Figure 79). Once they reach the feeding conveyor (1) the fibres, which have been checked and compressed by a cylinder or by a sheet, are fed into the card by feeding cylinders (2), which have a low peripheral speed, corresponding to that of the conveyor. The feeders rotate in opposite directions to one another and are covered in needles, inclined in the direction opposite to that of rotation.

These cylinders, which have to be strong and inflexible in order to feed the fibres to the beater cylinder (4) as evenly as possible, are accordingly very small. Indeed, if the cylinders are small, then so is the area of contact (approximately triangular in section) between them and the beater cylinder, the area in which the material escapes control.

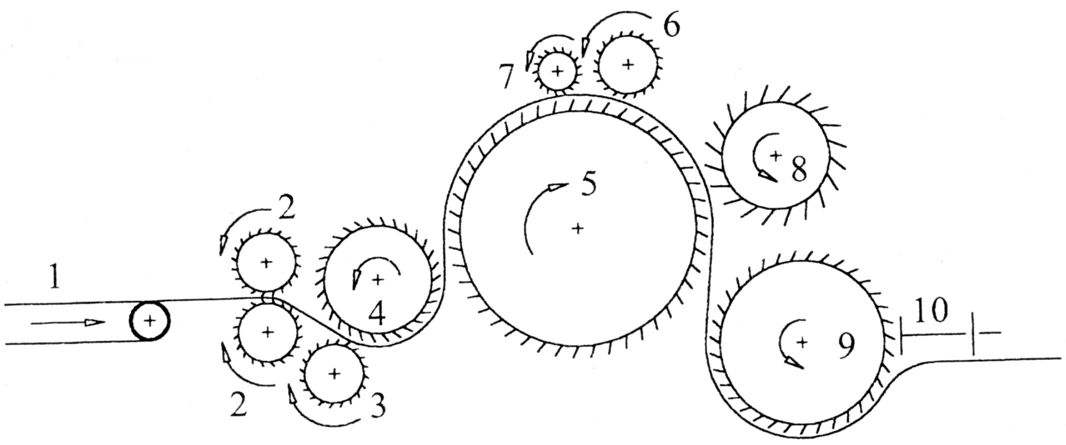

Fig. 79 Diagram of a card

The beater is the first cylinder to open the fibres and arrange them parallel to one another. Rotating in an anti-clockwise direction and equipped with clothing that is also inclined in an anti-clockwise direction, the beater cylinder, reaching a peripheral velocity that is considerably greater than that of the licker-in cylinders, subjects the fibres to a violent action, stripping the upper feeding cylinder and effecting a carding action with the lower one. This carding action serves to condense the fibres on the feeding cylinder, and it is therefore necessary to position a stripper (3) below it, in order to return the material to the beater cylinder.

The beater cylinder is stripped by the large drum, on the surface of which are located the various pairs of worker and stripper cylinders. The carding action is performed when the clothing of the drum (5), which is travelling at high speed, brings the fibres into contact with the clothing of the working cylinders (6), which rotate more slowly, and retain some of the fibres.

The fibres caught on the surface of the worker cylinders are detached thanks to the action of the stripper cylinders (7), which rotate more quickly and thus remove the material from the clothings, feeding it back into the processing cycle. The fibres are finally returned to the drum, which, thanks to the fact that it has a higher peripheral speed than the stripper cylinders, now strips them.

There is also a carding zone between the drum and the comber roller (9): the function of the comber roller is to retain and condense the fibres, before unloading them from the machine.

Delivery of the card web is helped by the raising action of the fly cylinder (8), which, having straight, long and flexible needles, draws the fibres to the surface of the drum, where the combing roller can easily detach them.

The effectiveness of this raising action, on the part of the fly cylinder, is significantly increased thanks to a pneumatic effect created by the fast rotation of this cylinder with its long, flexible needles, due to which the fibres are sucked from the base to the tips of the clothing needles.

The web of fibres picked up by the combing roller is detached by the doffer comb (10), which is equipped with a rapidly oscillating blade.

Clothings

There are two types of clothing for cards: the sawtoothlike wire and the flexible clothing. Flexible clothings (Figure 80) have needles embedded in a base strip, made up of layers of felt or flexible material.

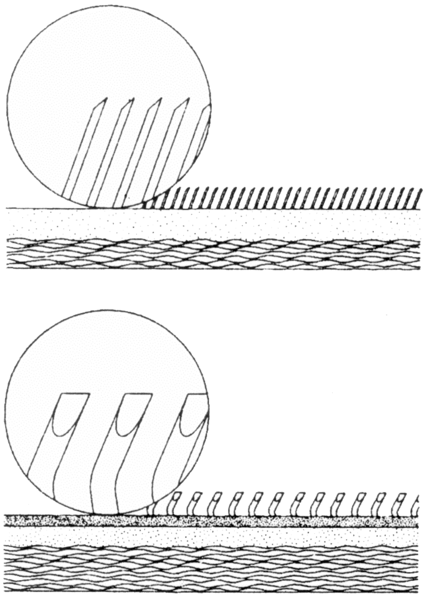

Fig. 80 Flexible clothings

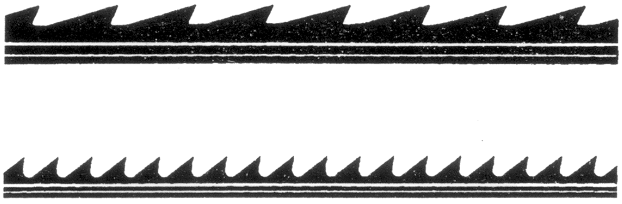

Fig. 81 Sawtooth wires

Wires (Figure 81) are made up of a steel thread with sharp-edged teeth. This makes them quite wear-resistant.

When it comes to choosing between wires and flexible clothings, it must first be remarked that there are, in general, clear advantages to be derived from using former. These advantages are, first of all, increased production levels, because wires are rarely saturated and the material is less recycled, and a less frequent need to carry out cleaning and re-sharpening, which consequently leads to a reduction in idle times. Furthermore, the life of wires is many times greater than that of flexible clothings, which means that they also cut costs considerably; finally, precisely because of the short time the fibres themselves remain on the card, wires also cause fewer fibre breaks, thus the semi-processed product has a longer average fibre length.

However, there can be major obstacles to the use of wires on cylinders other than those of the pre-carding unit, where sawtooth wires are essential in order to effect the first and the most intensive opening operation. One, when materials are particularly heterogeneous, is the presence of foreign bodies in the blends: in this situation, wires are more liable to break, and to sustain serious damage, than flexible clothings, because while the latter spring back quite easily, wires can often become irreparably dented, making it necessary to replace many metres.

Another contraindication for the use of wires can be the presence of very greasy blends.

Excess grease, that has not been absorbed by the fibres, is deposited on clothings. If these are flexible clothings, it becomes mixed with the layer of fibres that are deposited at the base of the clothing needles. Thus, it is periodically removed during cleaning. Wires, on the other hand, which become just as contaminated with grease, gather far fewer fibres and this makes them more difficult to clean. Finally, with wires, the material is not recycled to the same extent, and the carding and blending effect is less pronounced.
The flexible needles currently used are all curved knee-type needles. This is because, as they flex (Figure 82), the simultaneous rotation of the knee and foot allows the distance between the clothings to be kept constant, guaranteeing even processing and accurate counts.

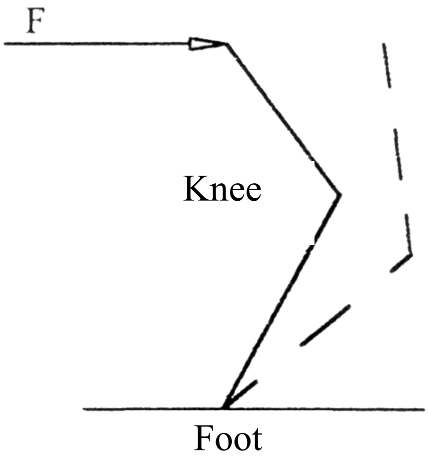

Fig. 82 Curved needle.

Loader

The equipment is fed by a loader, which has to deliver a precise amount of fibre blend in a given unit of time to guarantee accurate and continuous production of the required count. This necessity is the result of the continuity of production, which does not allow, while the machine is running, intervention to control or possibly correct the material count. The loader (Figure 83) takes material from the volumetric hopper, which is supplied by the storage boxes, and puts it into the pre-carding unit of the first machine.

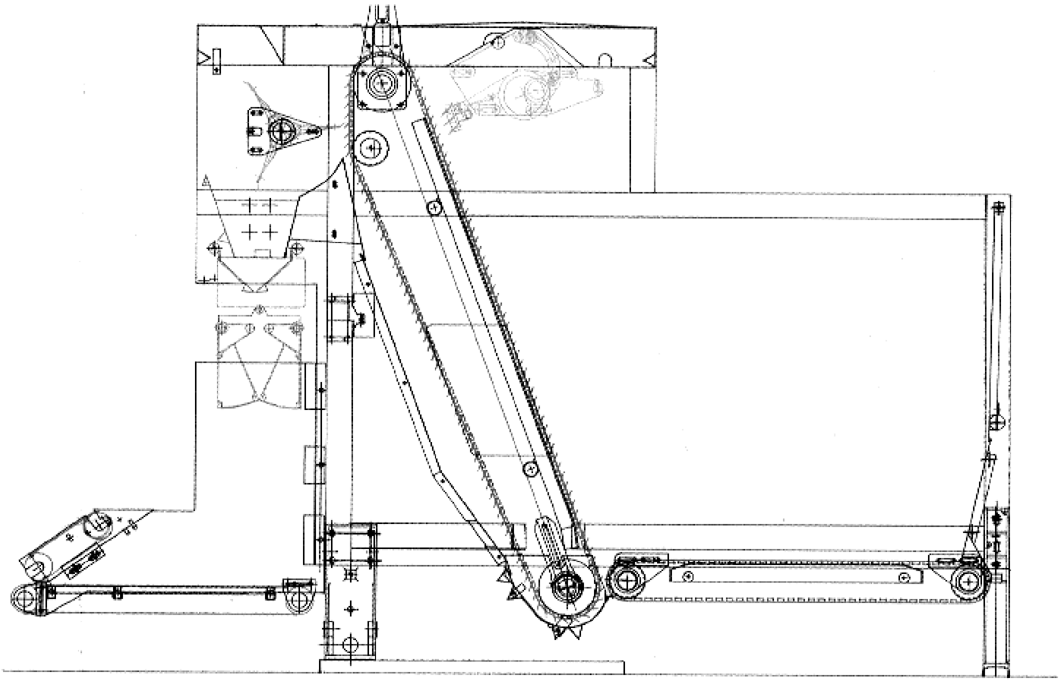

Fig. 83 Diagram of the loader

The most widespread type of loader is the weighing loader, which guarantees weighing constancy over time. The fibre blend is conveyed upwards from the lower part of the feeding chamber by an apron covered with spikes (blending apron). The fibres that have become attached reach the top of the roller and fall into the hopper, while any left over are knocked off into the feeding chamber by a lattice. The fibres are made to fall onto the conveyor at regular intervals through the opening in the hopper, which has two filling speeds: a rather high initial filling speed, to keep production up, and a slower speed, for precision completion of loading; once the required weight has been reached, a diaphragm prevents fibres already falling from landing on the conveyor.

In the most recent models, this high-precision weighing loader is mounted on the loading cells and the weighing operation is computerised. The computer:

- sets and checks the weight of the material fed to the weighing unit, intervening automatically to make adjustments
- controls the unloading of the material onto the feeding conveyor, in synchronisation with the speed of the equipment
- automatically regulates weighing cycles
- automatically triggers, according to the quantity of material being fed, the second running speed of the blending apron.

The carding room equipment

Carding room equipment can traditionally be broken down into three machines (or sometimes just two, when the raw material requires less intensive treatment) and a number of drums that is determined by the type of processing being carried out.

The carding action is repeated a number of times on each of the machines, thus, by the time they are delivered as a web, the fibres have undergone a considerable number of processing stages, which have left them clean and reasonably parallel with one another, even though they are undoubtedly shorter. A compromise has to be reached between the need to open the tufts and the need not to impoverish or excessively shorten the fibres and it is this compromise that, for each raw material, determines the most opportune number of machines and drums to be used in processing.

In the woollen spinning cycle, the basic equipment, of which a number of variants exist, is made up of three machines: the first is called the breaker card, the second the cross card and the third the divider card. An automatic conveyor links the various machines, guaranteeing continuity of production and making carding a single process, albeit one characterised by repeated, increasingly thorough operations.

By means of an underground belt, the automatic conveyor (Figure 84) plucks the web as it leaves one carding unit and feeds it to the next: during this operation, the inclination of the fibres can change by up to 90° in relation to the feeding direction.

Fig. 84 Automatic web conveyor with underground belt

The breaker card

The breaker card, fed, via the conveyor, by the loader, is made up of two drums connected by a conveyor cylinder.
The first drum, equipped with a feeder group and a series of working-stripping cylinder pairs, makes up the pre-carding unit, and is entirely wired. It opens further the material originating from the preparation stage, eliminating impurities and the largest neps, and thereby also protecting the flexible clothings on the subsequent processing cylinders against excessive wear and damage.
The peripheral speed of this first drum is around 300 m/min, that is around half that of the subsequent drums, because initially the fibres need to be processed more gently in order to avoid breakages or the uncontrolled formation of tangles.
Thanks to the action of a conveyor cylinder, the material passes from the pre-carding unit to the second drum, which is clothed with needles, and to the pairs of worker-stripper cylinders, the fly cylinder and the comber roller. The comber roller is unloaded by the doffer comb and the web is fed to the crossing card on a conveyor belt.

The intermediate card and epurator

The purpose of the conveyor that transports the material from the breaker card to the intermediate card is precisely to feed the web to the second machine, by means of condensation on an endless tape doubled with other tapes, in such a way that the fibres are overlapped forming a criss-cross effect with the feeding direction. This method of feeding the intermediate cross card creates a more intense carding effect and better blending of the material, particularly important when processing blends with a heterogeneous composition and many colours: indeed, in this way, any stripes of colour that are present are distributed across the whole width of the machine and the fault is better compensated for. This card is entirely equipped with flexible clothings and can be made up of one or two drums, according to processing requirements.
When it is delivered by the intermediate card the web passes through the epurator (Figure 85), which is made up of two hardened, ground and polished steel rollers, subjected to pressure by two pneumatic pressure devices, acting on the pins of the upper roller. This passage through the epurator results in the elimination (through the pressing effect of the rollers) of further impurities, increasing the web cleaning action crucial for optimal processing.

Fig. 85 Pneumatic epurator

Finisher card

This card, again entirely provided with needles clothings, is generally made up of a drum preceded by a fly cylinder with a pair of worker-stripper cylinders, and it serves to obtain a sliver that is as highly processed as possible.
The purpose of the divider (Figure 86) is to split the sliver produced by the condenser into a certain number of rovings – this number varies according to the working width and count required – and (by means of the rubbing sleeves) and to give these a rounded form, a prelude to the cylindrical appearance of the yarn; finally it serves to wind them onto beams that will subsequently feed the spinning machines.

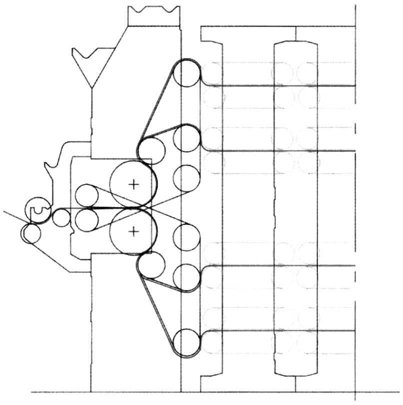

Fig. 86 Divider

Division of the sliver is obtained thanks to a series of leather aprons which, crossing over one another, effect a proper cutting action. Conceptually, this operation is the equivalent of drawing, and indeed the result is the same as that of a drawing of the web, numerically equivalent to the total number of divisions applied:

S divider = N° of rovings

In the woollen spinning process, the roving delivered by the divider, proceeds directly to the spinning machine, without the possibility of undergoing any further adjustment. This is unlike the considerable scope for adjustment presented by the worsted wool cycle, in which the length of the fibre allows repeated doubling operations and drawing on the drawframe. This is the reason why woollen yarn is characterised by rather high structural unevenness. This unevenness is the result of the upstream characteristics of the fibres and manifests itself in the roving stage, without there being any scope for corrective intervention in the subsequent passage to the spinning machine.

Composition of the carding room equipment

Due to the number of operations carried out and their crucial importance, the carding room equipment is a complex and imposing installation. Its role, basically, is to produce extremely regular rovings at the highest speeds compatible with the process.
The criterion which determines how many cards are used is above all the type of material being processed, in other words, the fineness of the fibre and the openness of the blend: characteristics that in turn determine the fibre count that can be achieved.

Indeed the equipment, like the whole spinning process generally, is quite rigidly specialised for the production of fine, medium and coarse counts, whose spinnability is influenced by the density of the clothings and by their number, by the number of carding points (the more of these there are the finer the count), by the number of rovings produced by the divider, and by the speed of the various cylinders. The number of machines and drums used depends on the extent of carding and blending that is necessary.
The automatic two-card system is suitable for processing coarse counts or high-quality yarns for knitted or woven goods, while the three-card system is mainly employed to process new or regenerated materials.

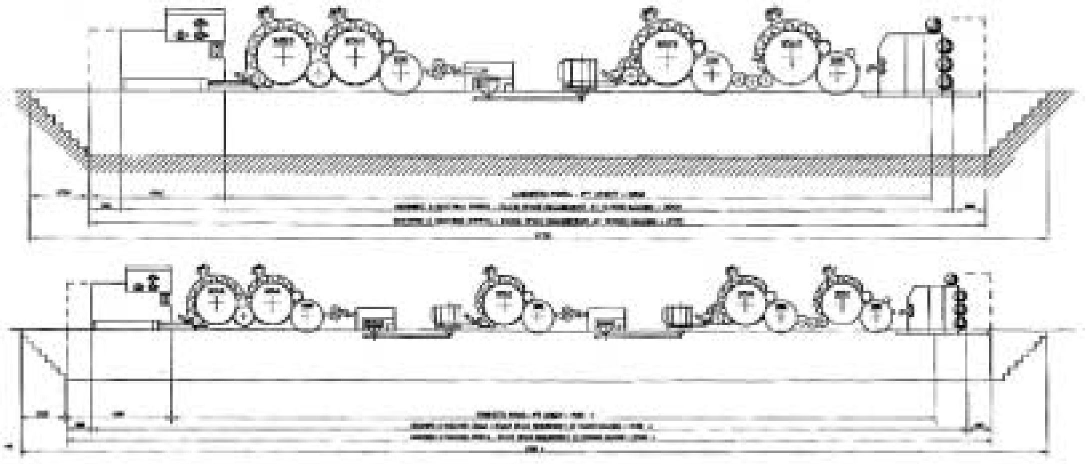

Fig. 87 Two- and three-card installations

Workplace safety and technical features

Considerable progress has been made in the area of workplace safety (owing to its structure, the card is, unfortunately, a highly dangerous machine): as a result, the carding units and the sides are now protected and fitted with safety devices. The widespread installation of automatic cleaning devices has made an important contribution to efforts to increase safety in the workplace, eliminating the need for manual intervention in this generally rather risky operation.
Technical characteristics of carding room equipment:

- working width: from 2,000 mm to 3,500 mm
- diameter of drums: from 1,500 mm to 1,650 mm
- diameter of comber rollers:1,280 mm
- number of working cylinders: up to 6 per drum
- number of cards: two or three
- number of quills: 8/12/16/20, depending on the working width and count
- number of rovings: max. 360
- production rate: max. 70 m/min, depending on the count and type of fibre
- range of yarn counts: up to 48 Nm

Settings and production

The main equipment settings concern the draft and production.

Adjustment of draft is important in order to obtain the required roving count, given that the draft imparted by the spinning machine in the woollen cycle has quite narrow limits. The mechanical draft can be calculated as follows

$$S = Vp / Va$$

in which Vp represents the speed of the comber roller and Va that of the feeders of the last machine.

Production, on the other hand, can be adjusted by increasing or reducing the speed of the comber roller in relation to that of the large drum, in other words by adjusting the condensation of the fibres for the formation of the web. The speed of the comber roller is thus limited by the evenness of the web, which must be uniform and not present thin places or tears

The divider output is expressed as:

$$P = Vp \times T\ web$$

in which

$$T\ web = N° \text{ rovings} / \text{roving } Nm$$

Automatic quill doffing

A recent development is automatic doffing of the quills on the divider, while the machine is running. This allows complete doffing of full quills, without reducing the speed of the equipment (Figure 88).

The cycles occurs as follows:

- automatic loading of empty quills
- gathering of rovings at the two ends of each quill
- automatic doffing of full quills
- shifting of empty quills into working position – collection of full quills on a special rack

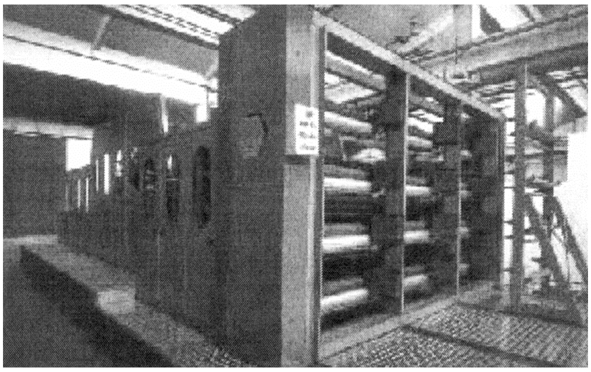

Fig. 88 Automatic doffing on the divider

As well as improving carding room productivity, the automatic doffing device makes it possible to feed the spinning machine with quills whose length corresponds exactly to that of the rovings, thus reducing roving waste.

Ring Spinning

Working principle

The beam with the rovings rests on the feeding cylinder, which, being grooved, makes it rotate through friction. The draft range is made up of a set of feeding cylinders and a set of drawing cylinders whose anti-static rubber-covered cylinders exert adjustable pressure. The yarn runs through the nip point of the two drawing cylinders with a to-and-fro motion to prevent sleeve surface wear.

The draft range, which is located on an inclined surface to allow the twists to ascend as far as the nip point of the two feeding cylinders, is followed by the yarn guide, which serves to keep the yarn perfectly aligned with the spindle axis, facilitating its winding onto the spinfinger (Figure 89). The spinfinger is essentially an extension, of varying shapes and sizes, of the end of the spindle.

The aim, in any case, is totally or partially to eliminate the spinning balloon, thereby reducing the yarn tension, and improving its strength, elasticity, evenness and obviously production rate (given the optimal exploitation of the traveller speed that derives from this).

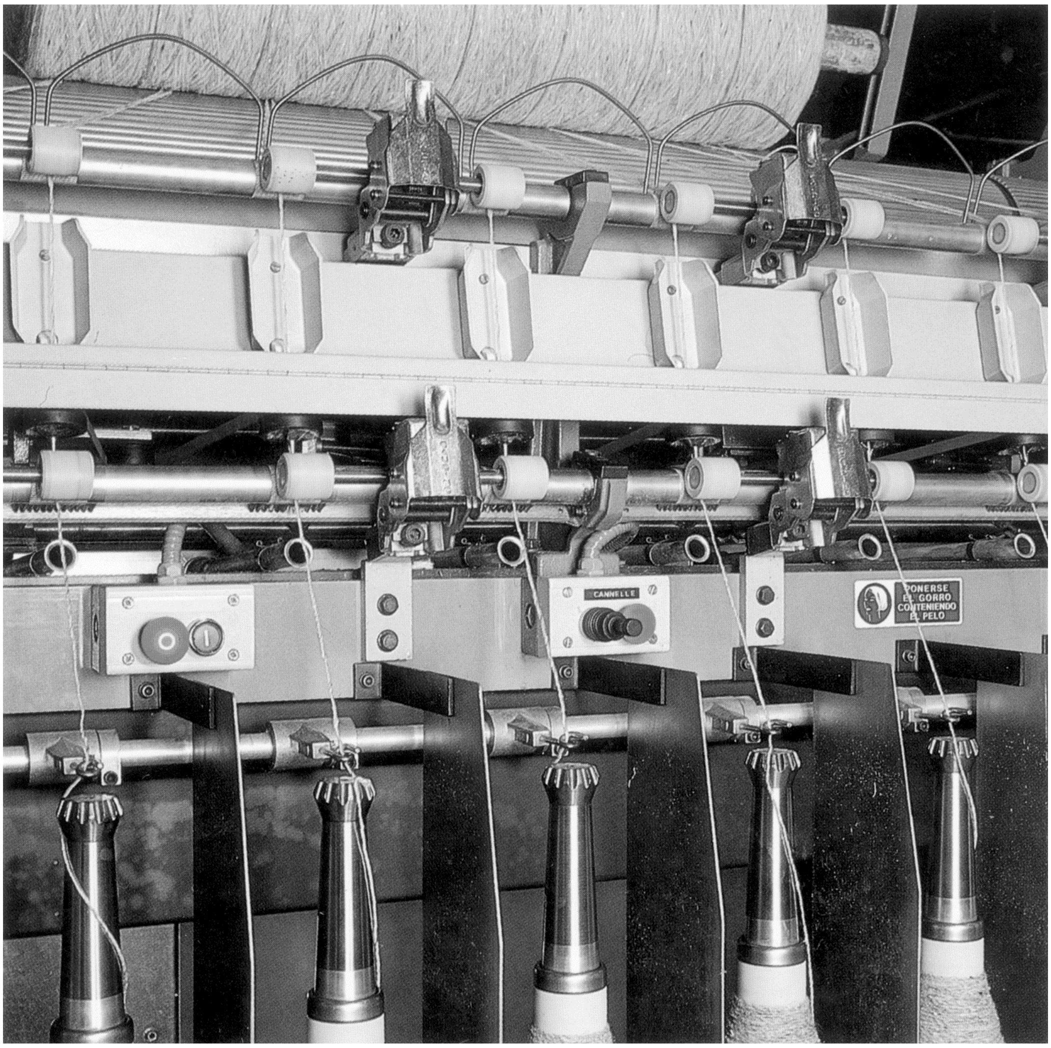

Fig. 89 Draft range and spinfinger

The yarn receives twists as it is pulled by a traveller that revolves on a ring around the spindle. Indeed, before being wound onto the spool, which revolves as one with the spindle, the yarn hooks up the traveller, which, being pulled, shares the spindle's rotary motion.
To effect winding, the traveller, which runs on a steel ring concentric with the spindle, is thus made to revolve around the spindle, effecting slightly fewer rotations per minute than the spindle itself, thus imparting one twist to the yarn per revolution of the same in the given unit of time. The twists per metre imparted can thus be expressed as

$$T/m = n_c / V$$

in which n_c indicates traveller revolutions and V the speed with which the yarn is wound onto the spool, which is also the same as the delivery speed from the drafting range.
The winding of the yarn, and the contemporaneous twisting of the same, delays the traveller in relation to the spindle, therefore the coils of yarn wound onto the bobbin correspond to the traveller delay.
The following relationship is thus established

$$n_f = n_c + n_a$$

in which n_f represents the spindle revolutions and n_a the coils.

Short fibre drafting

In this case, the rovings are not very cohesive or strong, therefore drafting must necessarily be very reduced (usually carried out at rates of between 20% and 50%) and supported by special fibre control devices. The shorter length of the raw material does not generally allow the fibres to be nipped by the pair of feeding cylinders or by the delivery cylinder, therefore resulting in a high percentage of floating fibres. Indeed, very short fibres do not fit the ideal pattern of behaviour within the draft range (whereby a fibre, nipped by its end by the pair of feeding cylinders, moves forward within the draft range controlled by contiguous fibres until it reaches the nip point of the pair of delivery cylinders, where it undergoes an acceleration), because floating fibres tend to change speed in an uncontrolled and premature manner, drawn by friction by those that the cylinders have already trapped. This is the cause of defective drafting, to which remedies can be sought in two ways:

1. through the adoption of drawing rates that are very low in relation to the length of the fibres
2. by carrying out, using appropriate devices, effective fibre control.

The so-called false twist draft is made up of a rotating organ, through which the roving runs, inserted in the draft range, close to the delivery cylinders. In a static situation, the roving would, in this way, receive false twists, that is to say in the opposite direction downstream and upstream of the rotating element. During motion, however, the situation that emerges is quite different, in that twisting is distributed and remains only in the stretch between the feeding cylinders and the point of rotation, while in the part that follows, as far as the drafting cylinders, twisting disappears, leaving the roving weaker and thus subject to breaks: this is why the rotating element is positioned as close as possible to the drafting cylinders.

Drafting and twisting is a perfectly valid procedure for fibres of a certain length, while for shorter ones it needs to be integrated with the drafting-laminating unit, which allows good control of the fibres, preventing them from floating. The control devices must guarantee the running of longer fibres as well, thereby effecting drafting in ranges of adequate width.

One valid solution is that of a pressure roller with high circumference, on which the fibres can assume a stable arrangement.

When wanting to apply a high draft ratio, thereby obtaining good adjustment of the roving, a draft range with a false-twisting device can be used, completed by a second range with a laminating unit: integration of these two systems makes it possible to increase the draft, and to achieve a stable value and stable results (Figure 90)

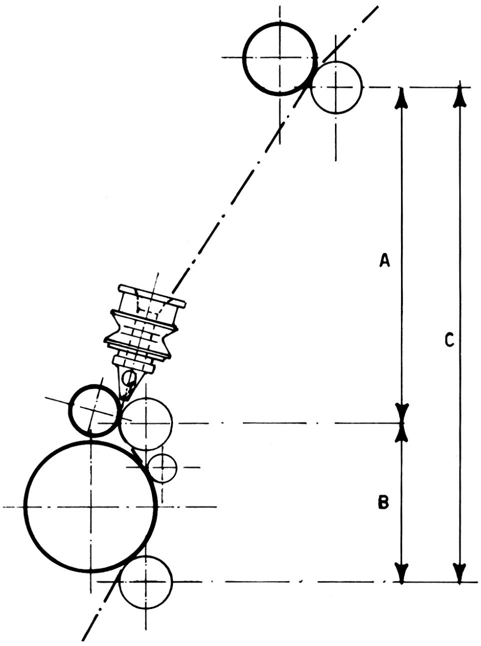

Fig. 90 Draft range with false twist followed by a range incorporating a laminating unit

In reference to the figure, the total draft to which the roving is submitted is calculated as follows

$$S_{total} = S_C = S_A \times S_B$$

Spinfinger

The spinfinger serves to retain the yarn, which is wound around it forming coils, thereby countering the centrifugal force that is the main cause of balloon formation.

This problem, typical of ring spinning machines since it derives from their very working principle, is very evident in the case of woollen and semi-worsted ring spinning frames, due to the coarseness of the yarn and the large size of the spool and ring. It is known that the factors negatively affecting yarn tension are essentially related to the size of the balloon, to the square of the rotation speed and to the various sources of friction: yarn-air, traveller-air, traveller-ring.

The coils wound around the spinfinger form a sort of reserve that supplies material when yarn tension is higher (winding of the kernel and on the smaller diameters of the frustrum) and gathers it in again when the tension drops. This allows it to cope with periodic changes in winding tension, eliminating the balloon totally (this is the solution adopted in the case of coarse yarns) or partially (the solution preferred for medium-fine and fine yarns).

The main difference between the two types is the path followed by the yarn, which, having formed a few coils around the spinfinger, runs around the tube to reach the spool formation level (this is in the case of total elimination of the balloon), while in the case of partial balloon elimination it is detached from the tube, forming a smaller balloon.

Clearly, therefore, to avoid the risk of fibres getting caught and breaking, the tube has to be well finished. The adoption of the spinfinger has allowed an increase in the tube length, with consequent benefits in terms of productivity.

Furthermore, the spinfinger allows the twists to be more evenly distributed, reaching as far as the delivery cylinders at the end of the draft range: sometimes, friction with the thread guide causes local elimination of twists and thus a considerable weakening of the yarn and increased risk of yarn breaks.

It is worth noting that modern, electronically-controlled machines use continuous spindle-speed variation during the formation of the bobbin (kernel, build-up and end), as well as during the coil deposition and winding/binding, in order to keep the yarn tension constant.

Ring

The rings are positioned on the ring rail, which has a channel that is connected with the central automatic-dosing lubrication system. The rings usually have a diameter of 75-95 mm in the case of fine yarns, 110-140 mm in that of coarse yarns and up to a maximum of 300 mm for very coarse yarns. Naturally, the spindle rotations are inversely proportional to the diameter of the ring, in accordance with the following:

$$V_c = \pi \times \Phi_a \times n_c$$

Where
V_c = peripheral speed of the traveller
Φ_a = ring diameter
n_c = number of traveller revolutions

The speed of the traveller is theoretically restricted to around 40 m/s (but this can be much lower if problems connected with the working principle are exacerbated by problems relating to the strength of the yarn, which is highly variable and depends on the type of fibres). Thus all wool spinning machines are characterised by a speed that is, on average, lower than that of worsted wool spinning machines. In particular, the table below refers not only to the classic set of rings with diameters ranging from 75 mm to 140 mm, but also to those reserved for particularly coarse yarns, with diameters of up to 300 mm.

GAUGE	**Φ RING**	**H TUBE**	**COUNT**	**SPINDLE**	
(mm)	(mm)	(mm)	Nm	(rpm^{-1})	
106	75 – 80	350 – 400	8 – 30	10.000	FINE YARNS
120	90 – 95	400 – 450	6 – 16	8.500	
145	110	450 – 500	4 – 12	7.000	COARSE YARNS
165	127	500 – 600	2 – 8	6.000	
180	140	600	1 – 5	5.500	
240	200	700 – 800	0,5 – 4	3.800	EXTRA COARSE YARNS
300	300	700 - 800	0,5 - 3	3.000	

Spinning machine automation

Efforts to automate the spinning machine concern both bobbin and quill change.
Following the automatic descent of the ring rail, the cycle occurs in the following stages:

- yarn breakage, removal and raising of the bobbins above the spinfinger
- unloading of full bobbins on to the conveyor belt
- automatic reloading of empty tubes onto the spindles
- cutting of the rovings being processed and unloading of empty quills onto relevant conveyor
- deposition of full quills (via a suspended chain device) onto the feeding drum
- automatic splicing of the rovings.

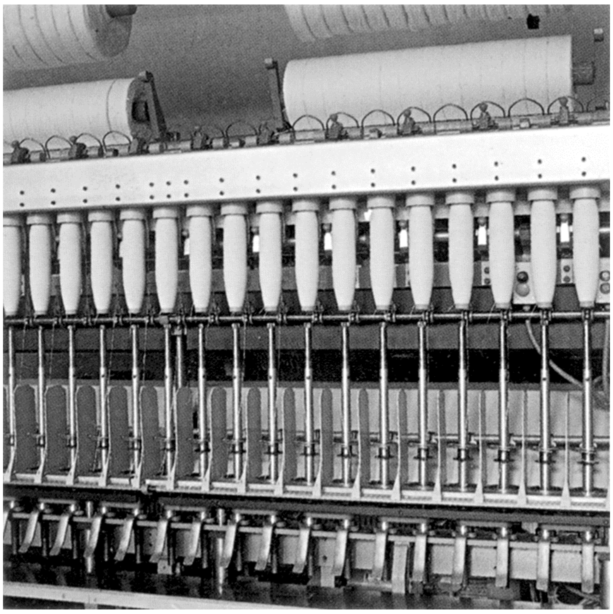

Fig. 91 Start of bobbin unloading stage

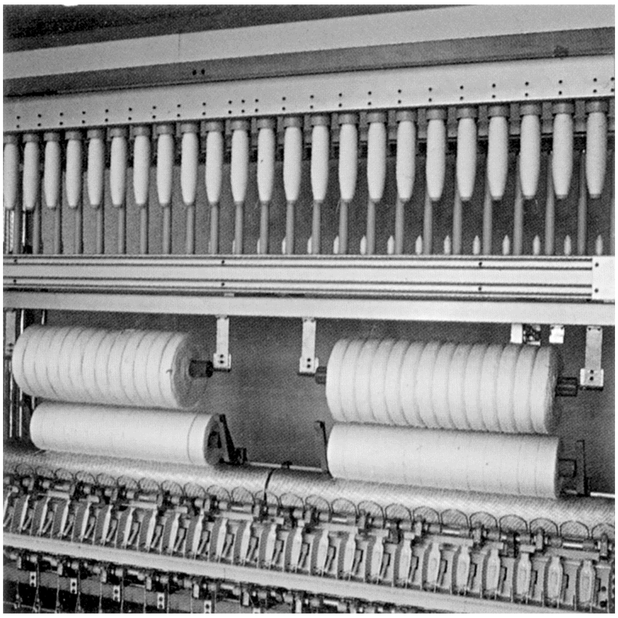

Fig. 92 Raised, removed bobbins

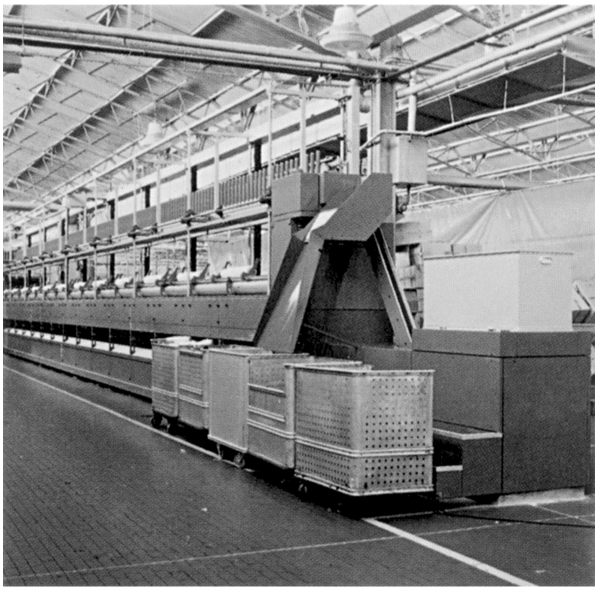

Fig. 93 Bobbin unloading and tube reloading

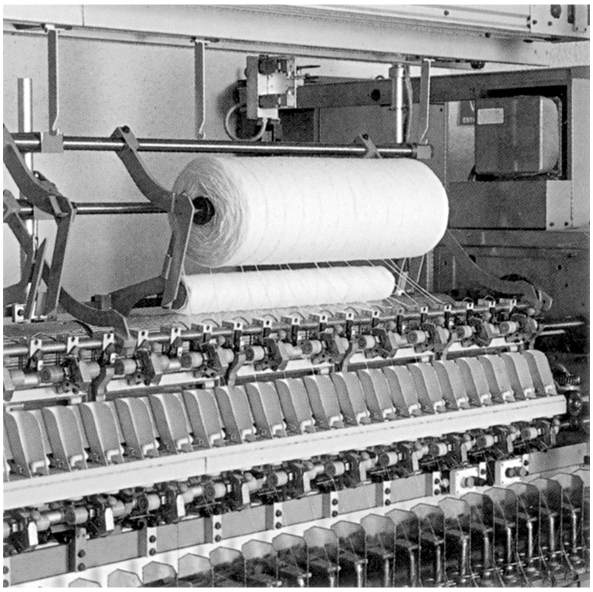

Fig. 94 Quill change and roving splicing

Selfacting Spinning Machine

Working principle

The selfacting machine is a discontinuous-type spinning machine that, operating cyclically, forms a given length of yarn and then winds it onto a cop.

These two stages, which take place separately, are characterised by the reciprocal movement of the two parts that make up the selfacting machine: a moving carriage, which, in each working cycle, effects a forwards and return motion, and is where the feeding quills are located, and another fixed carriage that accommodates the spindles (Figure 95)

Fig. 95 View of an automated selfacting spinning machine

In each working cycle, a length of yarn (the so-called run-out) is produced, which corresponds to the distance travelled by the moving carriage.

The working cycle of the selfacting machine can be broken down into three stages:

1) the forward motion of the roving-carrying carriage with drawing and twisting of the fed roving
2) carriage stopping and ultimate twisting, compensation for shortening and preparation for winding
3) carriage return and winding of the yarn onto the cop

1st Stage
During feeding, the beams onto which the rovings are wound are made to rotate by the grooved cylinders on which they rest, in such a way as to unwind the material, which then passes through a pair of cylinders to create a nip point and to be fed to the spinning machine.
In this stage the spindles start to turn slowly, while the feeding table on the rails, starts to distance itself from the spindles, moving at a speed greater than that of the roving unwinding. This results in progressive drafting, while the spindles increase their speed of rotation, imparting pre-twists. The spindles are positioned slightly lower than the feeding frame and show an approximately 15 degree inclination towards it, thus the coils of yarn that become twisted around the end of the spindle tend to slip off it, becoming transformed into twisted coils on the yarn. Each twist is thus produced by a spindle rotation and constitutes a failed winding (Figure 96)

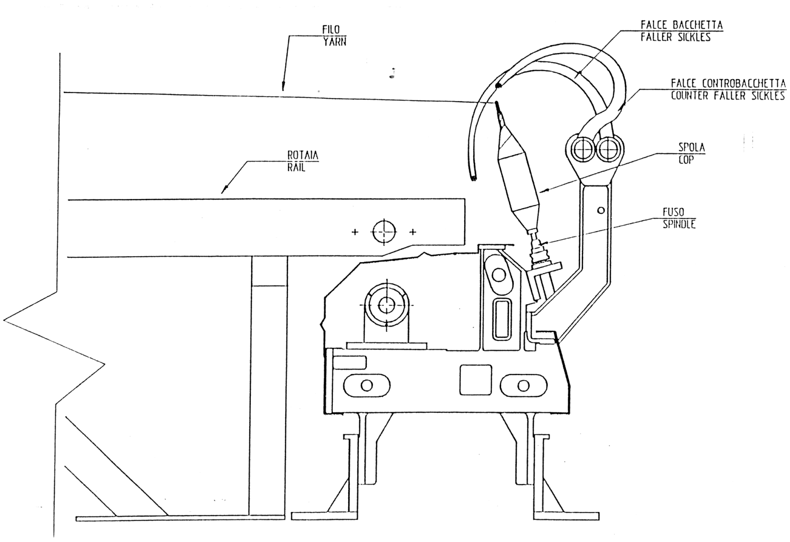

Fig. 96 Twisting stage

The pre-twists, thus called because they are formed during drafting and represent only part of the total, definitive twists, are fundamentally important because they bind the fibres together, making the roving strong enough to withstand drafting without breaking and increasing its evenness. The tension to which drafting subjects to the roving increases in proportion to the number of pre-twists imparted, while parallel with this the elongation at break is reduced: the twists per metre needed in order to obtain the highest elongation at break value at the highest possible draft ratio can thus be evaluated experimentally. Naturally, the draft ratio (usually between 20% and 50%) is also influenced by extremely variable factors, such as the type of material being processed, the characteristics of the fibres, and the amount of emulsion present on them.
Pre-twists are also very useful in compensating for possible roving irregularities. In fact, the fibres, due to their short length and marked heterogeneity will very rarely be well aligned and parallel with one another, as a result the roving will usually have an uneven shape, characterised by thicker and thinner places. Consequently, the pre-twist plays a positive role as the twisting action is stronger where the roving is thinner, giving to these points a higher resistance to drafting, unlike the thicker places – less twisted and therefore weaker – which will thus be homogenised with the rest of the roving. Behaving in this way, the fibres promote “intelligent” drafting distribution, varying the intensity more or less according to need.

Analysing this phenomenon in greater depth, it can be hypothesised that the pre-twists serve to slow down the movement of the fibres, extending the initial straightening and alignment stage, and are probably helped in this by the vibrations induced in the roving by the rotation of the spindles and the consequent escaping of the coils off the spindle tips. Spindle rotation increases progressively as the feeding table becomes more distant, according to a curve adjustable according to the requirements of the yarn: at the end of this motion, the roving is drawn, pretwisted and even.

2nd Stage

At the end of the drafting stage, the feeding frame remains still and the spindles rotate at maximum speed, imparting the twists that, added to the pre-twists already conferred, reach the definitive value to be given to the yarn. The twists are, in the same way as the pre-twists, distributed along the length of roving thus far processed although now the process is considerably speeded up to reduce as far as possible the duration of this stage, which is non-productive.

The twists lead to a shortening of the yarn, which can be compensated for in two ways: by returning the feeding carriage, or by overfeeding the roving.

At the end of twisting, a few coils of yarn remain wound around the end of the spindle, preventing the subsequent winding of the yarn onto the cop. These can be unwound by making the spindles rotate briefly in the opposite direction. The release of these coils reduces the tautness of the length of yarn produced, and this tautness thus has to be restored. This is where faller sickle comes in, to guide the winding, and the counter faller sickle, to maintain adequate tension during winding.

3rd Stage

The faller and counter faller sickles are two devices that can be likened to thin metal rods that form part of the spindle carriage and run across the entire front of the same: when the carriage starts its return, the faller sickle lowers rapidly as far as the maximum cop diameter, effecting the binding coils needed to render the cop compact; they then ascend returning as far as the minimum diameter, to effect the winding coils, which are overall about 4 or 5 times longer than the previous ones (Figure 97).

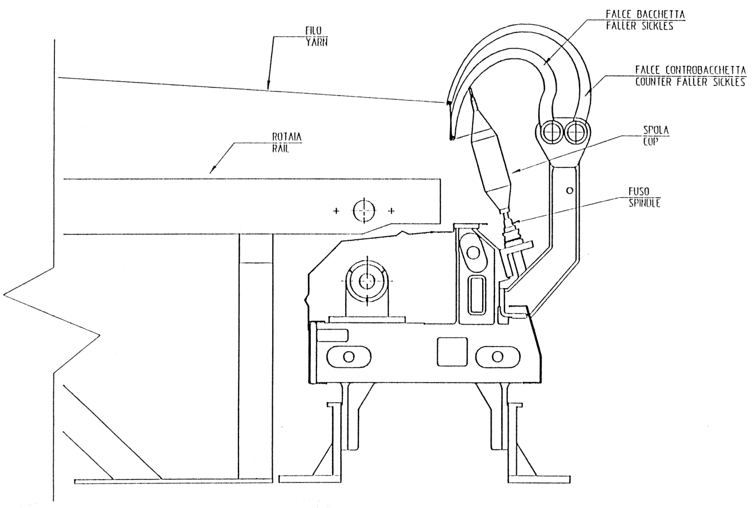

Fig. 97 Cop winding stage

While the faller and counter faller sickles control, respectively, the yarn distribution motion and its tension throughout winding, it is also necessary to vary the speed of rotation of the spindles in accordance with the laws regulating the formation of the cop's conical layers. Once the carriage has returned and the winding is finished, the faller sickles have fulfilled their function and return to their starting position, allowing coils of yarn once more to wind around the end of the spindle, at the start of a new working cycle.
Winding is the machine's productive stage, during which the yarn is wound onto the cop thanks to the rotation of the spindles and the contemporaneous return of the carriage.
On the other hand, it is also a very delicate stage that must ensure the formation of a compact and adequate-size cop, that will guarantee optimal unwinding during subsequent processes (winding, warping...)

Automation

In the electronically-controlled selfacting machine, the driving and control of feeding, drafting, twisting and bobbin formation is managed by a microprocessor that permits optimal regulation of the spinning parameters, in relation to the characteristics of the raw material, as well as the formation of a controlled-tension cop.
The spinning machine can be equipped with a quill and cop change automation system.
The cycle is made up of the following stages:

- doffing of the cops followed by their transportation and deposition in containers situated alongside the machine. The cop-doffing unit descends from its rest position above the machine and proceeds to slide the cops off the spindles, simply snapping the yarn, carrying out binding and underwinding.
- placement, on the spindles, of empty tubes picked from a container alongside the machine, w here they are oriented appropriately and positioned on a rack.
- quill change with unloading of the empty beams at the side of the machine. This stage is preceded by the pre-arrangement of the quills, with manual positioning of the new rovings in gripping devices (these are all part of the operator's routine tasks and do not, therefore, negatively affect performance). The empty quills are moved away from the feeding table and replaced by the full ones, prepared earlier.
- splicing of the roving by superimposition of the old over the new roving.

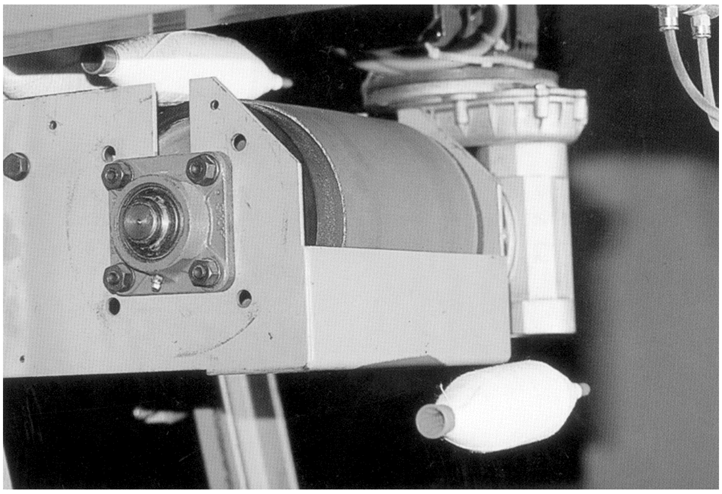

Fig. 98 Full cop doffing

Fig. 99 Container of loose tubes

Fig. 100 Tubes orderly positioned on the rack

Technical features

- number of spindles: max. 900
- max. spindle speed: 11,000 rpm
- max. mechanical speed of the feeding frame: up to 8 cycles/min (depending on the stroke)
- spindle gauge: 62-65 mm
- spindle height: 320 mm
- stroke: from 3 m to 6 m

Fancy Yarns

General remarks

A fancy yarn is characterised by special effects (knots, slubs…) that alter its section, rendering it irregular, in accordance with a pre-established pattern, and sometimes incorporating colour effects.

These products are widely used in the hand knitting and knitting sectors, which exploit to the full the fanciness of these yarns, but they are also used to a considerable extent in weaving too, particularly in women's clothing.

Fanciness in a yarn can be obtained using different processes, creating infinite scope for effects, often combined, which can be added to other designs that are now regarded as "classics".

The woollen spinning cycle, due to the way it is structured and even more due to the characteristics of the raw materials used, allows special fancy effects to be obtained within the spinning cycle

Spun fancy yarns

In the preparation stage, it is possible to create two types of fancy yarn: yarns with loose hairs and knop yarns.

In the first case, the effect is obtained by adding loose hairs to the blend, giving the yarn a fuzzy appearance and a silky hand. The presence of loose hairs generally necessitates three passages through the blending chambers, the second one involving an extended pause, long enough to allow the blend to "rest".

Loose hairs are generally fibres of animal origin (sheep, camel, reindeer), although sometimes synthetic fibres can be used (Trital, three-lobe fibres). These however give the yarn a more "brindled" appearance.

In the second case, the fancy yarn is obtained by adding pills of felted wool to the blend. Again, the blend must pass through the blending chambers three times, in order to ensure even distribution of the pills in the blend. To prevent opening of the pills during carding, the initial slashing should be particularly thick as it will be gradually eliminated along the carding line.

The presence of the pills gives rise to a diffuse and uneven swelling of the yarn section along its entire length. This is a result of the imperfect carding and the colour, too, will have a melange appearance.

In **carding** it is possible to obtain knop, malfilé and slub yarns.

The first, obtained through the insertion (using a special distributor) of pills on the second card web, will have a different appearance from the type described earlier. In this case, carding is carried out according to the normal slashing parameters, therefore the section of the yarn is larger only in the proximity of the pill, whose colour stands out and therefore does not give rise to a melange effect.

A malfilé yarn is characterised by its unevenly distributed thick and thin places. This yarn can be obtained using a blend of long fibres ($L > 40$ mm), which account for 60-70% of the total and short, noil-type fibres, accounting for the remaining 30-40%. This undergoes imperfect carding, with thick slashing for resisting the action of worker and stripper cylinders and comber rollers.

To obtain a slub yarn, carding is carried out as normal and the effect is inserted at the stage of the condenser card, prior to the divider.

A special, computerised device, programmed according to the size and frequency of the slubs, intervenes pneumatically on the fly cylinder, increasing both its descent on the drum and, therefore, its extraction of fibres from the clothings.

On the **spinning machine**, meanwhile, it is possible to produce doubled yarns, obtained by feeding two or more rovings into the machine's draft range: the resulting yarn is bulky with few twists.
Another interesting opportunity is offered by the friction spinning machine, which, normally employed to produce yarns for technical uses (automotive industry, protective clothing, filters…) and for the furnishing sector (covers, carpets), can also be employed to produce fancy yarns.

Friction spinning machine

The friction spinning machine (Figure 101) operates on the basis of a principle of mechanical/aerodynamic spinning.
Being an open-end spinning machine, it effects direct transformation of sliver into yarn and delivers, at high speed, very large packages.

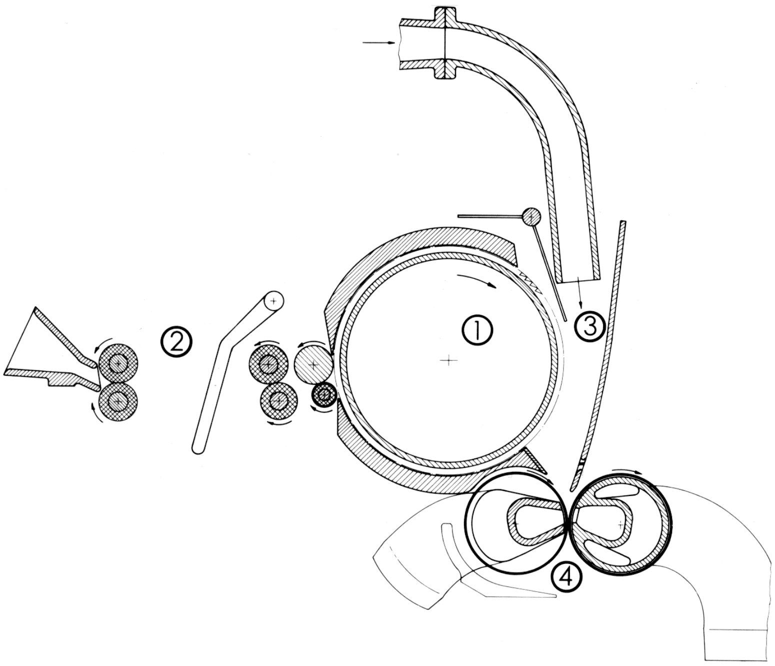

Fig. 101 Friction spinning machine

A rotating carding cylinder (1) breaks up the sliver applying a high draft between the entry (2) and the clothed surface of the cylinder itself. Thanks to a strong pneumatic suction effect (3), which increases the draft, the fibres are detached from the cylinder and transferred along the nip generatrix of the pair of spinning cylinders (4).

These are perforated and exert a suction effect on the fibres, which become twisted due to the friction effect and the torque imparted by the two cylinders, which have the same direction of rotation. The yarn is formed from the inside outwards by superimposition of the individual fibres, which, ultimately, become twisted round one another and strongly bound together. The yarn leaves the nip area of the two cylinders, parallel with their axis of rotation, and is then wound onto cylindrical packages at a rate of around 250-300 m/min.

The friction spinning method, while creating cohesion of the material only with a rather high number of fibres in the cross section (yarn count ranging from 3 to 10 Nm), is not as influenced by the characteristics of the fibre as all the other types of spinning. It allows the processing of natural or man-made fibres with counts ranging from 3 to 15 dtex and lengths of 5-100 mm: compared with traditional spinning machines, these machines clearly benefit from using heterogeneous, even regenerated, materials.

Furthermore, the possibility of using different types of filament as the core means that the yarn is quite strong. In order to obtain particular fancy effects, the spinning machine can be fed with slivers of different colours and materials. Within the maximum admissible loading limits (30 ktex), it is possible to feed various slivers (for example 5 6-ktex slivers), whose fibres will be arranged coaxially, creating a layered effect. Yarns can thus be constructed with the shortest and weakest fibres in the middle and the longer and the more valuable fibres at the outside or with whatever colour effect you like.

An experiment is currently being carried out to verify the possibility of using slivers originating both from cotton cards and from sets of carding cylinders with sliver delivery without the divider and from the worsted wool cycle.

Twisted fancy yarns

The classic fancy yarn is a twisted yarn made up of at least three yarns; of these, one serves as a support and is called the **core**; this is twisted with a second, usually overfed, yarn to create the desired design, this is called the **effect**. A second twisting stage serves to confer stability, uniting the semi-processed product resulting from the first operation with a third yarn, called the **binder yarn**. These three functions, core, effect and binding, can also be fulfilled by a greater number of yarns than this. A twisted fancy yarn can indeed be made up of a high number of yarns and there can be a roving in place of the effect yarn.

The twisting of fancy yarns is normally carried out using the following two types of machine:

1. ring twisting frame
2. hollow spindle twisting machine

The twisting of fancy yarns can involve two subsequent operations (this is the traditional procedure, currently less used), or a continuous two-stage process: in this latter case, a combined machine has to be used, equipped with a hollow spindle and ring system. Clearly this is the more productive solution, but the choice is generally dictated by the type of fancy yarn that is to be produced.

Ring twisting frame

In the first operation, the core and effect yarn are fed by separate cylinders, in order to allow overfeeding of the latter, while the twisting that binds them together is imparted, in accordance with the ring spinning principle, by the traveller.

In the second operation the binder yarn twists around the semi-processed yarn with a lower twist and in the opposite direction to the previous stage. This results in a partial loosening of the effect, resulting in a soft yarn.

Hollow spindle twisting machine

In this machine the hollow spindle with the binder yarn is positioned between two pairs of cylinders, while a hook, below the spindle and rotating in the same direction, twists the core and effect yarn (Figure 102).

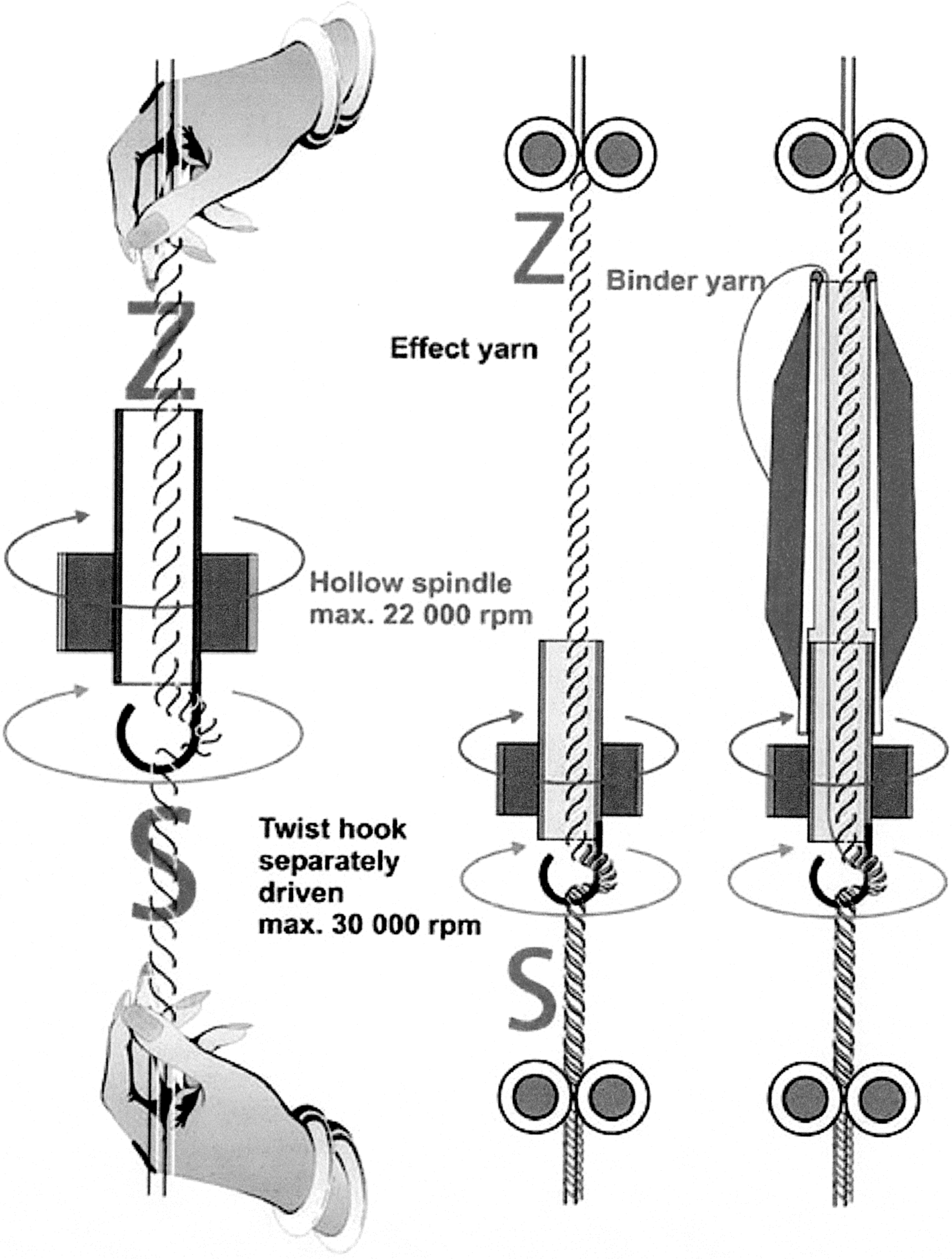

Fig. 102 Principle of the hollow spindle twisting machine

Given the intermediate position of the spindle – it is located between the pair of feeding cylinders and the pair of delivery cylinders – the twists imparted during this first stage are in the opposite direction between the first and second length of the two yarns.

The binder yarn runs inside the hollow spindle, parallel with the semi-processed core-effect yarn, as far as the twist hook, which makes it twist round the other two yarns, stabilising the product.

If the twist hook is driven as one with the spindle, and thus accomplishes the same number of rotations, the twists imparted to the core and effect yarn will number the same as the final binding twists. To prevent an excessively high number of twists making it necessary to stabilise the yarn with a steaming process, a separate hook twist drive has been developed that can rotate at a higher speed than the hollow spindle. The yarn is wound onto a package.

Spinning–twisting machine

The twisting of a fancy yarn can also be accomplished using a machine that combines the two processes, ring and hollow spindle.

In this case the first operation is carried out by the hollow spindle, preceded by the core and effect yarn feeding group. Below the hollow spindle, which holds the binding yarn, is located the ring spindle, which winds the yarn directly and the twists are loosened as an effect of the relative speed between the first and the second stages. Indeed, the ring spindle cannot rotate as fast as the hollow spindle and while this results in a softer yarn, the rate of production will inevitably be lower, given that the bobbin will also have to undergo a subsequent winding stage.

When the machine is fed with yarns rather than rovings, it becomes an out-and-out twisting machine (Figure 103).

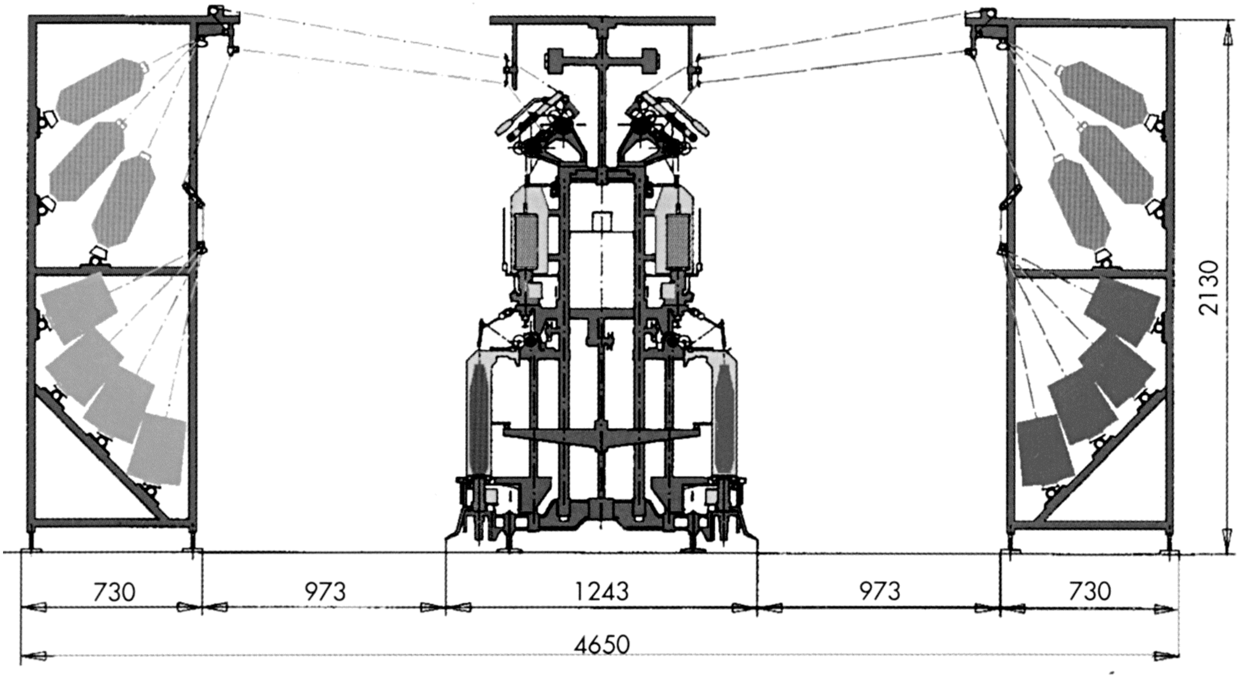

Fig. 103 Twisting machine

When the effect is obtained by a roving, the machine must also effect drafting; this is why it is called a spinning-twisting machine (Figure 104)

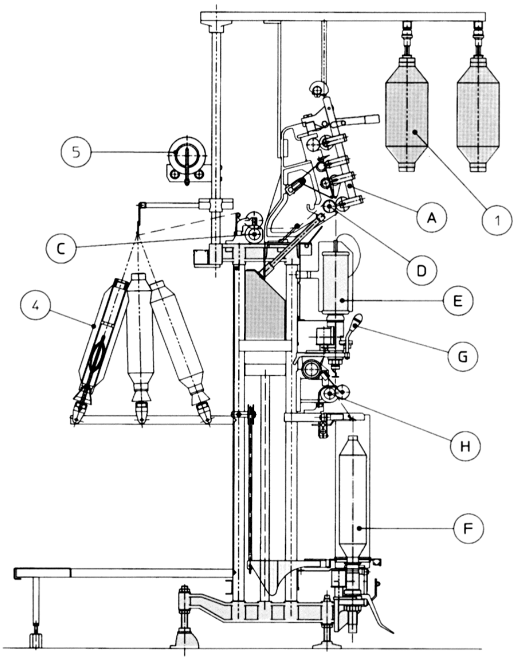

Fig. 104 Spinning-twisting machine with drafting line

The fed material is the roving (1) on spools, which is drawn by the laminating unit (A). The core yarns (4) are fed by the cylinders (C) and reach the exit from the drafting-laminating unit, where they are united with the effect yarn at point (D). Cylinder (5) is used for elastane, for the possible production of stretch fancy yarns. The binder yarn, positioned in the hollow spindle (E), stabilises the effect yarn, and the yarn, via the control cylinder (H), is then collected on the lower spindle (F), where the ring system evens out the twists. Using the handle (G), the operator can stop the spindle to repair breaks or replace the binder yarn package.

Fancy yarns can also be created by feeding more effect yarns, made up both of sliver in cans and of rovings on spools. In this case, the machine has two drafting lines (Figure 105), independently controlled, that make it possible to achieve a vast range of colour effects and constructions.

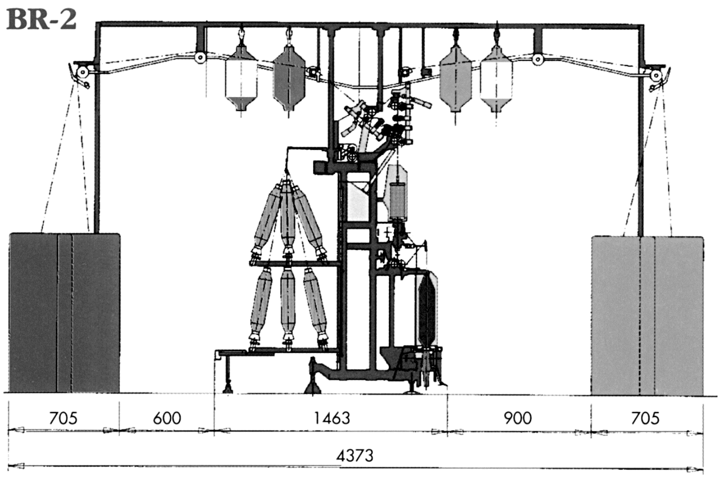

Fig. 105 Spinning-twisting machine with two drafting lines

Technical features of spinning-twisting machines

counts produced: 2-24 Nm
roving count: 0.5-5 ktex
ring diameter: 90 mm or 115 mm (depending on the count)
max. speed (hollow spindle): 12,000 rpm
max. speed (ring spindle): 8,000 rpm
effect: continuous or discontinuous