Woollen Carding

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The woollen carding process is designed to open the fibre tufts into individual fibres and blend them together again into a fibre web. This web is then split into many parallel strips that are rubbed into condensed slubbings, yarnlike threads but twistless and therefore lacking strength. These slubbings, the equivalent of the rovings of worsted or cotton spinning, are taken to the woollen spinning frame on long bobbins and spun into yarns for knitting or weaving. The overall process is therefore short and the quality of the card web determines the quality of the slubbings and of the yarn spun from them.

The Woollen carding process differs from the worsted process in that the card has many more sections because it is required to perform much more intimate mixing and blending than the worsted. Woollen cards usually have four or five sections, each with a main cylinder (the "swift") and workers and strippers arranged around them, an intermediate doffer links the sections. The woollen card also uses in its later sections "flexible" card clothing rather than rigid "metallic" wire. This flexible wire allows a high point density and helps to open up neps formed in the earlier carding parts. Much more lubricant is used in woollen processing than in worsted, around 4% compared to 0.5%. This to preserve fibre length through the long card, to reduce static electricity, and to help with condensing at the rubbers.

Input to the woollen card is usually by a weighing-hopper feed. Because any density variations at the input will generally appear uncorrected in the yarn, modern woollen cards use accurate weighing systems, whether weigh pans, roller-weigh systems or weigh-plate systems. Some also use secondary corrective systems such as Servolap which adjusts the feed rate according to a nuclear or X-ray measurement of the batt being fed into the card. The measurement, whether, weigh-system or X-ray then also controls the feed roller speed to provide a constant average feed rate of fibre.

The card-clothing gets progressively finer closer to the output. Many different combinations of clothing densities and types are chosen by carding engineers according to the fibres to be processed, which are often highly varied, and their training and beliefs. The main rule followed is that finer clothing (higher point densities) are required for the processing of finer fibres. Other than that, different factories processing identical fibre blends can operate with completely different complex (and secret) recipes to produce the same quality product.

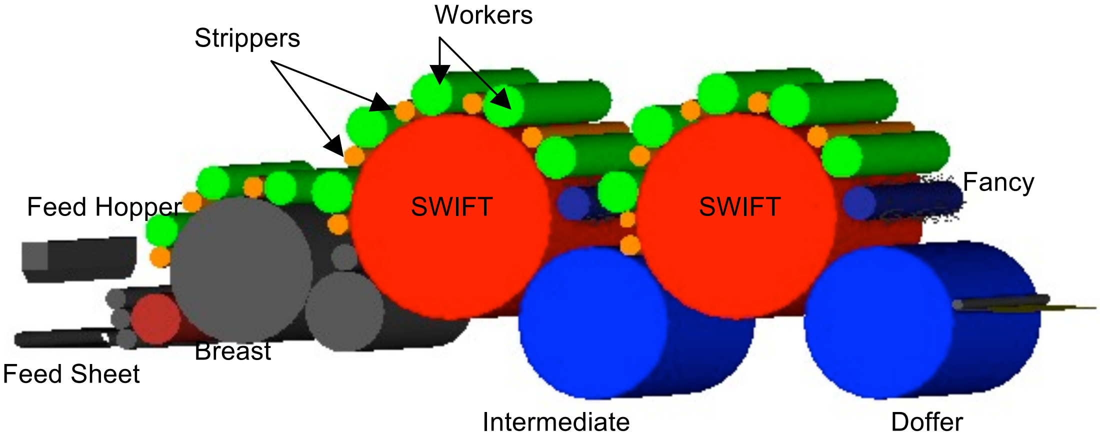

Figure 1. Schematic diagram of the input section of typical Woollen card.

The card operates by separating fibres and fibre tufts between rotating rollers covered in card clothing. The clothing or "wire" has many fine points like a wire brush that catch the fibres. In the diagram of Figure 1, the Breast and Swift rotate clockwise while the workers rotate anticlockwise and many times more slowly than the main cylinder. The teeth of the Swift wire face forward while the teeth of the worker wire faces backwards and so the speed difference and wire direction means the Swift and workers work point-to-point. Fibre on the Swift is separated at the worker-Swift interaction, some fibre passes to the worker and some fibre stays on the swift. The fibre on the worker goes around relatively slowly towards the stripper. The stripper returns the fibre to the swift, the fibre is split again at the worker and the process repeats with a time delay determined by the worker speed and size. In this way the fibres are separated and blended. The effect is also to smooth out density fluctuations. If all the workers were run at exactly the same speed then, because the swift is running much faster than them, they would always return the same fibre to the swift at the almost the same time. This would mean that a coloured tuft, say, or a fibre density fluctuation, would be reinforced by the worker action laying the fault back onto itself repeatedly. For this reason workers are usually driven by sprockets of diminishing size so that they have different speeds. A similar separation occurs at the doffers where some fibre is transferred to the output and the rest is recycled around the Swift. Thus most of the fibre is remixed many times in the machine direction before leaving each carding section. Weight control systems and the smoothing action of the card cannot however correct for cross-wise density variations at the feed. Because the transfer of fibre, and hence the blending and smoothing action, always occurs in the card's machine direction there is no cross-wise mixing within a card section. The card is therefore usually split into "forepart" and "finisher" sections, linked with a cross-lapping device that takes the web produced by the forepart, condenses it and lays it across the input of the finisher section as shown for example in Figure 2. This ensures mixing across the card and so improves blending of the different fibre types introduced as tufts at the feed section. It also provides smoothing of cross-wise density variations that occur at the input to the card. The correct operation of the cross-lapping device is crucial to the evenness of the web produced and hence crucial to yarn quality. Any fluctuations occurring at the cross-lapper due to poor overlaying of the slivers will only be partially smoothed out by the finisher section. After the forepart the cross-lapper then lays these well mixed longitudinal stripes across the finisher section which then mixes them again. The cross-lapping action also turn long scale-length variations that were along the machine into short term variations across the machine, the finisher section can then smooth out these short term variations but it has little impact on long scale-length fluctuations.

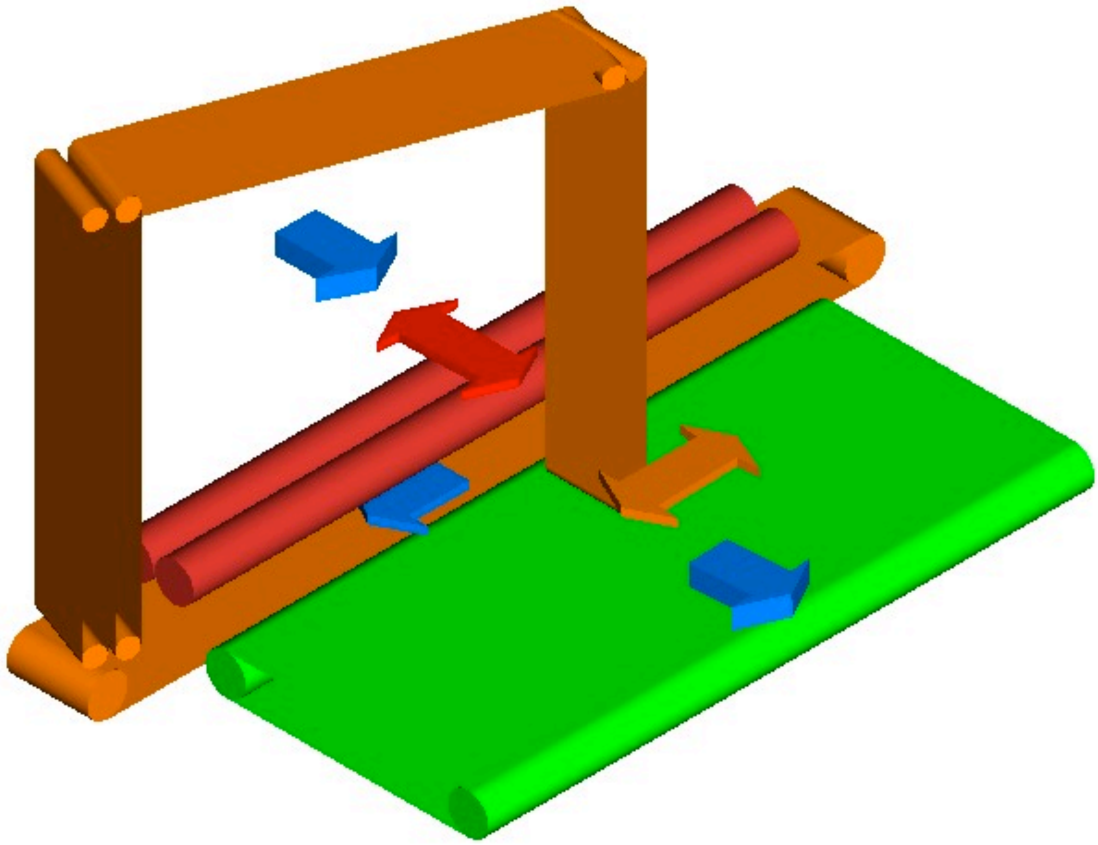

Figure 2. Woollen card Cross-Feed

The finisher section is similar to the two swifts of the forepart but has finer wire on rollers more closely set together. Sometimes the forepart produces a nep but the finisher can open the nep to give a clean web. Higher fibre loading in the working areas of the card, ie the worker-swift and swift-doffer interactions generally means more nep and poorer web clarity. More recycling around the swift and workers means better blending and opening but also gives higher card loading. Hence lower productivity is used if higher blending is needed so that the card loading is not excessive while recycling within the card can be high.

The fancy roller is positioned just before the doffer and runs in the same direction and slightly faster than the swift to lift the fibre embedded in the swift closer to the surface. This increases the efficiency of fibre transfer to the doffer reduces recycling. It also helps reduce the amount of fibre that becomes permanently embedded in the swift and that has to be periodically removed by “fettling”. The fancy is clothed with long flexible wire that is set to slightly penetrate the swift wire.

The final web from the finisher section is fed into a tape condenser. The tape condenser splits the web into many narrow webs and feeds them to rubbing aprons that are oscillating transversely to the machine direction while simultaneously rolling forward to carry the slubbings to the output. The rubbing action on the webs rolls them into lightly felted slubbings strong enough to be wound up and taken to spinning. At the feed section of the tape condenser alternate tapes trap the web against an upper or lower calender roller. As the tapes travel forward half go upwards and half go downwards so that the web is torn into thin continuous strips. These are usually fed into one of four sets of rubbing aprons such that each slubbing is separated by the width of four tapes. The tape width, and hence number of tapes across the card, is determined by the count range that is desired to be spun. Narrow tapes for fine counts and wider tapes for heavier counts. Fine count cards have tapes around 10mm wide and spin down to 40Nm or 20tex at the extreme, while medium counts of 150tex would have around 14mm tapes. Machinery manufacturers provide tables to advise on choice of tape width. In order to increase production rate, double and even triple rubbing sections are sometimes used.

After rubbing the slubbings are wound up onto bobbins via a surface drum. The surface drum keeps the speed constant whatever size the package has grown to. The bobbins are removed “doffed” when full and the condenser “creeled” with empty packages. The width of the bobbins is chosen to allow them to be handled easily if manual handling is required. For automatic systems larger packages can be used. The diameter of packages is limited because the slubbings are soft and cannot be wound tightly.

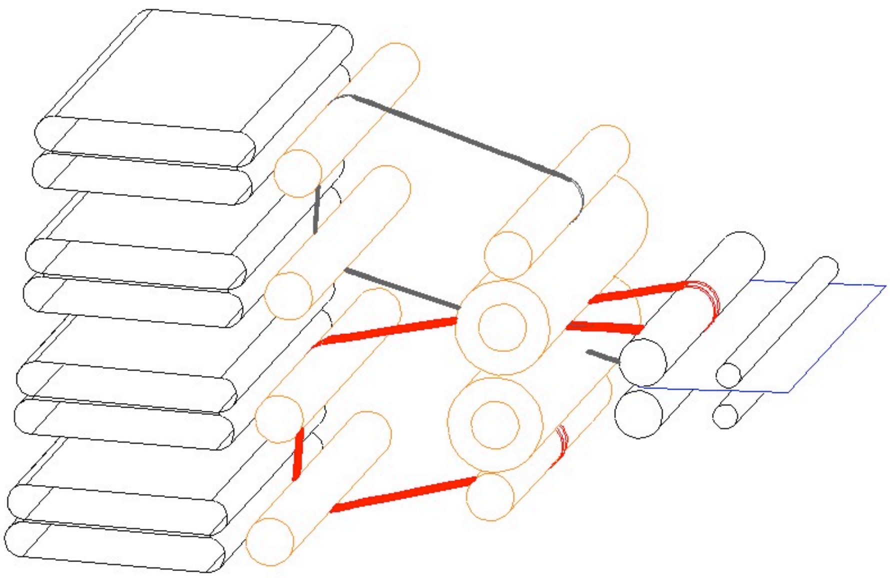

Figure 2. Schematic diagram of woollen card condenser

Woollen Spinning

Woollen spinning consists of three main steps: drafting, twist insertion, and winding onto the cop. There are two major types of woollen spinning machine: mule spinning and ring spinning. The main difference between them is that these three steps are performed differently by each machine and on the mule they occur in a discontinuous way whereby the drafting and twist insertion occur separately from winding onto the cop. The ring-spinning machine combines them into a continuous sequence and so is more productive.

Drafting Against Twist

Drafting serves two purposes; firstly it straightens the fibres in the slubbing so that their extent along the yarn axis is increased and secondly it reduces the linear density of the slubbing. Straightening the fibres increases the yarn strength (slightly at the expense of extensibility) while reducing the linear density at spinning allows a heavier slubbing to be produced at carding effectively increasing the productivity of the process.

On both the mule and the ring-frame each slubbing is fed from the creel via a surface drum to a pair of nip rollers that feed it into the drafting zone. Within the drafting zone a low level of twist is inserted into the slubbing and it is stretched by being drawn to the next stage by either the relative motion of the spindle as in the mule or by another pair of nip rollers running faster than the feed rollers, as in the ring frame. Woollen draft ratios are typically 30% and almost never higher than 40%. Drafting against twist controls the rate of drafting of each segment of yarn within the draft zone. Without twist there would be a tendency for thin places to draft more than thicker places, making them thinner still; causing more unevenness in the yarn and frequent slubbing and yarn breaks. Twist tends to run preferentially to the thinner parts of a slubbing because the thinner areas have lower torsional rigidity. The relatively higher twist increases the strength of the thinner areas and so provides a stabilising mechanism to counteract their relative weakness. In theory the thicker places could be preferentially drafted over the thin and as they become lower in linear density the twist redistributes to control further drafting, in this way it is possible for the drafted slubbing to have better evenness than the parent slubbing. In practice the yarn irregularities have been shown to be mostly due (about 80%) to the web irregularities already present at the carding stage and that conversion from web to slubbing and to yarn generally only makes things slightly worse. The twist level used during drafting and the draft level itself have a marked effect on the yarn quality. The optimum draft is usually around 30 to 35 % and depends on fibre length, fibre orientation, and slubbing uniformity. The optimum twist level depends on fibre-fibre friction and fibre orientation and length. The twist level is often not always directly proportional to the twister speed relative to the delivery speed as the twister can slip against the slubbing once twist reaches a certain level and resist further insertion of twist. The mule spinner has much lower productivity than the ring frame due to its discontinuous action but many manufacturers believe that it produces a more even yarn and it is still popular in the woollen sector.

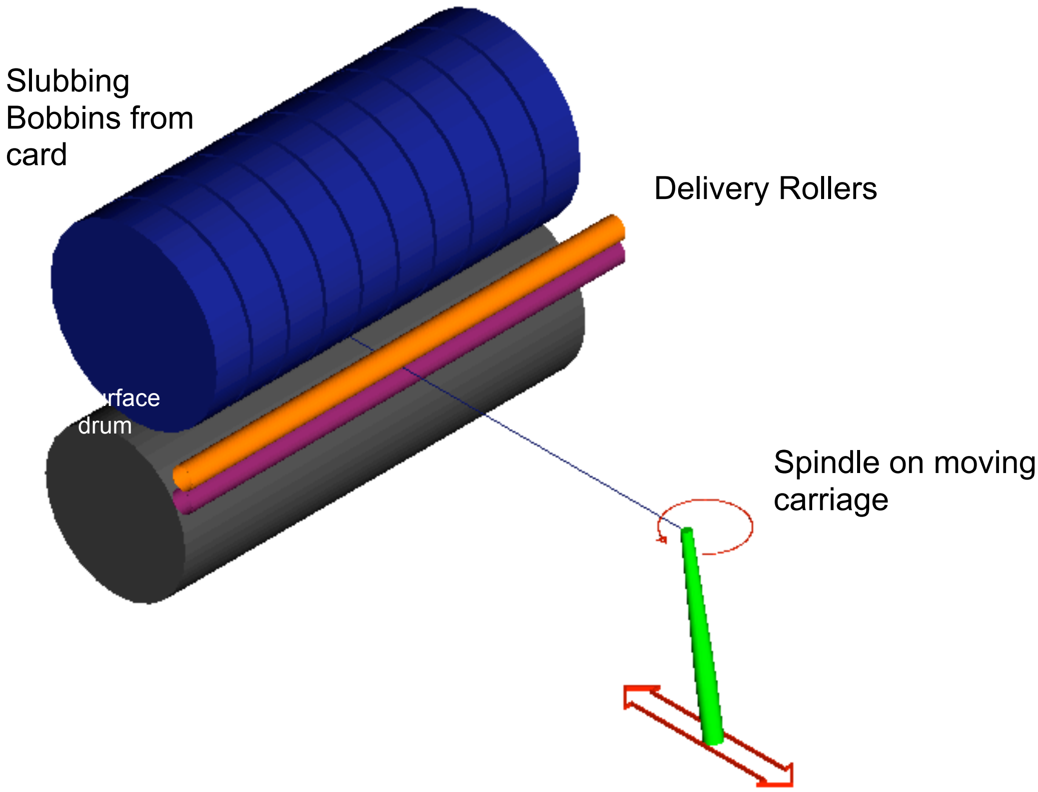

Figure 1 Schematic diagram of the Mule Spinning Frame

The mule frame is a horizontal machine and has a much longer draft zone in which the twist is inserted via the spindle. The spindle axis is almost perpendicular to the slubbing plane but is tilted forward slightly. During drafting and twist insertion as the spindle rotates the yarn flips over the top of the spindle inserting twist into the slubbing rather than winding it onto the cop. The flicking action is believed by some to help redistribute twist and set up vibrations that assist the drafting process. In the first stage of the cycle slubbing is delivered from the creel via surface drums and the carriage moves back at the delivery speed while the spindles rotate to insert a small amount of twist. At a predetermined point in the carriage progress backwards the delivery rollers stop while the carriage continues so that the length of twisted slubbing starts to draft while twist continues to be inserted. At the end of the draw the spindle speed increases to its maximum to insert the final yarn twist and then the yarn is wound onto the package as the carriage returns to the start. During winding a bar holds the slubbing down so that the spindle rotation causes the twisted yarn to be wound onto the cop, it also controls the yarn package build pattern. The longer draft zone on the mule may contribute to a better drafting action since the extra length allows a larger range of density fluctuations to exist within the draft zone simultaneously. Since the draft against twist mechanism is a competitive one, longer scale-length fluctuations can be handled in a longer draft zone.

A schematic diagram of the woollen ring spinning system is shown in figure 2. The "False Twister" is so called because it inserts twist temporarily. It rotates as slubbing is drawn through it and so twist propagates up-stream. As each section of twisted slubbing passes through the point of twist insertion the sense of rotation of the twister relative to it reverses and each turn that was inserted up-stream is removed as it passes downstream of the twister. The slubbing is therefore only twisted up stream of the twister and the draft is only controlled in the upstream region. The twister is designed and positioned to minimise the untwisted length between it and the nip of the draft rollers, if this length is much less than the fibre length then little uncontrolled draft is can occur

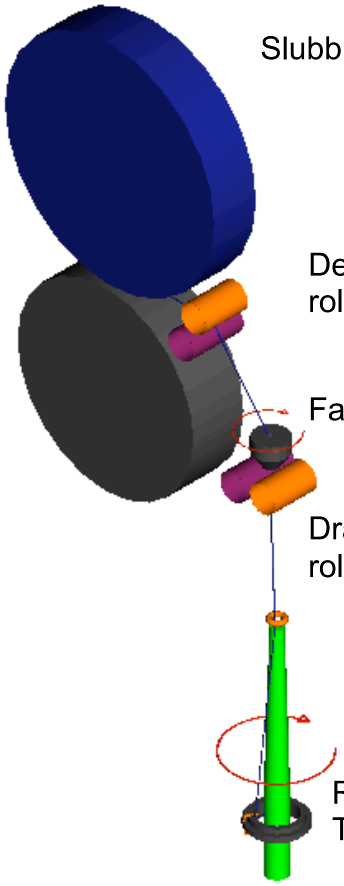

Figure 2. Schematic diagram of Ring Spinning Frame

but some uncontrolled drafting will still happen. This is another difference between the mule and the ring frame and the most likely reason for better drafting behaviour on the mule; the mule-spun slubbing is twisted along its entire length during drafting. A system has been devised (and was commercialised by the Delpiano company of Italy) whereby the front draft rollers are housed in a cage which itself rotates so that the twist insertion point is nip of the front draft rollers and there is no region of zero twist. It has the added advantage that the drafting twist is completely controlled; a frictional false twister can slip and so the actual twist level inserted is unknown. This was shown to produce a more even slubbing than conventional drafting and was claimed to be at least as good as mule-frame drafting. The system was more complex than conventional frames and some difficulties could arise with end breaks and roller wrapping. A wide range of false twisters have been used but they all seem to produce similar yarn qualities. Some twisters have knobs on their top surfaces designed to imitate the flicking behaviour of the mule. In these types the angle of the slubbing with respect to the twister axis is sometimes adjustable to vary the degree of flicking. It also changes the interaction between the twister and the slubbing and friction around it and so it is not known which effect is prominent when the angle is changed.

In ring-spinning the yarn twist insertion and the winding steps are combined. The ring has a lightweight traveller clipped to it through which the yarn passes on its way to the spindle cop. The traveller is dragged around the stationary ring by the rotating yarn and the friction between the traveller and ring means that the traveller turns slightly slower than the spindle so that yarn is wound onto the cop. As the spindle speed increases, the traveller-ring friction increases and centrifugal force on the yarn increases and so yarn tension increases. The traveller weight must be chosen so that the tension it generates overcomes the centrifugal forces on the yarn at all speeds, otherwise it will fail to wind properly and a large “balloon” of yarn will form. If the traveller is too heavy then the tension may frequently exceed the local yarn strength at high speeds and the yarn will break at the thinnest places. Woollen ring-frame spindles usually have castellated tops and spiral loops positioned close to them so that the yarn balloon collapses onto the spindle before departing it again towards the traveller. The smaller yarn balloon this generates compared to a free balloon reduces the spinning tension and allows higher speeds. The castellated spindle tops can generate extra yarn hairiness especially if spindle tops are damaged with knives when cleaned. Because the ring-frame is a continuous process it is much more productive than the mule-frame at the same spindle speed as the mule spindle is only spinning part of the time. However the mule frame is still quite popular with some traditionally minded spinners of fine woollen yarns. In worsted spinning and cotton spinning the mule has been completely superseded by the ring-frame and other newer systems such as rotor and air-jet. The woollen yarn has a completely different and aesthetically pleasing character compared to worsted spun yarns. The fibres are less parallel and the yarns are hairier and so bulkier knitwear and flannels can be obtained from the woollen system. The woollen system can handle shorter fibres than the worsted system and is highly amenable to processing multiple fibre blends including large proportions of recycled fibres. The woollen card provides excellent intimate fibre blending but the speed is limited so that as the yarns go finer, the kilograms per hour produced drops and costs go up. Because of the disoriented conformation of the fibres in the woollen yarn a greater number of fibres in the cross-section is needed compared to worsted yarns. The spinning limit for woollen is about 90 fibres whereas for worsted it is 35 to 40 fibres. The finest yarns spun routinely on the woollen system are about 50tex, although 25tex woollen yarns are spun by some fine spinners from high quality fine wool inputs, eg 17 micron diameter and 60mm long lamb’s wool.