6

Sliver preparation

6.1 Introduction

As previously mentioned, the modern opening line is almost completely automated and very little labor is required in that department. Between carding, and drawing, there is less linkage. It is common to use can-changing devices that defer some of the manual work to more convenient times without impinging on the productivity of the machine. Such machines are kept in 24 hr/day production between maintenance cycles except for rare event stoppages, which can only be dealt with by a human operator. There is increasing use of automatic can movers and bobbin transfer systems but these are not yet in widespread use worldwide. Linking is always possible, but it is still early in the machinery development cycle for such devices to obtain universal adoption.

There are several classes of spun yarn. One class is that of blended yarns that contain dissimilar fibers, and another is one where the fibers are nominally the same. An example of the first class is a polyester/cotton yarn. In the second class mentioned, it is necessary to blend the components because, in fact, fibers from different lots are not similar (although they are of the same type) but they are never described as blended yarns. With cotton yarns there are two subclasses. These are so-called carded and combed sliver. Carded yarns predominate but the more expensive combed yarns have a good market. Since combing is used for cotton processing and very rarely for other fibers, the topic has been separated from the other processing and it is discussed in Section 6.3.

6.2 Drawframe

6.2.1 The concept of drawing

Sliver drawing improves fiber orientation, intimacy of blend, and sliver evenness, as has already been described. Each drawing head is supplied with a number of slivers contained in cans. Each sliver comes from a different can, and the combination of these slivers constitutes the doubling part of the operation. The sliver then is passed to the drafting zone by a power creel, which transports the fragile slivers without uncontrolled stretching or other damage (see the left-hand part of Fig. 6.1). The drafting elements (which perform the drawing operation) then elongate the whole group of slivers to produce a single output sliver as shown in Fig. 6.1. The sliver leaving the drafting zone passes through a condenser to a large can where it is stored in readiness for transport to the next stage of the operation. (This sort of condenser merely consolidates the passing sliver but produces no doubling effect.)

The drafting system usually consists of three or four pairs of steel rolls and the top rolls have thick rubber sleeves called cots. (Drafting and drawing are discussed in more detail in Chapter 3 and Appendix 8.) A linear speed of 500 yd/min is common and higher speeds, currently up to 800 yd/min, are possible. This has the result that the productivity of the machines is in the order of 500 lb/hr for each head. For this reason, very few drawframes are needed and the cost/lb of drawing is low. Fiber wastage is also low at between 0.5 and 1%. A creel containing from four to eight feed slivers is used. The linear density of the delivery sliver ranges from 40 to 80 grains/yard. A sliver is often passed through two drawframes; the first passage is called ‘breaker drawing’ and the second, ‘finisher drawing’. (Note: 500 yd/min = 457 m/min, 800 yd/min = 730 m/min, 40 grain/yd = 2.8 ktex, 80 grain/yd = 5.7 ktex, 500 lb/hr = 227 kg/hr.)

6.2.2 The draw zone

Loading on a drawframe roll is high because of the mass of fiber being processed. For this reason it is not practicable to use aprons and special care has to be taken to use the correct bottom roll fluting, hardness of rubber on the top rolls, and settings. Typical types of fluting are spiral or axial. Another factor is the dust emission, which tends to increase with speed. Machines are now designed to removed dust and fly. The accretion of fly and contaminants, as well as the progress of wear on the elements, has to be monitored carefully. Errors can have a profound effect on later processes. One faulty component can produce a large amount of substandard material even in a short interval. The top rolls usually have rubber hardnesses that vary between 70° and 90° Shore, to control wear and performance. Buffing of the cots has to be carried out with care to avoid roughening the rubber, or else lap-ups will become a problem. When the rubber layer is reduced by buffing to an unacceptable level, the rolls have insufficient elasticity to control the fibers and the evenness of the sliver delivered

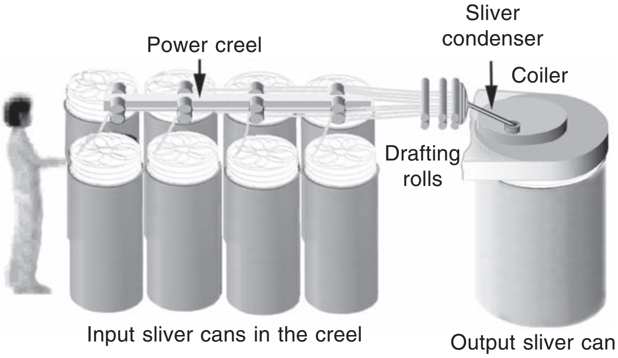
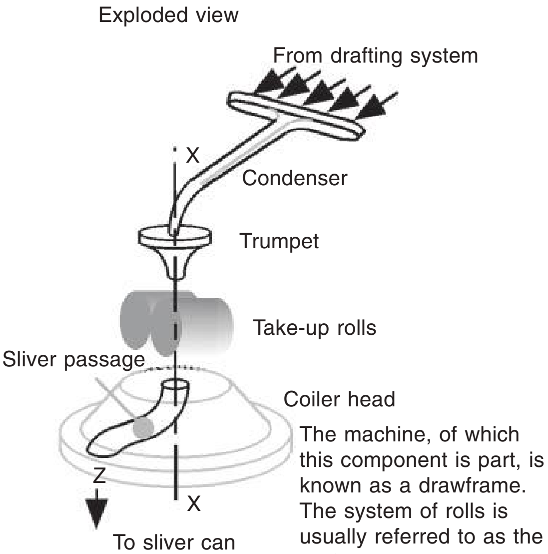


Fig. 6.1 Drawframe layout

deteriorates. Sometimes the rubber surfaces are coated with lacquer, treated with acid, or hardened by UV irradiation to increase performance, but some treatments lack durability. Changes to the rubber also produce error; for example, accidental irradiation by prolonged exposure of one portion of the rubber to sunlight causes variations in hardness that produce results similar to a mechanically damaged roll.

6.2.3 Sliver condensation

Sliver leaving the drafting rolls passes through a condenser containing a sharp contraction designed to produce lateral fiber migration and enhance sliver cohesion (Fig. 6.2). It then passes through a trumpet, which further condenses it. One or more devices to measure linear density are usually mounted here. The trumpet should be changed for differing sliver weights. A rule of thumb is that the throat diameter (in mm) of the trumpet should be between $1.6\sqrt{n}$ and $1.9\sqrt{n}$ (n is the linear density in ktex) depending on the weight of the sliver. Take-up rolls discharge the sliver into a sliver passage, which rotates about XX. Sliver is deposited into a can, which rotates at a different speed and about a different axis, to make the coiled pattern described earlier. There are also alternative, planetary systems. The sliver trumpet and the underface of the coiler head get very hot. A hot spot that is particularly hot and wears more than elsewhere is the exit of the sliver passage marked Z in the diagram. This must be smooth and properly shaped when spinning polyester or other man-made fibers that produce oligomers and other materials that can sublime at high temperature. (Sublimation is the process of a change in state from a solid to a gas.) Any emission of gas at these hot spots condenses on cooler surfaces to form a hard, crystalline deposit. These deposits alter the local coefficient of friction and provide sites for fiber damage.



The machine, of which this component is part, is known as a drawframe. The system of rolls is usually referred to as the drafting system.

Fig. 6.2 Sliver delivery from a drawframe

6.2.4 Autoleveling

One of the purposes of drawing is to improve the evenness of the sliver and the process of doubling is not enough. It is now common to fit an autoleveler on the first drawframe and the principle of such an autoleveler has already been mentioned in Section 5.9.2. The autoleveler measures the linear density of the sliver and compares it to a standard. A signal, proportional to the deviation, is used to cause a change in draft ratio sufficient to reduce the error signal and correct the error as far as possible. At present, little more than linear density is used to control the sliver preparation. Increasingly, this is measured using online measurements from tongue-and-groove, capacitive, or optical transducers. Often, these transducers are sited at the input and output of each of the machines between carding and final drawing. Measurements are also made in the laboratory on samples of sliver.

6.2.5 Fiber hooks

Carding produces hooked fibers, which cause errors in drafting, reduce the strength of yarn, increase the end-breakage rate, and lead to a general deterioration in performance. The hooks are pulled out to some extent in the two passages of drafting, but sufficient are left to make it worthwhile to present survivors to the ring frame as trailing hooks. Since there is a reversal in hook direction at every transfer (Fig. 6.3), and since the card produces a predominance of trailing hooks, it is necessary to have an even number of transfers. This implies that there should be an even number of passages of drawing. Within reason, the more passages of drawing, the less the hairiness of the yarn produced. However, four or more passages overwork the fiber and the normal custom is to use two passages unless a combing process is used. Each transfer adds a small cost to the product.

6.2.6 Monitoring

An interesting development is the coupling of a computer to the transducers of all the drawframes, the signals being used as a means of monitoring the performance of the frames and personnel. The signal is monitored automatically at whatever interval is selected within the capacity of the system and exceptions to the normal are reported. The program can be made to print out spectrograms, which can indicate, at a very

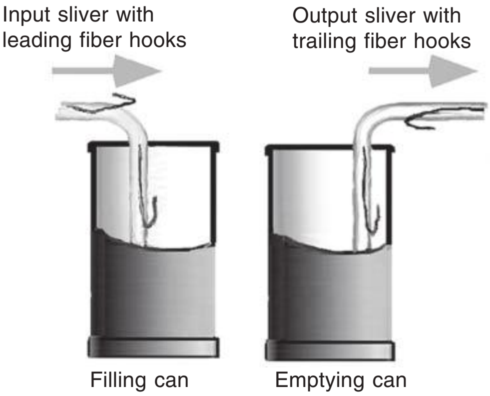


Fig. 6.3 Fiber hook reversal

early stage, any mechanical trouble that develops. This is a valuable feature since normal quality audit procedures might not find the trouble for many hours, in which time great volumes of faulty sliver are produced.

The drawframe is a favorite place to site an autoleveler because there are fewer drawframes than cards; there are arguments for using either of these positions and many operators use both. Initial expense alone is not always a sufficient reason for omitting such control systems. The levelers have to be set to correspond with the correct interpretation of the error signal. For example, a capacitive type transducer produces a slightly different signal for polyester than for cotton. Also, different fiber stiffnesses can cause a pneumatic trumpet to give a different result. Consequently, careful calibration is essential for best performance. Furthermore, variations in the sliver being processed can cause blend inhomogeneities and it is useful to level the components at as many stages as is feasible. However, autoleveling is no substitute for good preparation; the effects of variable preparation may be disguised by autoleveling, only to appear again at a later stage.

Drawing is a very important process stage, and it is used in all forms of staple yarn production. As has already been mentioned, it serves not only the functions of fiber alignment, blending, and long-term error reduction; it also serves to smooth out inevitable differences in card sliver, especially if the routing of sliver cans is carefully controlled. Drawing is a sort of central clearing house because there are so few frames needed and a sizable proportion of the total production passes through each drawframe.

6.3 Combing

6.3.1 An outline of the combing operation

For high quality yarn, an extra process is introduced called combing. The purposes of combing are to (a) remove short fiber, and (b) improve fiber orientation. Combed sliver has a ‘silkier’ appearance than card sliver because of the enhanced fiber alignment.

The first stage in this series of processes is lap winding which follows a drawing stage (Section 6.2.1). One or more passages of drawing are used before combing to straighten and orient the fiber hooks for best combing performance (Fig. 6.4(a)). A batch of cans is moved from the transient storage area following drawing to the creeling area for a ‘lap winder’. Comber lap is then prepared from drawn slivers. The cans are assembled in a lap winder creel, which transports the slivers to the running lap winder (Fig. 6.4(b)). Many slivers (often 12) are combined to make a closely spaced sheet of slivers, which are wound as a continuous layer on to a cylindrical center (Fig. 6.4(c)). The resulting ‘lap’ might be as large as 20 inches (≈ 0.5 m) in diameter by 12 inches (≈ 0.3 m) wide and weigh about 45 lb (≈ 20 kg). The lap is transported to the combing machines where combed slivers are produced (Fig. 6.4(d)). The sheets of slivers are combed and thereby drafted down to fiber webs. These webs pass over curved guide plates to the table of the comber where the fiber webs are layered to form a sandwich. They then pass to a drafting system that restores the linear density of the strand and converts it to a combed sliver. Combed sliver is coiled in a can and passes to a transient storage area. The last stage in this series of processes is the ‘finisher’ drawing using conventional drawframes as shown in Fig. 6.4(e). For space reasons, the combing machine is shown as having four combing heads but actual machines have more. The process involves a great deal of doubling, thus one

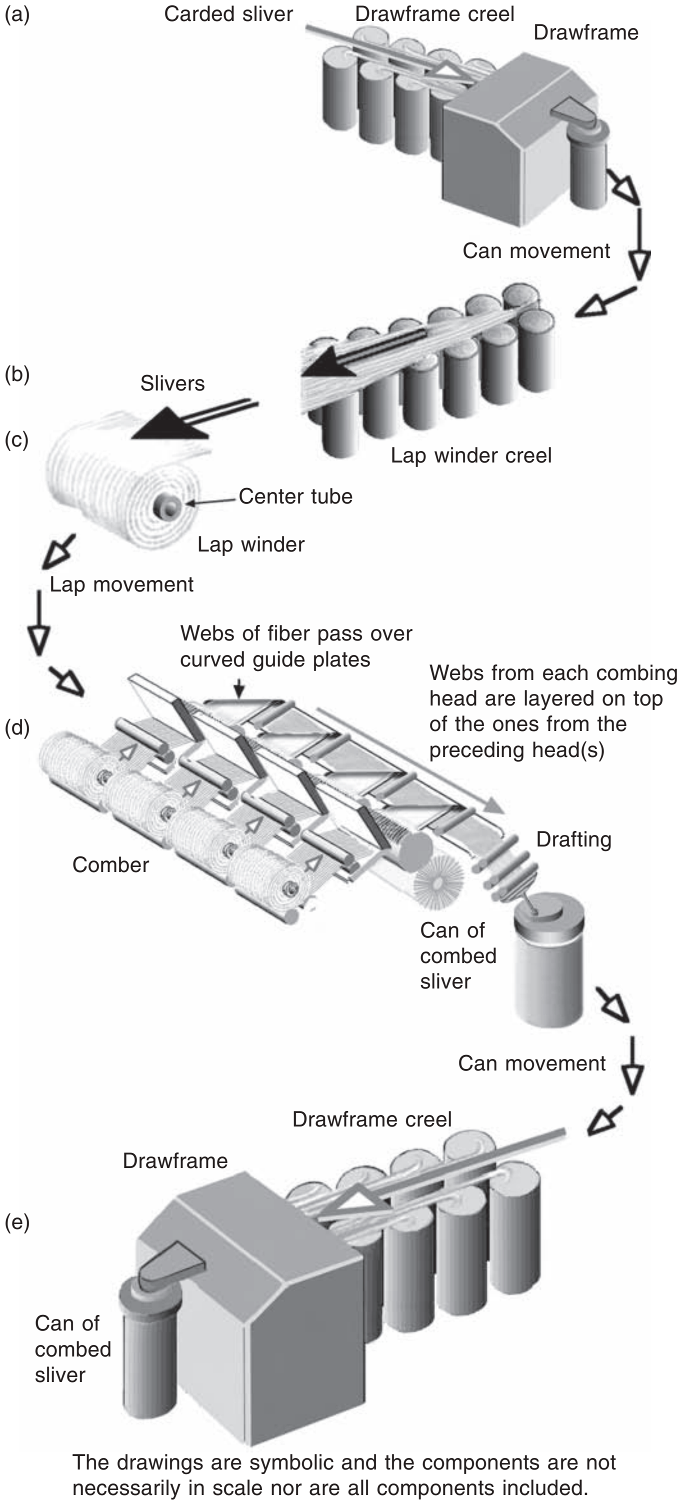


Fig. 6.4 Drawframe to lapper sequence

expects the slivers to be more even than usual; further the combing process introduces a desirable orientation to the fibers that provides the yarns with a silky desirable appearance. Extraction of short fiber coupled with the good fiber orientation increases the strength of the yarn made from combed sliver. In normal practice, only fine cotton yarns are made using the combing process; it will be realized that the yarns are expensive.

6.3.2 Lap quality

The output speed of a lap winder is up to 120 yd/min (≈ 110 m/min) and it has a draft of only 2 to 4; consequently there is a considerable doubling effect and very little drafting error. Within the limits imposed by the capacity of the cans in the creel, the short-term evenness should be improved.

Theoretically, the CV should be $1/\sqrt{m}$ of the average value in the input slivers, where m is the number of slivers in the lap ribbon. However, the variance between the slivers has to be taken into account. Variation between the slivers can cause some to be gripped weakly by the drafting rolls and extra errors are created in drafting; it is important to use even and similar slivers. It is also important that the ribbon of fiber is wrapped on the lap at the correct tension. Too low a tension produces a soft lap that is prone to damage in transport and handling. It also increases storage space needed. Too high a tension makes it difficult to unwind the lap at combing, especially the last few layers. The ribbon does not part cleanly; there are hairy connections between the departing ribbon and the remaining cylindrical part. These are known as 'split laps'. Klein [1] reports a web doubling process in which the pre-combing drawframe stage is replaced by a ribbon lap machine that follows a sliver lapper. Web doubling has many features to commend it and, in the future, it may well appear in other processes, perhaps even in carding. Many laps are mounted on a combing machine to yield the same number of comber webs, which are combined by layering and the layered ribbon is drafted and then condensed to form combed sliver.

6.3.3 The combing process

Figure 6.5 shows the main elements of the combing process. Such machines are complex and the sketches are meant to extract only the essence of the process. A common feature is the combing roll, which is shown in different positions in diagrams (a) and (b). Diagrams (a) and (b) show the left and right parts of the machine. In some machines this is called a half roll. The combing roll contains one or more segments, known as combing segments, which have toothed wire or needles to penetrate the fringes and remove short fibers. Diagram (a) shows a ribbon of slivers that has been delivered from the lap by the feed rolls A. The ribbon is then nipped by the elements X and Y, with a fringe of fibers protruding to the right. The diagram shows the fringe being combed by the combing segment at B. When the combing segment has passed, and the primary combing portion of the cycle is complete, the nippers are moved towards the detaching rolls and are then opened. Meanwhile, the detaching rolls F have reversed and carried back a portion of the fiber web processed during the last cycles. The newly combed web carried forward by the nippers is now laid on the returned web to make a piecing D. At this point, the comb E in diagram (b) penetrates the two layers as the detaching rolls resume their forward motion. The movement through the comb provides a secondary combing that removes some fibers that escaped

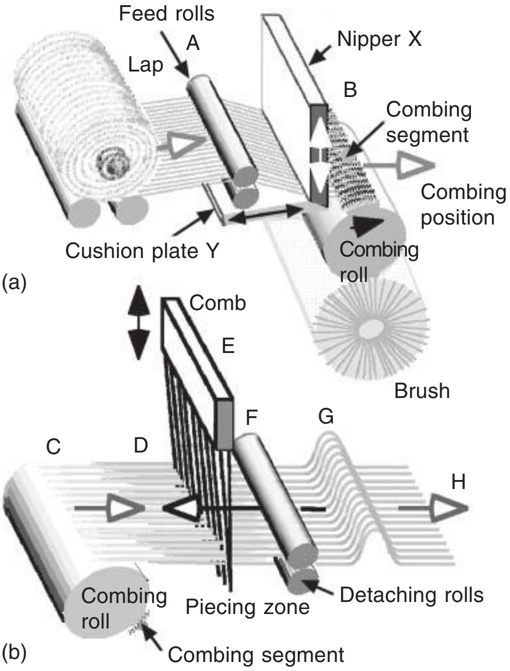


Fig. 6.5 Stages in combing

earlier removal. The comb is then withdrawn and the nippers are returned to their original position to start the next cycle. As the combing segment passes underneath, it meets a brush that removes the noil, which is then removed by a suction system. Noil is a by-product of the comber; it comprises good and reasonably clean fiber but it is often used as a component of the fiber supply for rotor spun yarns and some other products.

The rectilinear motions have to be balanced because modern combers work at up to 300 nips/min. There are multiple combing positions in a single machine and the output from each position is combined with that of the others. The doubled web is then condensed through a trumpet and drawn to form a sliver. Adjusting the draw ratio permits adjustment of the output linear density. The doubling and drawing continue at constant speed. Since the detaching roll has an oscillating motion superimposed on the steady speed, there is a need for a loop G in the individual webs to accommodate the differences in velocity. In some machines the web is condensed into sliver before doubling, and in others the webs are laid together sandwich fashion. If the teeth of the combing elements become bent or damaged, nep and other defects can be produced. The outermost teeth seem most prone to damage and inspection of the selvages of the webs sometimes provides an early indication of a need for maintenance work.

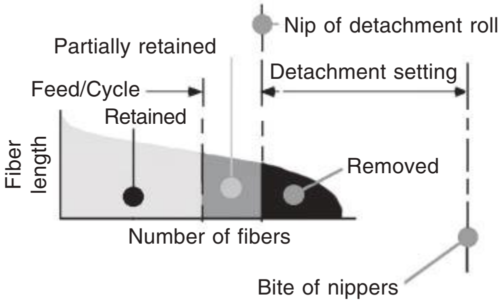
Settings can be adjusted to remove the desired amount of noil. Removal of too much is an expensive proposition because of the cost of fiber, but removal of too little reduces the quality of the product. Economics usually decide the issue; the sales appeal of a combed yarn often resides in the label ‘combed’ and the decision is not wholly a technical one. Fractionation of the fiber is imperfect and some long fibers are removed with the shorter ones; also some longer ones are broken. Thus, the comber is an instrument that usually improves the short fiber content but it does not bring it to anywhere near zero.

6.3.4 Comber noil

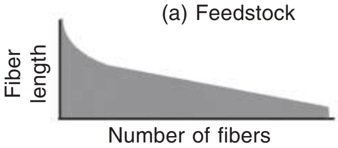
Parallelization of the fibers in the input, and the linear density thereof, are important in combing. With insufficient drawing or too heavy a lap, the comber tends to pluck clumps of fibers from the stock rather than handle single fibers. Uneven slivers tend to give uneven gripping of the web which allows more plucking to occur than would be found with good slivers. To avoid overloading the combs, the sliver weight should be limited, otherwise quality suffers. Many people regard the percentage of noil removed as a litmus test of quality, whereas it is often the case that more can be gained by paying attention to the quality of the lap than by increasing the amount of noil removed. Short fiber is removed to improve the characteristics of the yarn. The average fiber length in the noil can be varied. Within limits, the more short fibers that are taken out, the stronger the yarn, and the less hairy and more expensive it is [2]. Figure 6.6(a) shows various regions of a typical fiber diagram before combing. The section colored black represents the proportion that is almost completely removed as comber noil and the detachment setting controls the proportion. The section shown as light gray is almost completely retained and the section shown as dark gray is only partly retained, the remainder going to comber noil. Several factors influence this mid-zone including fiber type, CV, and orientation, as well as machine condition and speed. Normal levels of noil removal vary between 6 and 14%. A fiber diagram of the noil removed is shown in Fig. 6.6(b) and it will be seen that removal of some longer fibers occurs; this is unavoidable.

6.3.5 Web layering

There is a doubling arising from the layering of the webs from the individual combing heads on the comber table. If there are x heads, the theoretical CV is $1/\sqrt{x}$ of the mean input value but to get the linear density of the output sliver back to a value compatible with the following drawframe, there has to be a drafting stage. As will be realized, the drafting will introduce some error and the improvement in CV is less than might be expected. The extent of the change in evenness in the combing process depends on the fiber and the setting of the machine.



(a) Feedstock



(b) Noil

Fig. 6.6 Fiber diagrams relating to combing

6.4 Creel blending

6.4.1 Basics of drawframe blending

Drawframe blending is used to improve the uniformity of the blend and this applies no matter whether the slivers being ingested are similar or are completely different. Slivers of each single component are blended at the drawframe; this avoids difficulties in carding fibers of widely different characteristics. The idea is to combine a number of slivers as they enter the drawframe and this very process of doubling blends the fibers. In the first passage of drawing, each ribbon could be of a specific type of fiber. In this case, we use a deviation in blend rather than a deviation in linear density for our calculations. Suppose a spot in one of the slivers has only 40% of fiber A instead of 50% and the difference in mass is made up by fiber B. This is 80% of the expected value for fiber A, which makes the blend ratio 40/60 in the bad spot and 50/50 elsewhere. Assume that the linear density of each input sliver is 4 g/m and there is normally 2 g/m of both fibers A and B. At the bad spot the linear densities of fibers A and B in the one bad sliver are 1.6 and 2.4 g/m. The theoretical blended eight-sliver totals are now $(7 \times 2) + 1.6$ and $(7 \times 2) + 2.4$ g/m giving the proportions 15.6/16.4. This represents 97.5% of the perfect value for fiber A instead of 80% in the bad spot. Thus, not only does the doubling reduce the error in linear density, it also improves the blend evenness. However, as mentioned elsewhere, drawing introduces error that offsets these gains. It will be noted that in Table 5.1, drawing did not always decrease the CV and in the second passage the CV usually went up a little.

6.4.2 Fractionation

A card and opening line can separate blend components, especially if the fibers differ in attributes. For example, the flats in a flat card tend to remove the coarse and short fibers and the delivery might be depleted of these components irregularly. The fractionation of the fiber changes the population of fibers and the consequential variations in populations of fibers affect the blend from place to place in the material flowing through the system.

The blend for one particular fiber attribute differs from that for another attribute within the same population. This is because of the many permutations of fiber properties in the stream of material passing through. A typical industrial performance is shown in Fig. 6.7 and it will be noted that, not only does the linear density (or ‘sliver weight’) have a CV but so do all the fiber properties. The CV of the component level is a measure of the perfection of the blend. Obviously, a 0% value would mean that the blend is perfectly even. The ‘Uster 25%’ refers to the Uster statistics, which show the range of worldwide mill performances in respect to evenness of linear density of the product. A 25% rating means that 25% of all spinners are better than the subject one. The other symbols are explained in Table 5.1 but special mention is made of the CV of the short fiber content (SFC) which is usually much higher than the other values discussed here.

6.4.3 Longitudinal fiber migration

The process of drafting causes fibers of differing characteristics to move relative to one another during processing. This migration of fibers mixes them and is an unintended form of blending and it applies whatever input fiber components are involved.

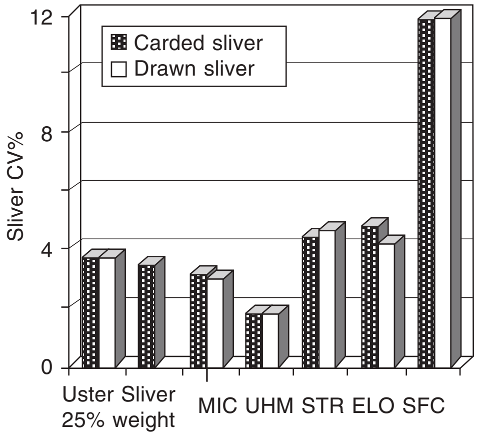


Fig. 6.7 Variability in sliver

Assume that the input material to a machine that drafts the material enters as a series of sections labeled A, B, C, and D, as shown in Fig. 6.8. The number of fibers in each cross-section is assumed to be the same. After passing through the machine, drafting causes longitudinal migration of the fibers and a cross-section of the output contains fibers with mixed labels as shown. The labels refer to strata parallel to the material flow. The fiber order in the input is not preserved and there is a mixing of the input segments. Not all components migrate at the same rate. Mixing will be biased according to some fiber attribute or attributes. The exact mechanisms are still unclear at the time of writing. Each output cross-section contains a sampling of several length-segments entering the machine.

6.5 An industrial case study

A case of a particularly bad laydown in a mill not equipped with a mixer is now discussed to emphasize the importance of adequate blending [3]. This is not a normal circumstance and should be considered as a worst case scenario.

The bale laydown consisted of 40 bales and the bale plucker took about 5 minutes for a round trip. The length of card sliver delivered in the average time for the bale

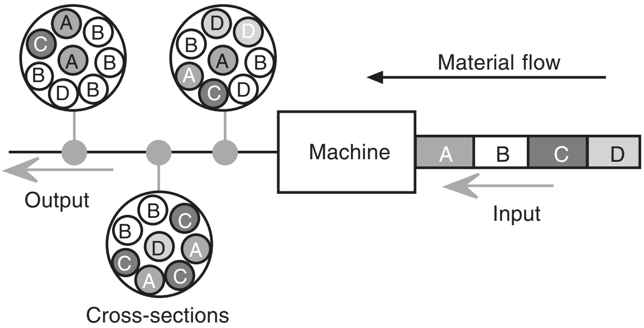


Fig. 6.8 Effect of processing on a blend

plucker to make one round trip was about 700 yd (≈ 640 m). Tests were made at 10 yd (≈ 9 m) intervals along the sliver and at corresponding times from the bales. FFTs of the data series were made to show the periodic components of the various fiber attributes. (FFTs are Fast Fourier Transforms, which convert data using the time along the X axis to a frequency or wavelength basis. A typical use of the wavelength basis is the radio spectrum.) To simulate the blending occurring in the opening line, the data were smoothed over a moving interval of 20 bales. (A ‘moving average’ is a succession of the averages over successive batches of data and the width of each batch is termed an ‘interval’. If all the intervals are made the same we refer to a ‘moving interval’.) The CVs of fiber fineness (micronaire) from these tests are shown in Fig. 6.9(a). The result was primarily affected by the bale-to-bale difference in the laydown. The laydown contained many bales, the round trip time of the bale plucker cycle was long, and the mixing volume of the blending system was small. There was an approximately 700 yd (≈ 640 m) error wavelength in micronaire due almost entirely to this cause. Tests at other establishments with adequate blending only showed weak tendencies towards this sort of error. The importance of the particular variability shown arises because of differences in dye uptake with cottons of varying fiber fineness.

There are factors other than fiber fineness affecting the dye shade but they showed little or no effect on the result in this case. It is interesting to look at yarn made directly from card sliver because this avoids the distortions from yet another production stage. It was expected that different dye shades would show similar patterns in the fabric.[1] One yard (≈ 0.9 m) of each 10 yd (≈ 9 m) sample of sliver was converted to

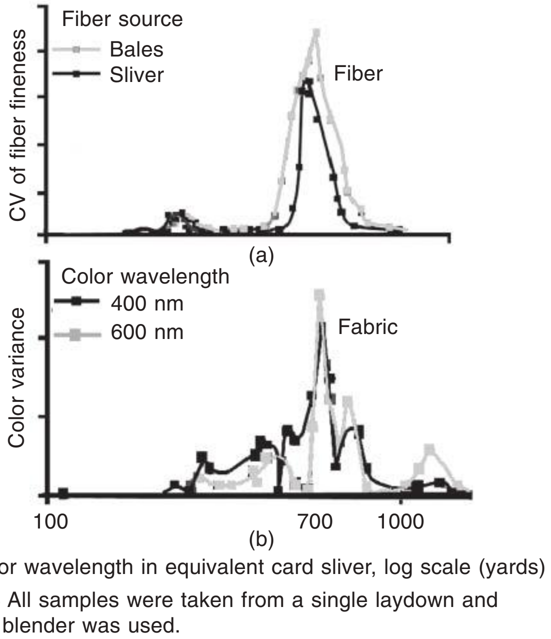


Fig. 6.9 Fiber fineness and dyeability

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[1] Color is also measured as wavelength, but the unit is nm, that is 10^{-9} meters, rather than the thousands of yarns used as the abscissas in the graphs here.

yarn on a sliver-to-yarn ring spinning machine, and a portion of each sample of yarn was knitted into fabric. Each product could be directly related to the corresponding length of card sliver. Figure 6.9(b) shows that the fabric had variations in dye uptake consistent with movements in the bale plucking head across the bale laydown.

Extremely long-wavelength errors such as those generated in very long bale laydowns, or large variations throughout the height of the laydown, cannot be completely extinguished by normal blending devices in the opening line. However, mixers of adequate capacity can usually smooth the results to an acceptable level.

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