11

Quality and quality control

11.1 Quality

11.1.1 Definition of quality

Modern use of hyperbole has widened the meaning of quality to such an extent that it is desirable to narrow it for the present purpose. The whole textile enterprise is founded on bargaining between supplier and customer. Two of the most important factors in the contract (explicit or implicit) are quality and price. Other factors, such as delivery schedules, service, reputation, etc., also apply, but can be set aside for the present argument. In textile technology, quality is often defined in terms of various attributes of the fiber, yarn, or fabric, but this alone is insufficient. What forms the basis of an acceptable bargain for a given product for one particular end use may not be acceptable for another set of conditions. Consequently, quality may be defined as a set of attributes for a product that fulfills the needs of a customer or user.

Interlinked with the physical characteristics of the product is the question of price. Securing superior physical characteristics of the product often involves higher costs for the supplier and this usually results in higher prices. Profit margins for the yarn producer have to be sought in the differences between cost and price. The consumer looks for the highest quality at the lowest price.

There are several aspects of quality control, some aimed at preventing difficulties and some aimed at curing the cause of them. A routine of sampling, testing, and adjusting is the standard method of day-to-day control. Also customer complaints or difficulty reports often require test work. Consequently a quality and control department is usually equipped with fiber, yarn, and fabric testing equipment.

11.1.2 Quality factors

Acceptable quality is determined by the user, and fabric makers are major users of yarn. The desirable attributes for fabric may be classified as those related to fabric appearance, fabric durability, and freedom from faults. Often, woven fabric durability and yarn strength are found to be linked. Similarly, the ease with which the yarn can be manipulated in making fabric is often related to the yarn strength, fault rate, and hairiness. However, these relationships are not universal. For example, whilst warp yarns for weaving are required to be strong, knitted fabrics have no great need for a strong yarn. However, they both have a need for non-twist lively yarn with good evenness of linear density, hairiness, and dye affinity.

The appearance category may be subdivided into evenness of linear density, hairiness, coloration, light reflectivity, and refraction. (A minor segment of the market specializing in novelty yarns may have different standards from those more generally practiced, but space precludes further discussion of these.) Evenness is often expressed in terms of variance, standard deviation, or CV of the attribute concerned; consequently there is considerable discussion of these factors in this chapter. Fabric durability is a matter of yarn strength, yarn structure, and fabric structure. Yarn strength is mostly a matter of yarn structure and fiber strength. These matters become more complex when blend yarns are used, especially those in which the fiber properties of the constituents differ greatly. Freedom from yarn faults involves not only minimizing the production of faults during spinning but also the removal of them in winding. Furthermore, removal of a fault requires the joining of cut ends and the join itself is sometimes an unacceptable fault. Yarn processability is important, not only to the fabric maker but also to the yarn maker himself. Obviously, a weak yarn is more difficult to process than a strong one. Other factors also apply, and these include twist liveliness, yarn hairiness, residual yarn fault level, and yarn package construction. Deterioration in any of these factors can cause difficulties in yarn manufacture and in quality of the product.

11.1.3 Analysis of customer complaints

Since the standard of quality is set in the marketplace, and since the standard changes from time to time, it behoves the spinner to keep abreast of what technical properties the market is demanding and how the product mixes of his or her company meet that demand.

Again, there is no absolute definition of what the demand is, and considerable skill is needed in interpretation of the data. The customer complaint level gives a good window on the technical requirements but it varies according to the state of the economy. When the economy is booming, complaints lessen and there is a danger of complacency among those responsible for the quality control system. When the economy declines, complaints mount, and unjustified complaints are mixed with the justifiable ones. Nevertheless, analysis of the customer complaints is a prime tool for keeping track of the quality levels. Technical analyses are also important because, not only do they permit the solving of problems, but they can provide an information channel to the marketing people. Thus, the testing facility is an important part of the business.

A typical spectrum of complaints is shown in Fig. 11.1, but the spectra vary according to the nature of the businesses. Nevertheless, the sample can be used to make several points. Mundane affairs, such as shipping, can sometimes be even more important than a technical issue such as the CV of linear density. The sample quoted in Fig. 11.1 was for fine staple yarns and it might be noted that yarn appearance and winding ranked at the top of the list. Neither of these categories uses a single measurement as a criterion. Rather, the judgment is made using a complex list of factors. As a contrast, filament yarns have different criteria and complaints range more in the field of polymer morphology than in evenness of the product. Changes

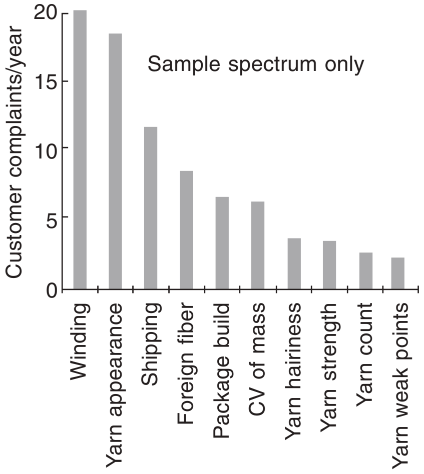


Fig. 11.1 Spectrum of complaints

in mechanical and thermal stress history are very important in this latter field since stress history determines the dyeing performance of these types of yarns.

Winding complaints are often derived from unsatisfactory conditions in the earlier processing. Thus, a high volume of complaints labeled under 'winding' might stem from bad spinning, which might, in turn, arise from poor spinning preparation. Yarn appearance usually includes yarn faults such as neps, thick and thin spots, etc. It also includes some factors that are difficult to quantify by laboratory measurements. The importance is illustrated by the fact that more than 16.5% of all fabric faults in shirting, in one set of market data, were from spinning faults.

The item 'foreign fiber' usually comes from improper stripping of the bale coverings in the process of laying down the bales in preparation for the next offtake run. It is not easy to handle a bale of fiber after the straps have been removed. Consequently, the operators have to develop techniques of removing every last strand of bale wrapping from the underside of the bales. Regardless of whether the bale wrapping is jute, polypropylene or some other material different from the fiber within the bale, the foreign fibers show up after finishing the fabrics. Sometimes it is due to differences in dye affinity, sometimes to differences in fiber size and color.

11.2 Quality control

11.2.1 Fiber quality control

Testing is a very important part of quality control and needs more space than can be allocated in this chapter. Most of the data presented in this section were gathered in the 1990s but they are subject to change as developments of equipment and techniques improve. Many of the various quality factors have improved by roughly 0.6% per year in the last half a century and the trend is likely to continue in the twenty-first century. The Uster Corporation periodically issues a very comprehensive statistical analysis of worldwide data under the title *Uster Statistics* [1] and the reader is referred to the current issue at the time of need for information.

A well-founded quality control program should carry out tests in a controlled atmosphere and all samples should be conditioned by immersion in that atmosphere for an adequate time. Further discussion is given in Appendix 4.

Routine tests require well-founded sampling plans. The raw materials should be sampled regularly but the schedule depends on the fiber and the variability thereof. Generally speaking, there is less testing of man-made fibers in the mill as compared to that used for natural fibers. In this case, greater reliance is placed by the mill on the fiber maker for help in quality matters than is the case with natural fibers. Consequently, remarks in this regard will be mostly confined to natural fibers.

Labeling and sampling varies according to the type of fiber. Modern practice with cotton is that every bale is labeled with the normal fiber parameters, but that does not necessarily mean that every bale has been tested. There is a growing practice of module averaging in which a fairly large number of samples is measured from a module and the averages are assigned to every bale taken from that module. Debate continues whether it is better than testing every bale with only two or three samples. Some yarn makers use HVI or other mass testing lines to measure every bale,[1] to assist them in preparing optimum cotton blends. These testing lines carry out a battery of standard tests on fiber (usually cotton) in a continuous fashion. HVI stands for ‘high volume instrument’ used in testing cotton, and it is a proprietary name. With wool, the fibers may be in bulk, and sampling might require core-boring tools. The mass is sampled randomly; the samples are subdivided, doubled with other samples from the same mass, and then subdivided again before testing. Sometimes there are more than two subdivisions and doubling stages in the sampling process. The International Wool Testing Organization (IWTO) specifies that there should be at least 100 test zones. With bast fibers, at least 20 bunches are selected at random, and a strick is removed from each and tested. The strick is divided lengthwise, one portion is discarded, and the remainder is separated into tip and root portions. These are halved repeatedly as necessary, the tip and root samples being kept separate. Composite samples of both tip and root are tested. Even man-made fibers are tested by some with the dividing and doubling techniques.

Of the fiber attributes, length is often considered the most important. Specific ways of testing are given in Appendix 4 but it is thought worthwhile to give an example of how processing and testing can influence the results. Normally, fist-sized samples of fibers from the bales are brought to the laboratory and are conditioned before testing. A clamp is used to secure and withdraw a sub-sample of fiber from each main sample submitted. The fibers protruding from the clamp are called a ‘beard’ and the fibers actually tested are in this beard. To measure length, it is necessary to straighten the fibers by some sort of combing action. The number of fibers in a cross-section of the beard is determined by light penetration through, or electrical capacity of, a small ‘slice’ of the beard running parallel to the clamp. The measuring head is traversed perpendicular to the clamp to a position where it measures 50% of the signal it had recorded at the clamp. The position of measuring head is then taken as a measure of fiber length. There are different ways of testing, which cannot be further discussed here.

The combing removes loose fibers and changes the fiber distribution. Compare a

---

[1] Choosing only one or two samples per bale provides little or no guidance about the within-bale variance of the fiber attributes measured. These variances are often of the same order of magnitude as the between-bale values measured. Consequently, one of the dimensions needed for total control is missing.

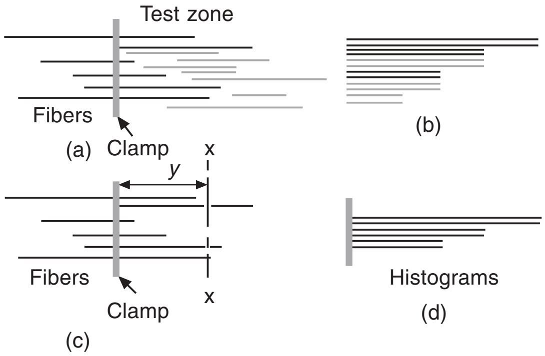


Fig. 11.2 Fiber length sampling

theoretical result before combing with one after. Figure 11.2(a) shows a population of fibers, some of which are clamped and some are just free of the clamp. The latter are shown in gray whereas the clamped fibers are shown in black. A real sample would contain hundreds, if not thousands, of fibers but for clarity the diagram shows only a few. If all the fibers in the zone are counted, the histogram of length in the sample is as shown in diagram (b). If the unclamped fibers that were shown in gray are removed as in (c), the histogram changes as shown at (d). Even if the statistical frequencies are normalized to 100%, the histograms still differ. The latter is a length-biased sample, which differs from reality. A third form of sampling is when the fibers along the line xx are counted as a function of y. This is called a tuft curve. The results can be expressed as histograms or cumulative frequency curves. Thus, the method of testing and the history of the material can strongly affect the result. This is important when the results are the basis of decisions, especially if the methods used by the supplier and the supplied are not co-ordinated.

In HVI testing, most of the loose fiber is removed from a beard and a 50% span length is measured. This is the value of y when the number of fibers along xx is 50% of the total in the clamp. The 50% span length is about 0.58 times the classers' length.[2] Detailed distributions are given in the *Uster Statistics* 1997 [1]. Mean short-fiber content is shown to be unaffected by processing but the amount of trash steadily decreases with processing. This is not to say that the CV of short-fiber content is unchanged; as will be shown later, there can be significant differences. Again, according to Uster, the short-fiber content by weight can vary from 14% down to 6% for the best 5% of production.

A second important fiber attribute is fiber fineness. With wool, fiber fineness is measured by fiber diameter expressed in microns, whereas with cotton, the fineness is usually expressed by the micronaire index. Micronaire is a measure of the permeability of a fiber wad of a defined size when it is mounted in a defined chamber. While it is true that micronaire is related to fiber fineness, it is also related to the maturity of the cotton; nevertheless it is an industry standard. For many sorts of American cotton, there is little variation in the micronaire/fiber fineness ratio with fiber length. However, there are some high micronaire cottons that display up to 30% difference between short and long fibers. If long-staple cottons are excluded, the differences can usually

---

[2] The classers' length is one obtained by a manual method now largely obsolete.

be ignored for fibers between 3 and 4.5 micronaire; in other words the micronaire value is a reasonable measure of fiber fineness within the quoted range.

A third fiber factor with cotton is yellowness, as measured by the coefficient '+b' [1, 2]. The value varies from 7.9 to about 11 for short cottons and from 8 to about 13 for long cottons, the higher figures being more yellow than the low ones. The yellowness comes from natural dyes in the fiber and from yellow-tinged wax coatings. It is desirable that the yellowness should be low to reduce the scouring and bleaching of the fabric that might be necessary; above all, it is desirable that the figure should be uniform throughout the product. Preliminary measurements [3] suggest that there might be as much as 5% difference between adjacent lengths of sliver. Generally, few measurements have been made of this variability, but perhaps more attention should be paid to it.

A fourth factor with cotton is the amount of trash present. A typical HVI measurement relates to the surface area of a bale sample occupied by dark colored trash. According to the *Uster Statistics* [1], the trash surface area reduces as the fiber length increases. For short cottons, the worst trash counts can change from a value of 2% to 1.5% as the fiber length changes from about 1.0 to 1.2 inches. The best case has a count of under 0.1%, irrespective of fiber length within the quoted range. The long cottons show a similar pattern, although the values are lower.

Other important factors are nep and short-fiber content. With short cottons, the patterns of both neps and short-fiber content with respect to fiber length are similar. Long cottons show fewer neps and lower short-fiber contents than short cottons.

11.2.2 Quality control of intermediate products

Intermediate products such as sliver, roving, etc. are tested on a routine basis; the items tested depend on the business. Commonly, linear density of the intermediate material, such as sliver or roving, is measured daily at each step; yarn strength, yarn hairiness, neps in the card web, and yarn fault levels are also checked daily. However, even strict periodic sampling may give erroneous results if there is a periodic variation from a prior process that is slightly different from the sampling frequency. The two frequencies are said to beat against each other and they produce a beat frequency that shows up in the result. Where exploratory tests are being used to diagnose a problem, a viable experimental plan is required and that involves a knowledge of the variables likely to cause the problem. When long-staple sliver samples have to be transported between plants or units, it is desirable that sliver be twisted to prevent disturbance of the structure and fiber distribution (for wool tops between 15 and 30 ktex, Anderson [4] recommends 20 turns/m).

In assessing the results of testing, it has to be realized that the total variance[3] of random errors measured is the sum of the variance *between* the bales, zones, or other large divisions and the variance *within* them. The between-zone variance is possibly due to fiber acquisition policy whereas the within-zone category is a micro-variation in the supply, often caused by processing. This distinction is sometimes helpful in seeking to reduce the variance in properties.[4]

---

[3] Variance is the square of the standard deviation.

[4] Standard deviations have to be weighted to take into account the number of samples taken and $(\text{Standard Error})^2 = s^2/m_s + s^2/m_z$.

11.2.3 General yarn defects

Defects are usually regarded as single, random deviations from the normal parameters describing the yarn. For example, a single fairly long thick place (or 'slub') would be called a defect, whereas a systematic series of thick and thin places would usually be classified as irregularity or unevenness. Unevenness will be described later. Sometimes slubs appear periodically; they are recognizable by their torpedo shape.

Defects can occur in either staple or filament yarns. In filament yarns, many defects arise from differences in morphology of the polymer rather than from differences in linear density. (Morphology is a term used to describe the molecular structure of polymers.) Changes in morphology result in alterations in dye affinity that have a powerful effect in the category of yarn and fabric appearance. However, married fibers, drips, and debris also cause problems. The dominant defects in staple yarns arise from processing the fibers and interactions between procesing and the fibers. The possibilities of producing unacceptable yarn for staple yarns are greater than for filament yarns because a large percentage of staple yarns contain natural fibers, with their inherently variable sets of characteristics. Also natural fibers are associated with non-fibrous materials, which have to be removed. This is not to say that filament yarns are without problems. Complaints arising from filament defects are a matter between the spinner and his or her fiber supplier whereas natural fibers are subjected to some uncontrollable influences such as weather. For these reasons, discussion will be centered on staple yarns.

As mentioned, yarn defects can be caused by a variety of circumstances. Some machine errors tend to be organized, but others occur at random. The organized effects, such as those due to eccentricities and drafting waves, have already been discussed. Random errors, such as the production of slubs, piecings, corkscrews, crackers, etc., have not yet been discussed (see Fig. 11.3). Many of the fault types (a) through (d) are caused by drafting. Drafting under too dry conditions can cause static electricity to be generated by the sliding fibers, with the result shown in diagram (c). Balls of fiber on the yarn caused by accumulations of lint on the traveler (d) are often composed of short-fiber debris from drafting. Occasional long fibers bridge the nip lines in the drafting system and disrupt the process (e). Loose fly, captured by the

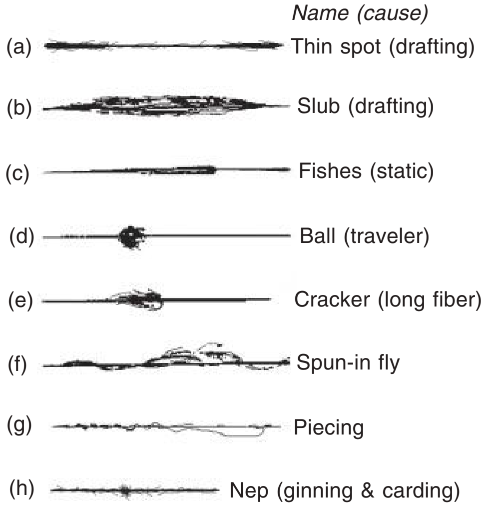
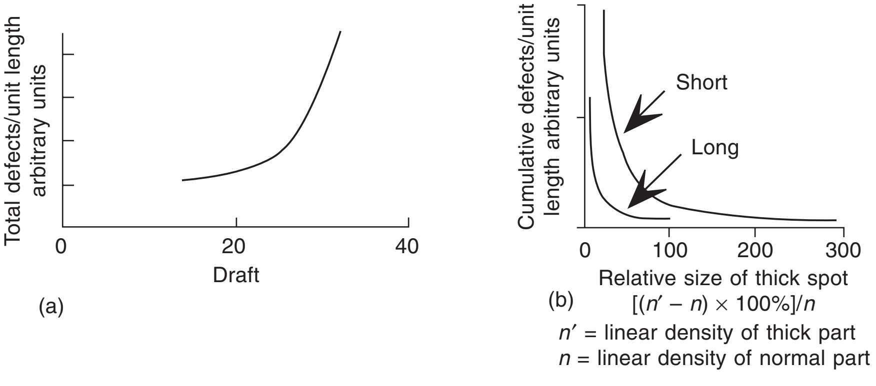


Fig. 11.3 Some fault types

yarn between the front drafting rolls and the pigtail guide (f), is usually 'spun in' at only one end [5], whereas fly deposited before that is held more firmly. A piecing is the result of an end-break (g) and neps (h) have already been discussed. If the best mills now are compared to those described by Thomason in 1971 [6], one can see reasons for some of the improvements by merely walking around and noting the vastly improved state of cleanliness. Some results typical of the ring spinning industry are shown in Fig. 11.4(a) [2]. Following the discussion in Section 3.7.7, where the known increase in difficulty in drafting at high ratios is discussed, it should be no surprise to find that the fault rate is a function of the draft ratio. Uster Tester data [1] relevant to thin spots in the yarn show that an average carded cotton yarn spinner might experience ranges from 1/km to 150/km dependent on counts between 16s (38 tex) to 45s (13 tex) respectively. The corresponding thick spots range from 120/km to 800/km. Not only are the thick spots more prevalent but they can cause trouble in later processes unless removed. Defects have a range of thicknesses and lengths that are classified accordingly. The Uster Classimat [7], an apparatus for classifying yarn defects by length and thickness, has four length classifications, labeled A to D, which range from 1 mm to 40 mm. It also has 4 thickness classes, labeled 1 to 4, each centered at various levels between 100 and 400% of normal yarn linear density. Often there are relationships between these thicknesses and lengths (e.g. Fig. 11.4(b)). There are fewer large defects than smaller ones and there are fewer long defects than shorter ones, as might be expected. A profile of combinations of length and thickness is set to give limiting settings for defect removal in winding. This usually includes a protocol at various levels in the A3, B2, C1, and other categories. Multiple winding of yarn to remove defects can also damage it. Polyester/wool and acrylic fibers are especially vulnerable to such damage.

In staple spinning, irregular faults can be produced by improper maintenance, machine settings, and raw material supply. For example, too close a roll setting in a drafting system can lead to fiber breakage, slub creation, and derivative faults such as traveler accumulations of fly. Wear of machine parts occurs after a period of use and this wear frequently leads to the production of defective yarn. An unclean or improperly conditioned atmosphere can cause problems. Failure to remove trash in opening and carding can lead to the production of yarn faults, especially for trash over a certain small size. One can often discriminate between failure of the cleaning machines in the opening line to remove trash and the failure of the card to remove it, by inspecting for trash particles embedded in the card flats. Poor cleaning in the



(a) (b)

Fig. 11.4 Defects in yarns

opening line results in significant deposits of trash in the wire of the flats. The production of neps is frequently a significant quality control problem; controls at carding help in this respect.

11.2.4 Staple yarn defects arising from the fiber

Defects inherent in the supply of natural fibers arise from the presence of non-fibrous material and defective fibers. These may be categorized as:

1 For cotton: immature fibers, neps, trash, etc.
2 For wool: grease, suint, vegetable matter, etc.
3 For man-made fibers: concentrations of finish, oligomers, undrawn or improperly drawn segments of fiber, etc.

Other fibers have foreign or unwanted matter in their supply too.

These materials adversely affect processing, which, in turn, produces error. But here we consider the direct effects on such properties as dye uptake, fiber reflectance, and appearance of the final product.

Differences in fiber color can also produce disturbing effects leading to complaints. The differences can be from batch to batch, there can be differences within a yarn lot, or there can be differences within a package of yarn. These differences are categories of yarn length (which range from a few yards to thousands, or even millions of yards) and the fabric faults they produce fall into the categories of barré and streaks. Figure 11.5 shows two examples of color variation in fiber yellowness. The top diagram shows the variation in card sliver that was made from a single bale of cotton. The inch-to-inch measurements[5] show a variation range of about 5%, despite being taken from source that is often treated (wrongly) as invariable. The bottom diagram shows the variation in a sample of commercial combed sliver in which the number of sliver doublings involved was greater than 3000. Despite the doublings, a significant error is visible and the wavelength of the whole error cycle was probably in the hundreds of yards. Such a variation could have led to barré problems in greige fabric.

Nep varies from processing stage to processing stage. According to Uster [1], the nep level in the bales (≈ 100 to 900 nep/g) is slightly lower than the level in the fiber approaching the card. This level is then reduced in carding to the range 25–300 nep/g. For the longer cottons used for combed yarns the nep counts in the bales are less and they can be reduced to the range 7–80 nep/g after combing. The neps in this form of measurement are of an absolute minimum size. The actual reductions are determined by the fiber as well as the design, settings, and maintenance of the machines. An average ring spinner produced carded yarn between 6s (100 tex) and 45s (13 tex) with nep counts of 150 and 50 nep/g respectively (AFIS Data [1]). In an Uster tester type of measurement, a nep is defined as a very short fault of more than 200% of the yarn diameter. Consequently, with this type of measurement, the size of the neps recorded, vary with the yarn count. Data from the Uster tester [1] suggest that average ring spinners produced nep levels in the range from 25 nep/km

---

[5] It is not possible to measure such samples on an HVI instrument and therefore these measurements were made on a flat-bed scanner. Adobe ‘Photoshop’ software was used as a photometer applied to color images of sliver, the images were converted to the CMYK mode, and the yellow separation was used. The percentage of yellow represents the color depth and is related to the +b value normally used in textiles.

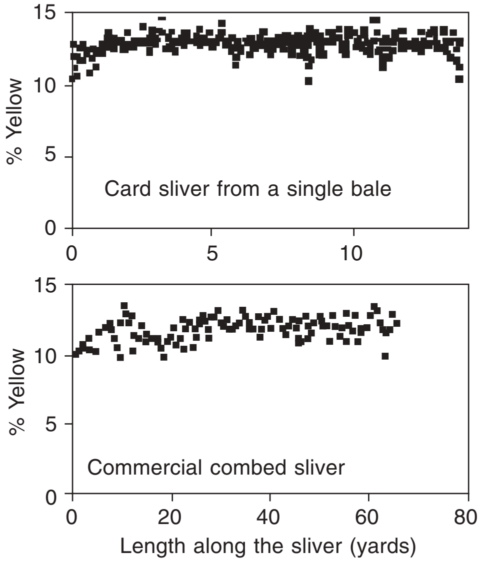


Fig. 11.5 Variation in fiber color

(≈ 0.3 nep/g) at about 6s cotton count to 1300 nep/km (≈ 100 nep/g) at 45s cotton count. A 45s combed yarn gives an average nep count of about 12 nep/g (it would be rare indeed to make a 6s combed yarn). Thus it can be seen that care is needed in interpreting results. In rotor spinning, the corresponding AFIS figure is about 200 nep/g irrespective of count. Thus, rotor spinning produces a slightly inferior yarn as far as nep is concerned. This may be due to nep created in the combing roll of the rotor spinning machine. In cotton spinning, neps are often associated with other defects, for example as in Fig. 11.6(a). To emphasize the importance of the quality control regime in a mill, consider Fig. 11.6(b), which shows the results of tests in two separate mills spinning different counts of cotton yarn. A 50s yarn usually shows a different nep count from a 30s, but this is not the issue in this case. Rather, one mill

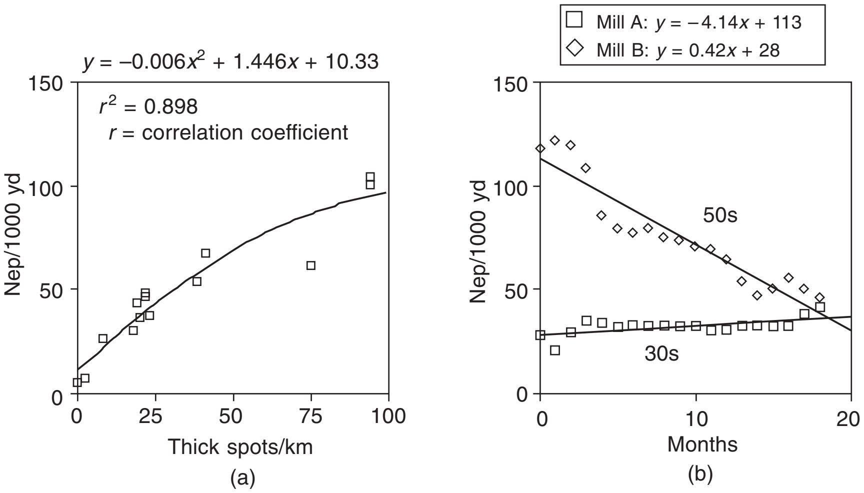


Fig. 11.6 Nep control

had worked to reduce neps and the graph shows the result. The other mill had a reasonably good nep count for the end use and, unfortunately, saw little need to work hard at the problem. The example is intended to show the value of progressively plotting fault production.

Some data relating to yarn faults in various types of yarns are shown in Fig. 11.7. The yarns are of average quality. All the faults shown decline in number as the linear density increases (i.e. the count decreases). Worsted yarns show up poorly in thin spots whereas 100% carded cotton yarns show up badly in thick spots. It is, perhaps, not surprising to find the number of thin spots for worsted yarns to be high when it is remembered that wool is more variable in length and fineness than cotton. Also, it is not surprising to find that combed cotton yarns perform well in this respect. It is interesting to see that the nep performance for wool is relatively good, whereas the performance of carded cotton is relatively poor. Presumably this is because cotton is so much finer than wool. It is a little disappointing to see the relatively poor nep performance of air-jet yarns; perhaps this is due to the extra drafting.

Trash, dust, and visible foreign matter are progressively reduced by processing and the levels in combed yarn can be reduced to the order of 1% of the values pertaining to the bale material. The best and worst spinners of carded ring spun yarn produce 0.1 and over 10 trash particles/g, respectively, at 50s count; the figures for 6s yarn are approximately 8 and 30, respectively. Thus the quality of the processing is seen to play a very significant part in the quality of the product.

The use of waste fiber affects quality. Before regulations restrained yarn makers by making truthful labeling mandatory, more mixed waste was used than now. Thus, we had shoddy in the wool trade, recycling of blend fibers of indeterminate blend ratios, filaments and fibers made from recycled polymers, and so on, but such practices are rarer today. The name ‘shoddy’ is now synonymous with poor quality. Comber noils are sometimes recycled within a mill but it is also a frequent practice to sell the noil to yarn makers who make lower grade products. For these latter people, the noil

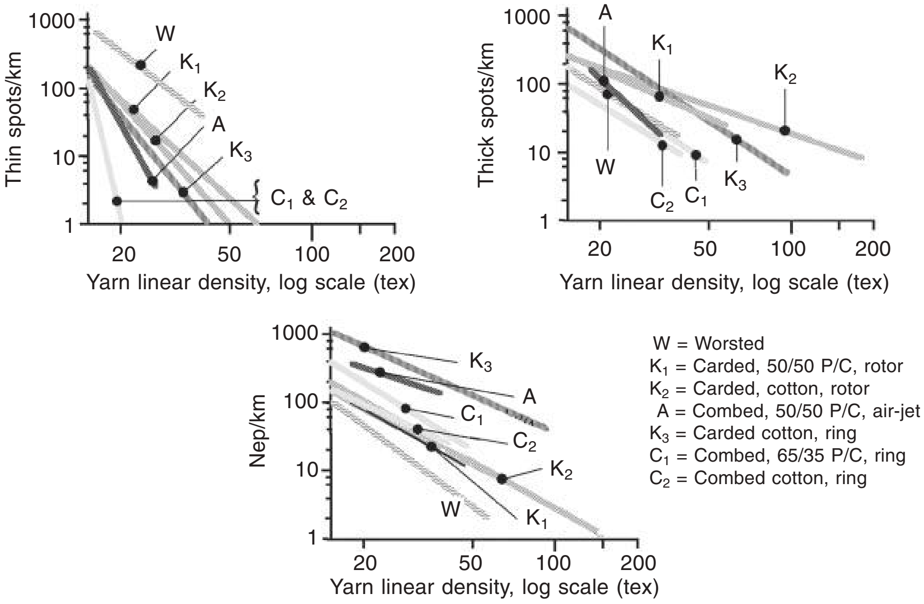


Fig. 11.7 Fault rates for average yarns

is a relatively cheap raw material. Undercard and flat waste are sometimes recycled, but much of it is disposed of. Pneumafil waste (see Section 5.11.3) is nearly always recycled within the staple mill. Intense competition and pressure on prices make prudent recycling a necessity. As in Fig. 11.8, the amount of pneumafil generated with cotton yarns is substantial and it rises with count. Recycling has to be carried out with care.

In filament/staple processing there is less possibility of recycling the waste internally.

11.2.5 Staple yarn defects arising from processing

The analysis in this section will be organized from winding back through the processes until we reach the bale laydown. Many yarn faults are removed during the clearing operation and are replaced by standard knots or splices. Not only does this make it possible for faults to be produced and then be removed without the manager being aware of the fact, but it calls into question whether the yarn should be tested before or after clearing. Normal practice is to test samples after piecing. Study of the piecings from a given operator or machine will quickly show a characteristic appearance. This sometimes enables the source of a problem to be traced.

Every time an end breaks, the process has to be restarted by piecing, and these piecings are always imperfect, even if they are acceptable. If the purpose of testing is to detect the source and frequency of fault production, then there might be an incentive to test the yarn before clearing. It would then become necessary to sample the thousands of ring bobbins or equivalent packages entering the winding process.

If the purpose of testing is to protect the customer, it is necessary to sample the wound packages destined for the customer. These latter packages contain the contents of the input bobbins minus the portions of yarn removed, but with the added knots or splices. It is not possible to regard these final packages as single specimens; in reality each one is a series of yarns from almost randomly chosen bobbins of yarn. However, with linked winding systems, the order of the component yarns on the cheese or cone is usually the same as that of the rovings on the ring frame, which can be turned to advantage. The amount of testing required to truly sample the material delivered is much higher than normally realized. This is especially so if there are large variances between individual bobbins. Remember that, as the CV reduces, the required sampling frequency is also reduced.

The residual fault rate describes the yarn after clearing. It depends not only on the original processing during yarn manufacture but also on the setting of the clearing and splicing mechanisms. Thus, test results may be ambiguous. The levels at which the clearers are set determine the size of defect removed, and the setting of the splicer

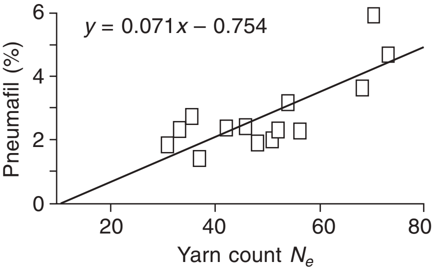


Fig. 11.8 Pneumafil production rates

determines whether the splice is acceptable or not. The more defects removed, the greater is the chance of an unacceptable yarn. A frequent problem in this latter regard is the production of long fiber tails to the splice. Such tails interfere with the processes that follow and these faults should be avoided.

Defects can be caused in roller drafting as well as the normal set of errors already described. Wrong ratch settings, worn guides, eccentric spindles, etc., might cause fiber breakages or other fiber disturbances. Nicked, fouled, or damaged pigtail guides, balloon control rings, travelers, rings, flyer grommets, or the like can also lead to defects in the product. The nicks become more prevalent after certain abrasive man-made fibers have been used on the particular equipment. Often these machine defects cause episodes of hairiness not easy to detect in the yarn but which become very troublesome in later processes.

Apart from locally irregular drafting, fiber debris may be discharged into the air. Since the highest draft is at the spinning frame, this is a good place to look for the sources of defects. Concentrations of fly from this or other sources may then become wrapped around the yarn to produce faults. Slubs and fishes are usually created by electrification or by faulty settings of the drafting system. It might be noticed that the defect level is a function of draft, all other things being equal. A badly arranged or maintained traveling cleaner can blow concentrations of fiber onto the yarn, roving or other strand. Raw materials that contain an excess of short fiber might lead to an undesirable discharge of fly into the atmosphere. If the atmosphere is such as to encourage fiber electrification, this fly may concentrate into tiny clumps which deposit on the yarn during manufacture. Alternatively, the fly can be deposited on material being stored in the workplace. Undrawn or married fibers, particles of foreign material, irregular fibers and the like can temporarily interfere with the drafting process and produce slubs. Deposits of fibers on the traveler or elsewhere may cause defects if the deposits are suddenly licked into the product stream. Also they can cause the ends-down rate to increase. A sharp look-out for such accumulations is required.

When spinning blends of natural and man-made fibers, there can be accumulations of fiber finish that become particularly troublesome on the balloon control rings, main rings, and travelers. The deposits are often white and powdery, which explains the common description of it as ‘snow’. They might vary in quantity from one fiber maker to another or from one fiber merge to another, and some are very easy to remove by washing, but economics do not allow for a washing operation of machine parts.

There is an intermediate case where too light a roll pressure creates a string or a series of defects rather than a classical case of irregularity. The effects of too light a roll pressure can be magnified if the roving is fairly highly twisted and is irregular. The hard ends described earlier can cause outbreaks of such strings of defects. All these various examples have in common an irregularity of occurrence, but an experienced eye can usually recognize the probable source.

11.2.6 Staple yarn defects arising from air conditioning

A cause of defects is the entrapment of accumulations of fly on the roving or yarn, either at the ring or roving frame. Spun-in fly can usually be associated with poor cleaning procedures or equipment. Every time an end breaks in a roving frame, the broken end lashes the neighboring machine parts and creates a ‘snow storm’ until the frame can stop. Inertia of the machine prevents an immediate cessation of motion.

Therefore, even if the machine is switched off immediately after the break, it continues to broadcast fiber until it stops. There is a ‘run-down’ time. Apart from this, there is a steady discharge of fibers from the roving and drawframes as they work normally. This discharge often results in the creation of very loose fluffy rolls of fiber on the floor of the mill; these often escape the patrolling cleaners, some parts of them becoming airborne again and migrating to other areas. Also, concentrations of fiber finish that accumulate on machine parts can cause irregular faults. If any of the accumulations fall into crucial operating zones of the machines, faults are created.

In ring spinning, the traveler sometimes pushes trapped fly into ball-like shapes and this type of defect can sometimes be associated with a high incidence of traveler fouling. It is vitally important to keep the critical areas free from lint accumulations, which is no easy matter. For example, a small fraction of a percent of the fiber passing through a frame is liberated into the air to form fly. This may not sound much, but in fact it represents hundreds of pounds of fly being deposited every day. If the deposition rate is 0.02% of the fiber flow in a mill processing 2000 lb/hr, the deposition rate is over 60 lb of fly/week. If you do not believe it, fix a wire mesh in front of (say) one section of rings and you will find that, in an hour, several milligrams of dirty fiber will be collected. At the ring rail level, the fibers will be on the side of the mesh nearest the rings. At the level of the tops of the bobbins, the deposits will be on the outside. The rotating bobbins act as a pump that sucks air from the room into the balloon space. If the air is dirty (it usually is), fibers and contaminants are pulled over the freshly made yarn being wound onto the bobbin. Adequate cleaning is vital and this involves the use of traveling cleaners as described earlier. The main air conditioning should also have adequate cleaning capabilities. Management must also consider the sources of lint, because it is better to eliminate as many of the emissions as possible rather than clean them up afterwards. On the supervisor’s tour, a sharp look-out for accumulations of fly around light fittings, ceilings, and roof fittings is very helpful in this respect. A study of the airstreams within a mill can help to determine if fly is being transferred from a seemingly non-critical area.

11.2.7 Defects in fabric

The ultimate product is usually in fabric form, and a judgment of quality is normally made on the number of defects per square yard. Frequently, demerit points are assigned according to the length, diameter, and type of defect. For that reason, many spinners knit samples of yarn to test for defects and barré. In weaving, there is a requirement for adequate yarn strength and a lack of any defects that would cause end-breaks in beaming or weaving. For example, consider a warp beam with 3000 ends of yarn that has a defect rate of ‘only’ 10 per 1000 yards. On average, there will be $3000 \times 10/1000 = 30$ faults per yard of warp. This is unacceptable. The faults can give problems in at least three ways: (a) the end-breakage rate in beaming and weaving is increased, (b) the fabric is degraded because of the yarn faults, and (c) the fabric is further degraded because of the weaving faults due to the increased breakage mentioned in (a). Figure 11.9 shows measurements of yarn strength made just after spinning and it will be seen that the strength is not constant. As mentioned elsewhere, end-breaks in spinning occur when the yarn tension exceeds the strength of a weak link in the yarn in the process line. A similar philosophy applies to weaving but now the weak spots concerned are in the wound yarn. Some faults have been removed but the yarn might have been strained by high tensions or damaged, and a new crop of weak spots

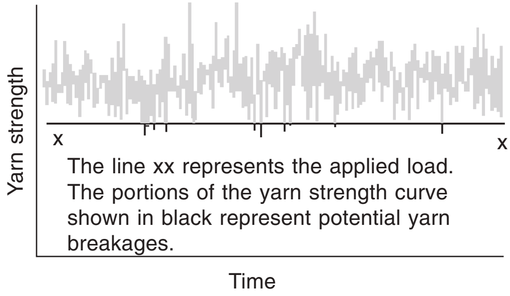


Fig. 11.9 Variation in yarn strength

might now exist. Straining the yarn reduces the work needed for rupture and the ability to weave well. Thus, the picture given by yarn testing may well be too optimistic and the weaving performance might be worse than predicted. To demonstrate the impact of yarn faults, let us consider a square weave fabric made from the same yarn for both warp and filling. If the yarn diameter is proportional to $(1/\sqrt{N_e})$, where N_e is the yarn count, then the end or pick density is $(k\sqrt{N_e})/CF$ per unit length. The factor k includes not only the constant relating yarn diameter to $(1/\sqrt{N_e})$ but also takes into account the weaving crimp: CF is the cover factor, which is defined as (area covered by one or more yarns)/(area of the fabric). The length of yarn (L) in a square yard of fabric is:

$$L \approx [\#\ \text{ends/yd} + \#\ \text{picks/yd})$$

$$L \approx (2k/\sqrt{N_e})(CF) \qquad [11.1]$$

If the defect frequency is f defects/yard, the average number of defects/square yard is Lf. If the fabric has a different construction (say, woven or knitted), we may replace $2k/CF$ by a different factor (K), which takes into account the difference in structure.

$$\text{Number of defects/sq yd} = Kf\sqrt{N_e} \qquad [11.2]$$

In ring spinning, the fault rate increases with draft, as shown earlier in Fig. 11.4; the major draft occurs in spinning and the largest number of defects arise there. The number of defects can, in practice, be related to the yarn count and the quality of the spinning operation. The cover factor does not vary greatly within a given class of fabric; therefore, fabric defect rates for a given class of fabric are affected mostly by changes in $\sqrt{N_e}$.

11.2.8 Testing for yarn defects

Usually, yarn defects are classified by length, local linear density, and fault frequency. A typical distribution is shown in Fig. 11.4(b). It will be seen that short defects are more common than long ones. Generally, a series of combinations of length and linear density of the faults is used to determine whether the fault should be removed. The choice of these combinations depends on the market involved and the experience of the user. The amount of yarn that must be tested depends on the fault frequency. With a fixed length of yarn (say 100 000 yd), there are two opposite dangers. On the one hand there may be costly over-testing of a yarn, but on the other hand there may be a risk of having tested an unrepresentative sample. In consequence of the need for long samples, there is considerable incentive to use online monitoring.

11.2.9 Monitoring

An example of the interplay between economics and technical advancement is the use of online monitoring at the ring frame. Because of the low output of a ring spindle, the amount of capital expense that can be justified is limited. Monitoring every spindle means that thousands of measurement points are involved and the provision of a transducer of any great complexity would be too expensive. A solution is to have a patrolling sensor that detects the presence or absence of the thread leaving the drafting system. One such device is carried by a patrolling cleaner and another uses a transport system mounted on the ring rail. The direct advantage is that those end-breaks are signaled immediately they occur and this permits closer management of the repairs. An indirect advantage is that this allows analysis of end-break patterns and becomes a means to study regional effects of the air conditioning, pneumafil settings, and machine maintenance. The system can have a beneficial impact on the processing costs and product quality but the capital cost is still high and the advantages have to be weighed carefully against the costs of installation.

Another interesting development is the roving stop mechanism. The idea is to clamp the roving as it enters the drafting system when the end breaks. This reduces the amount of pneumafil greatly. When the end is repaired, the whole drafting system for the particular spindle has to be rethreaded. This can be automated. It has been seen to be very effective from a quality point of view and the cost can be moderate. Adaptations have been made to use the electrical signals that operate the clamps for spindle monitoring.

Monitoring includes searching for defects. For example, it is common in rotor spinning and filament production systems to use online recording of the passage of defects in the flowing material. This is especially important because the product is rarely rewound before use in manufacturing the fabric. Such strategies move the testing from the laboratories to the production machines themselves.

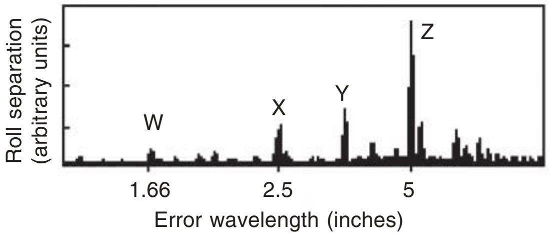
11.3 Yarn evenness

11.3.1 General

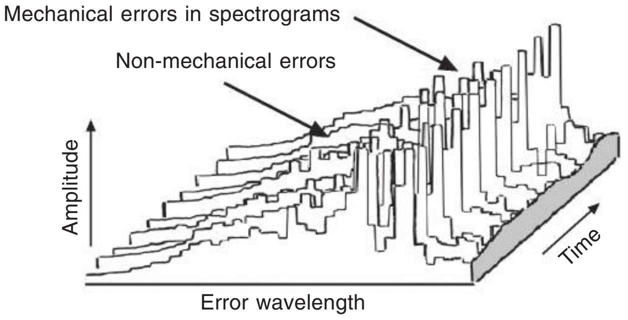
Yarn evenness is made up of several components. Repeating what has been said elsewhere, errors come from mechanical problems or from fiber flow problems. Either may produce short- or long-term errors.

11.3.2 Harmonic irregularity due to mechanical faults

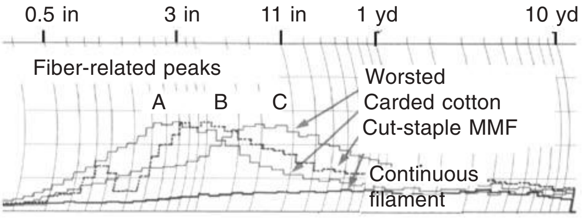
The class of mechanically caused errors consists of wholly repetitive variations such as those caused by roll defects. Such errors are harmonic and the repeat period may be expressed as error wavelength. A harmonic error produces a series of single ordinates on a spectrogram, and the highest of these lines is usually the fundamental wavelength. If a delivery roll is purely eccentric without any other error, the fundamental error wavelength in the output strand is the circumference of the front roll. A roll with a flat on it produces a fundamental wavelength and a number of harmonics (at 1/2, 1/3, 1/4, etc., of the fundamental wavelength). The defect is often caused by leaving the load on the rolls when the machine is not running. Occurrences of these harmonics in the test data should raise questions about the work practices in the mill. It is relatively simple to estimate the source of each spike. The spectrum of mechanical peaks shown in Fig. 11.10(a) was made by recording the changing separation of the centers of the front rolls of a drawframe [8]. No textile material was passing through the frame at the time. The technique exposed the mechanical errors more precisely than testing the sliver; furthermore, the use of an encoder made possible exact correlations between the error and the result. The spikes at W, X, and Z were from the top front roll, W and X representing the second and third harmonics, respectively. (The spike Y came from another source and need not be discussed here.) On a spectrogram of sliver from a drawframe, the mechanical errors also produce spikes but it is unavoidable that there is some fiber-related error as well. A single spectrogram is often not very useful in determining mechanical errors because of the profusion of random spikes from non-mechanical sources. If spectrograms are taken at precise time intervals and they are assembled as a three-dimensional graph, then if the spikes persist throughout the time dimension of the graph then the cause is mechanical and they represent a truly harmonic variation. Random spikes can be separated from the harmonic ones in this way [2,9]. A faulty element in the drafting system causes organized 'spikes' to appear, as shown in Fig. 11.10(b). This example is an especially bad case, included merely to emphasize the difference between the two types of error.



(a) Mechanical errors



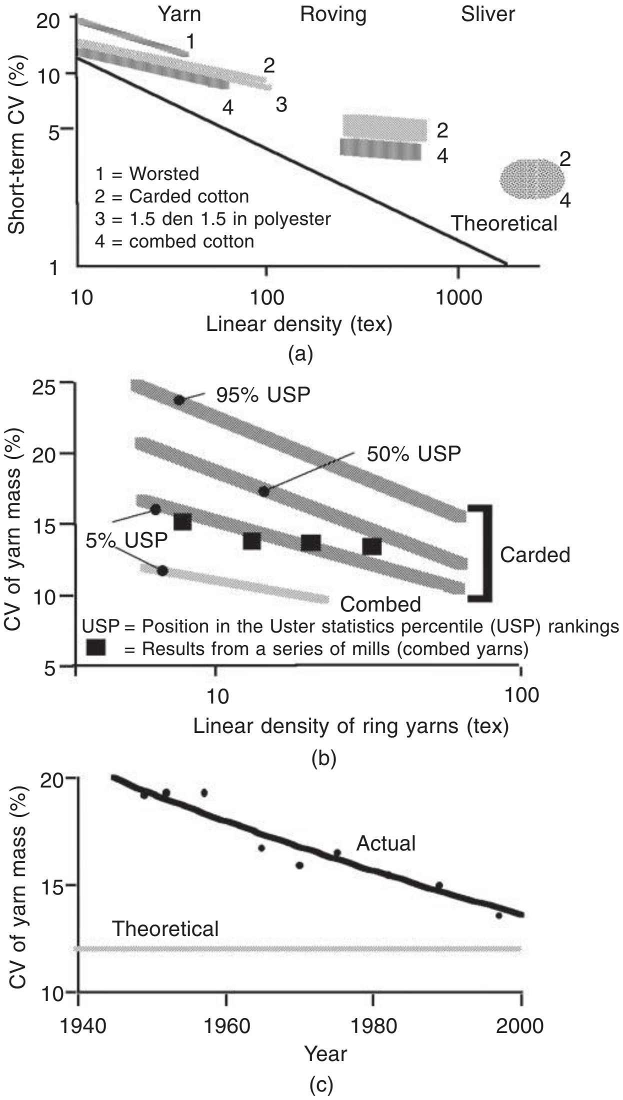
(b)



(c) Fiber-related errors

Fig. 11.10 Three views of error spectra

Fiber-related errors are more difficult to diagnose. The sources of error are many, and they are dispersed. They range from (a) variations in the fiber selected, through (b) the maintenance and setting of the machines, to (c) the environment in which the operation occurs. A starting point is the theoretical random error that is dependent on the number of fibers in the cross-section; consequently there are different values to be expected from sliver, roving, or yarn. The evenness also depends on the fiber length and its variability. Thus, there is a spectrum of values according to the strand involved, as indicated in Fig. 11.11(a). A yarn contains errors from spinning, roving, drawing, carding, and other processes. The error wavelength carried forward to the yarn gets ever longer as the initial generating point is positioned nearer the beginning of the process line. Also performance of one machine in a serial line of processes



(a)

(b)

(c)

Fig. 11.11 Three views of strand variations (CV) affects the following machines. A simple calculation can show that errors due to carding produce yarn errors in the order of a million yards. Errors from sources earlier in the process line produce even longer errors in the yarn. At the other end of the scale, the delivery rolls of a cotton ring spinning frame produce errors of only 4 or 5 inches. Fortunately, the errors produced from the early stages are smaller than those from the later ones. Mechanical errors from the ring frame produce short, highly organized errors that produce moiré. Errors from the early process stages produce barré in the fabric. The very long error wavelengths arising from the early processes produce bobbins that contain yarns that vary in average count. The spinning bobbins can become mixed between spinning, winding, and shipping. Consequently, the fabric making equipment often has to deal with random step changes in yarn count that show up as barré. Controlling the whole line is a technological art based on experience as much as on science and technology.

11.3.3 Irregularity in linear density due to staple fiber variations and their interactions with the machinery

Figure 11.11(a) shows some values of CV for various yarns and intermediate products and it might be noted that an overall regression would not be parallel to the theoretical line. Diagram (b) shows some carded ring yarn evenness values as judged on a worldwide basis in the late 1990s. The values are for the error wavelength range 0.2 inch to 30 yd. Even the best yarns show CV values that range from 16% at 50s count to about 10% at low counts. Longer-term variations, represented by the bobbin-to-bobbin values, range from about 1% CV for the best spinners to a value for the worst spinners that varies between about 3% and 5% at the counts mentioned above. These long-term variations arise in the preparation.

Fiber-related errors in the last draft zone show up as distributions of variance on a spectrogram that produce so called ‘hills’. They encompass a range of wavelengths between one and ten fiber lengths, with the crest of the most common hill being located between two and three fiber lengths. Wavelengths shorter than about half a fiber length are unreliable and are not used. As with mechanical errors, the fiber-related errors from previous drafting zones are elongated and the new crop of errors is added. This means that there is a hill from the front draft zone, and sometimes a less prominent one from the back zone. To get sufficient data to produce a spectrogram requires the testing of a sufficiently long length of the strand concerned. This strand then becomes waste fiber. Consequently it is not feasible to test for the errors from the earlier processes as well as those from the current one with the spectrograph. Materials from these earlier processes are tested immediately after the particular process concerned.

Remember that the use of CVs does not discriminate between the sources of the errors concerned, and an alternative method is needed. One way to minimize the drafting errors is to (a) test the strand emerging from the subject machine for evenness, (b) adjust the roll setting by one increment, (c) retest the strand and see whether or not the amplitude of the crest of the hill has changed, (d) readjust the setting based on the difference in amplitude, (e) retest, and so on until the minimum value is found. By using the crests of the hills, one avoids the interference from other errors. The ‘hill’ discussed is not always very smooth and there are sometimes spikes that have little to do with mechanical errors. One way of resolving this is to take a sequence of spectrograms and array them. False spikes, unrelated to any mechanical error, will stand out from the array, while the truly harmonic ones ‘march’ across the array in a steady straight line. Experience over many years has made possible the production of the Uster statistics, which give a good guide for judging performance. An example is given earlier, in Fig. 11.10(b), where the shaded lines represent the different percentiles of evenness from spinners throughout the world. Somewhat similar but more comprehensive diagrams published by Uster Corporation are very useful for normalizing data to compare plants on a meaningful basis.

Rather than refer to a particular CV at a certain count, it is better to refer to the position in the Uster statistics percentile rankings (USP). For example, a mill spinning 30s then can be compared to another spinning 10s with reasonable results. Of course, differences in fiber, machine maintenance or operational difficulties intervene, but a normalized comparison is likely to expose difficulties that otherwise could be missed. A group of mills can accumulate their own data and pursue a similar strategy. There is a frequent practice of testing competitors’ products to get a basis of comparison but care has to be taken to preserve an ethical stance on such testing. Figure 11.11(b) shows some mill data of the early 1990s compared to the 1997 Uster statistics [1]. The particular individual mills belonged to a commercial group and their results then fell in the 50 to 60 percentile range (the lower the percentile, the better). However, mill data within any manufacturing group commonly vary less than with international experience because of differences in the range of skills and equipment used. Nevertheless, experience has shown it to be a powerful managerial tool because, once norms are established for the group, logical comparisons can be made despite differences in product and equipment. A similar procedure can be used for the Uster data regarding thick and thin spots as well as neps.

Over the years, there has been steady improvement in the spinning equipment, the methods of testing, and the application of the technology. The data given in the foregoing are affected by this and some idea of the change can be obtained from Fig. 11.11(c). For example, the CV of mass for a 60s combed cotton yarn has declined over a half century. Thus care has to be taken to keep the standards up to date; the values steadily approach the minimum theoretical values. The same is true of other fibers and preparations. This is one of the reasons why defects have assumed such relative importance.

11.3.4 Irregularity of yarn hairiness

Hairiness of yarn is a factor in the appearance of fabrics, and variations in hairiness can produce optical effects that show up as streaks or bars or other visual disturbances. The Uster hairiness value, H, represents the total length of all the hairs protruding from the yarn, in cm, with reference to a sensing length of 1 cm. It is measured using infra red light to avoid color problems [9]. In an average carded cotton ring yarn on the bobbin, H varies from about 10 for 6s ($\approx$ 100 tex) yarn to about 4.5 for a 50s ($\approx$ 12 tex) yarn [1]. Subsequent winding and unwinding changes these data dependent on the conditions prevailing at the two operations. The variation between the best and the worst yarns is about 30%. The values quoted are averaged over a substantial length of yarn and there are significant short-term variations. Uster report within-bobbin variations which are in a range that can be expressed as 18 to 28% CV. The between-bobbin values vary between 1.2 and 10%.

11.3.5 Irregularity of yarn strength

Yarn strength for a staple yarn varies from about 10 cN/tex for the weakest yarns to 30 cN/tex for the best ones. A graph of the tenacities of various sorts of yarn is given in Fig. 11.12 and it will be seen that rotor yarn has lower values than ring yarn. The values for long-staple cottons for very fine yarns (not shown in Fig. 11.12) yield up to 30 cN/tex tenacities. At the bottom end of the scale, poor worsted yarns have tenacities around 7 cN/tex, poor rotor yarns produce about 10 cN/tex, and poor combed 65/35 P/C ring yarns produce about 19 cN/tex. Tenacities appear higher when tested at 400 m/min.

Figure 11.13 shows the CV of tenacity for various yarns. The best cotton yarns vary from about 4% for 6s carded ring yarn to about 9% at 50s count (≈ 12 tex). The worst yarns have CVs of the order of 10%. Combed cotton yarns have CVs varying from 4.5% at 15s count (≈ 40 tex) to 12% at 120s count for the best yarns. The worst yarns vary from 8.5% CV to 15% CV for corresponding counts (≈ 5 tex) and worsted yarns have high CVs of tenacity. It should be noted that the CVs of tenacity measured at higher testing speeds tend to be a little higher than those quoted.

11.3.6 Faults in fabrics

Coefficients of variation of the yarns do not tell the whole story; acceptability is conditioned by the wavelengths at which the errors occur. Spectrograms, such as

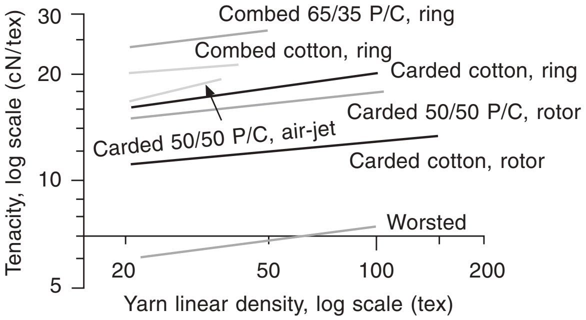


Fig. 11.12 Comparison of yarn tenacities (best 5% of yarns tested at 5m/min)

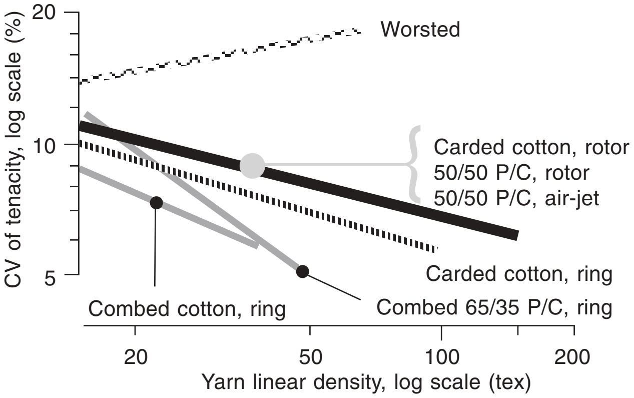


Fig. 11.13 Average CVs of tenacity of some staple yarns (tested at 5 m/min)

shown earlier in Fig. 11.10(c), show that different fibers produce the majority of their short-term errors at different wavelengths [9]. The area under the curves is a function of the variance in the yarn; the pattern of peaks is as important as the magnitude of the variation. The pattern affects what is seen in the fabric; the CVs of mass give only an overall value, with no wavelength component [10].

Another way of illustrating the same point is to observe the fabrics. Knitted fabrics are sensitive to yarn errors. A selection of photographs of knitted fabric appearances and their accompanying spectrograms is shown in Fig. 11.14. In the space available, only a taste of the subject can be given, but there is some value in discussing the types of error shown. Picture (a) is of fabric made with normal yarn and serves as a reference. Picture (b) shows the effect of poor fiber control in the front drafting zone of a ring frame – the mottled look will be noted – and picture (c) has errors produced in both front and rear drafting zones. The long waves from the rear zones produce the wood-grain effect. All yarns were 20s cotton. Experience has shown that improvement of short-term error without a corresponding improvement in long-term error leads to the production of fabrics of unacceptable visual character.

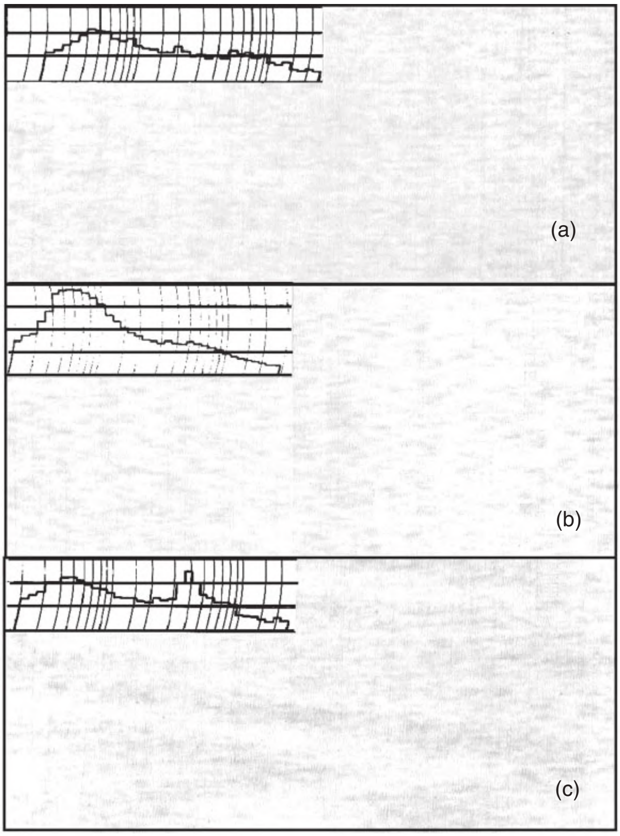


Fig. 11.14 Fabric faults arising from yarn errors

11.4 End-breaks and quality

11.4.1 End-breaks in spinning

The topic of end-breaks has already been mentioned. From an operational point of view, the end-breakage rate is a symptom of how well a plant is running. A high end-breakage rate points to a combination of machine, material, and human faults. If (a) the travelers need changing, machine maintenance is in arrears, or the machine is otherwise defective, or (b) the roving is bad, or there is a poor choice of fiber, or (c) the operators are not performing well, then a high end-breakage rate will result. If the training is poor, the assignment is too large, etc., then poor results should again be expected. The design of the machine is also a factor and so is the use of monitoring (human or otherwise). When all these factors are controlled, the author's experience suggests that the end-breakage rate is then quite a strong function of yarn count (Fig. 11.15(a)). Some authorities have different experience and their rate is less variable with count because their range of expertise and equipment is much wider than in the case quoted. The mean duration between end-breaks is shown in diagram (b); three lines are shown and one might say that the lines represent the best, the average, and the worst spinners in the world. As has been mentioned elsewhere, the end-break duration is a matter of assignment and operator training. It also depends on the duties assigned to the operator other than piecing-up. It is fairly obvious that the end-break rate is a function of spindle speed but it is less obvious that it is a function of how long the traveler has been in service. The rate increases similarly to the case shown in diagram (c). Replacing travelers more frequently adds costs to production but it is offset by the reduction in costs from lower end-breakage rates. The ends down rate also is very strongly affected by the number of yarn defects/unit mass (usually compared on the basis of defects/bobbin) as shown in Fig. 11.15(d).

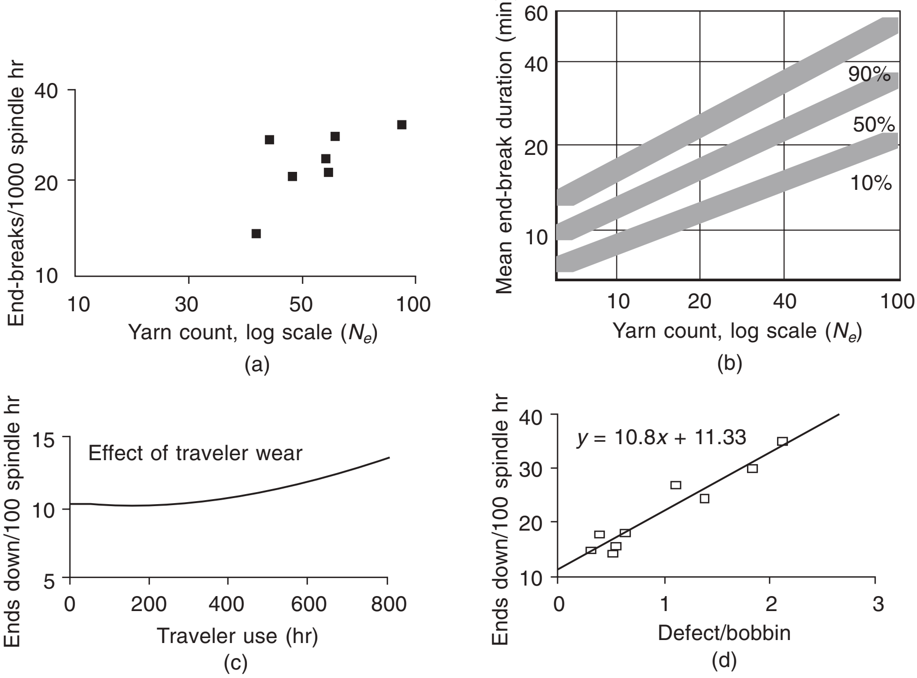


Fig. 11.15 End-breakage in ring spinning

One inexpensive and effective way of detecting the places where excessive end-breaks occur is for the supervisor to tour the ring room looking for deformed bobbins. When an end breaks, the building mechanism continues to work. The result is that, when an end is repaired after a delay (which is normal), the package looks like that shown in Fig. 11.16(b) instead of Fig. 11.16(a). The longer the delay, the greater is the deformity. Greatly deformed bobbins mean that (a) the operator assignment is too high, (b) the operator is poorly trained, or (c) the operator is inefficient. A high frequency of widely scattered deformed bobbins means (a) the machine maintenance is substandard, (b) the settings are wrong, (c) the sliver or roving supplied is substandard, or (d) the operator assignment, training and efficiencies have to be reviewed. Such tours should be frequent because it is only possible to make judgments on frames where the bobbins are built sufficiently to make the deformities evident. Thus, a single tour misses the frames where a doffing has occurred fairly recently. The tour can also be used to check the spindles. If viewed with a simple flashlight, the balloon can be seen easily. If a bobbin is out-of-plumb, it is quite possible that the upper tip of the bobbin will touch the yarn in the balloon when the rail is in a low position. Also, if a wrongly sized traveler is used, the same thing might happen. Such interference causes intermittent hairiness in the yarn which, in turn, leads to hairiness, moiré, and barré in the fabric. In addition, the use of too light a traveler can produce temporary balloon collapses which are likely to cause end-breaks. The collapse can be seen with the flashlight. The phenomena just described are seen most at the low rail position, soon after doffing. A localized pattern of end-breaks is often found near doorways,

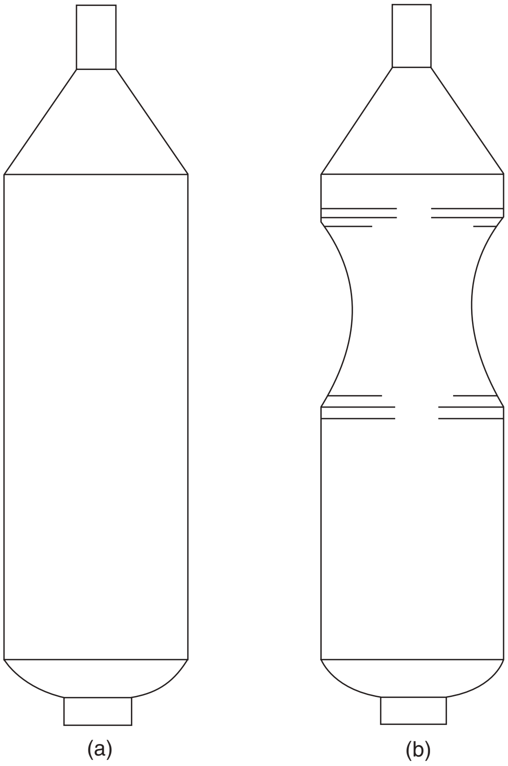


Fig. 11.16 Normal and deformed ring bobbins

local heat sources, or in a group of machines supplied with substandard sliver or roving.

An accurate way of accomplishing the objective just discussed is to use a monitoring system, but this is a somewhat expensive option. For ring spinning, one has to weigh the advantages and disadvantages of monitoring. For more highly productive machines, the advantages usually outweigh the disadvantages. Thus rotor spinning, air-jet spinning, and many processes associated with the production of filament yarns are likely to be fitted with a defect monitoring system.

11.4.2 Quality control and economics

As an example of the rate of production of faults, if production of a 24s yarn is 1000 lb/hr and the spinning fault level is only 1 in 10^6 yards, then $24 \times 840 \times 1000/10^6 = 20.16$ spinning faults are still produced per hour. (See Q1 Appendix 2 for the length of yarn in 1 pound.) If the fault rate is worse than this, the burden increases proportionately. High fault rates cause losses in efficiency of spinning, winding, twisting, beaming, and weaving. They also degrade the product. The degradation increases the complaint level, reduces the price that can be demanded, and reduces the volume of sales. As mentioned elsewhere, many of the spinning faults are caused by poor preparation.

It is hoped that the foregoing illustrates that the decision of how and where the yarn or the preparation should be sampled is not a simple one. To be economic and effective, it is essential that the multitude of spindles in a ring spinning mill should be properly monitored. Also, it is of similar importance to monitor the earlier stages of production properly, particularly regarding those errors and faults that lead to later trouble. Frequently, it is necessary to backtrack to find the cause of error. This requires that the product be properly labeled. Testing is only effective when it is accompanied by good organization and interpretation. Similar thoughts apply to the production of textured and filament yarns. Many of the problems in the final product have their origins in the early stages of yarn production.

References

1. Färber, C and Furter, R. *Uster Statistics No 40*, Zellweger Uster, Uster, Switzerland, May 1997.
2. ASTM D2253 Measurement of Cotton Color with the Nickerson-Hunter Colorimeter, Textiles, ASTM, Philadelphia, Annually.
3. Lord, P R. Unpublished data from the author's private records.
4. Anderson, S L. *Textile Fibres: Testing and Quality Control*, Manual of Textile Technology, Textile Institute, Manchester, UK, 1983.
5. Hattenschweiler, P and Bühler, M. *Uster Bulletin No 21*, Zellweger Uster, Uster, Switzerland, Nov 1973.
6. Thomason, W A. A New Era in Quality Control – Yarn Fault Management, *Uster News Bulletin No 18*, Uster Corp, Charlotte, NC, Jan 1971.
7. Douglas, K. The Uster Automatic Electronic Yarn Clearing Installation, *Uster Bulletin No 22*, Uster Corp, Charlotte, NC, USA, 1974.
8. Lord, P R and Grover, G. Roller drafting, *Text Prog*, **23**, 4, 1993.
9. Douglas, K. *Uster Bulletin No 35*, Uster Corp, Charlotte, NC, USA, Oct 1988.
10. Douglas, K. *Uster Bulletin No 15*, Uster Corp, Charlotte, NC, USA, Jan 1971.