HOW THE MACHINE MAKER DEALS WITH THE ISSUE OF SHORT FIBER CONTENT (AN ITMA 99 PERSPECTIVE)

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Abstract

The adverse effects of short fibers on yarn quality and processing performance have been well recognized for many years. Different sectors of the textile industry from fiber producers to yarn spinners have struggled with these effects and many practical efforts have been made to reduce their impacts. However, these efforts have often been hindered by a continuous trend to increase productivity. This trend has led the machine maker to place a greater emphasis on areas such as high speeds, automation, and transportation. Indeed, the 1980's and the 1990's have witnessed a sole emphasis by the machine maker on design features, which allow the machine to run faster, and to automatically handle the material flow. The axiom that supported these developments was that "automation can indeed produce a highly consistent product". In theory, this axiom is undoubtedly true. The problem, however, is that yarn quality has not significantly improved over those twenty years of development. Instead, it has deteriorated in many areas including appearance, hairiness, fly shedding, and yarn imperfections. On the other hand, the gap between the top quality levels (the 5% Uster Statistics), and the bottom quality (the 95% Uster Statistics) has progressively widened over the same period. These factors have resulted in a shift of emphasis, by machine makers, towards high quality yarn through an improved yarn structure. This shift was clearly witnessed in the last ITMA show of the century (Paris-1999).

In this paper, we provide a brief review of some of the new machinery developments devoted to handling the problem of short fiber content through improvement of yarn structure. These developments are divided into two main categories:

[1] The prevention approach in which short fibers are prevented from being represented in the final product; or
[2] The corrective approach in which short fibers are incorporated properly into the final product.

Introduction

The yarn as spun today does not have the basic necessary features to be woven or knitted. The reason for this deficiency lies in two main quality problems:

- Poor surface integrity
- Strength loss and strength variability

The surface integrity of a spun yarn can largely be determined by two main parameters: yarn hairiness, and abrasion resistance. Strength loss is determined by the ratio between yarn tenacity and fiber tenacity.

In general, the yarn as spun today has too high hairiness, and too low abrasion resistance to be woven into a fabric, and to provide a highly efficient knitting process. In addition, low yarn strength and inconsistent strength along the yarn axis are major contributing factors for many of the performance problems during weaving preparation.

From an economical viewpoint, these two adverse features cost the textile industry millions of dollars every day. This high cost is reflected in many areas including:

- The need for a costly remedy process called "slashing or sizing" in which the yarn surface is coated with a chemical film to reduce hairiness and improve abrasion resistance. This process is typically used for woven fabrics, and a de-sizing process, in the fabric form, to remove the surface chemicals normally follows it.
- The need for a costly waxing process to improve the surface integrity of yarns used for making knit fabrics.
- Very low efficiency during weaving preparation, particularly in processes such as warping and rope beaming (normally used for denim yarns).

Obviously, there are many causes of the poor surface integrity and strength loss of spun yarn. However, if one attempts to list two or three of the most contributing factors, short fiber content will certainly be among them. Indeed, short fiber content is an essential factor in all models relating fiber attributes to yarn quality and/or processing performance. Accordingly, any solution to the two yarn problems mentioned above must account for the effect of short fibers.

In recent years, different sectors of the textile cotton industry have made significant efforts to effectively handle the problem of short fibers. Some efforts have directly targeted short fibers and others have dealt with the issue as an integrated factor in the overall yarn structure. In this paper, we will provide an overview of these efforts with special emphasis on the spinning sector.

Developments to Overcome the Impact of Short Fiber Content

Efforts for handling the adverse impact of short fibers may be divided into two main categories:

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- The preventive approach
- The corrective approach

In the preventive approach, short fibers are prevented from being represented in the final product. In the corrective approach, they are accommodated and better utilized in the spun yarn. These two approaches are discussed below.

The Preventive Approach

The traditional preventive approach to handling short fibers has been the use of combing in spinning preparation. The combing process is normally used to produce a smoother, finer, stronger, and more uniform yarn than otherwise would be possible. Therefore, combing is commonly confined to high grade, long staple natural fibers. In recent years, combing has been utilized as an "upgrading" process of low quality cotton fibers with short or medium staple length. The primary objective of combing is to remove short fibers through fast and intermittent combing actions. Other important objectives of combing are removal of trash and neps and production of fiber strands (combed slivers) of smooth, and highly oriented fibers.

These objectives are accomplished through two stages of processing: (i) combing preparation and (ii) combing. The purpose of combing preparation is to form a uniform fiber lap suitable for the combing process. The combing process works in a precise sequence to straighten the fibers, and remove short fibers, trash and neps. The output of the combing process is called “combed sliver”. This sliver is uniquely different from the card sliver in that it has fibers of much higher degree of parallelization and straightening, and it exhibits a significantly lower cohesion than the card sliver. The high degree of fiber orientation in the combed sliver results in yarns that are stronger and more uniform than those produced from carded slivers.

The key parameter in evaluating combing performance is the percentage of long fibers in the comber waste (noil), and the percentage of short fibers in the combed sliver. Figure 1 shows typical fiber length distributions of comber noil and the combed sliver. As shown in Figure 1.a, most of the fibers in the comber noil are short fibers of 12 mm Ro less. Any long fibers found in the noil should be considered as a true waste. Figure 1.b shows that the percentage of short fibers in the combed sliver is very low. Excessive short fibers in the combed sliver typically indicate poor combing performance.

Another prevention approach is through proper opening and cleaning in spinning preparation. It is well known that excessive opening can result in fiber damage and short fibers. In recent years, machine makers have introduced significant developments to reduce fiber damage in the opening and cleaning line. Examples of these developments include the Trutzschler Cleanomat® system, and the Rieter opening and cleaning system enhanced by the VarioSet® control. The primary goal of the VarioSet® system is to provide flexible and accurate means for setting or selecting machines with respect to two main parameters: the cleaning intensity, and the relative amount of waste. The Trutzschler Cleanomat® system consists of different combinations of cleaning units that can be selected in view of the cleaning propensity of different cotton types. Detailed discussions of these systems are outside the scope of this presentation.

Before proceeding with other preventive approaches, we should point out that the performance of an opening and cleaning unit can not be fully characterized without careful evaluation of possible fiber damage. In general, any cleaning process will inevitably involve some fiber damage. Traditionally, this damage has been determined by comparing short fiber content in the output material with that in the input material. If a cleaning unit caused severe fiber fragmentation, the output material would have a much higher short fiber content than the input material. In addition, the mean length of the output material will be smaller than that of the input material. This situation is illustrated in figure 2.a.

In some situations, short fiber content in the output material is found to be slightly lower than that of the input material as shown in Figure 2.b. Assuming no testing error is involved, this situation is often a result of the extraction of short fibers with the machine waste (Figure 2.c). Using the mass conservation law, we developed the following simple expression to account for the extraction of fiber fragments in the waste:

$$EFD(\%) = \left[\frac{SFC_{out} - SFC_{in}}{SFC_{in}}\right] \times 100 + CF_w \qquad [1.a]$$

where EFD is the extent of fiber damage, SFC_{out} is the percent short fiber content in the output material, SFC_{in} is the percent short fiber content in the input material, and CF_w is a correction factor which accounts for the short fiber content extracted with the waste. This correction factor can be determined from the following equation:

$$CF_w = W(\%)\left[\frac{SFC_w - SFC_{out}}{SFC_{in}}\right] \qquad [1.b]$$

where SFC_w is the percent short fiber content in the waste material, and W is the percent waste.

In the spinning sector, the most significant development is the introduction of Murata Vortex Spinning (MVS). This spinning system represents a significant modification of the conventional air-jet spinning to allow the production of 100% cotton yarns. The idea of this development is to improve two important features of the jet-spinning system: (i) the number of wrapper fibers, and (ii) the length of wrapper fibers. Wrapper fibers are the main source of strength of air-jet yarns.

As in the conventional Murata Jet Spinning (MJS), a finished drawn sliver is directly fed to a roller drafting system (see Figure 3). The drafted fibers are then passed through an air-jet nozzle and a hollow channel (called a spindle). Fibers exiting the nip of the front rollers are sucked into a spiral orifice at the entrance of the air nozzle, and they are then held together more firmly as they move towards the tip of a needle protruding from the orifice. At this stage, the force of the air stream twists the fibers. This twisting motion tends to flow upwards. The needle protruding from the orifice prevents this upward propagation (twist penetration). Therefore, the upper portions of some fibers are separated from the nip point of the front rollers but they are kept open.

After the fibers have passed through the orifice, the upper portions of the fibers begin to expand due to the whirling force of the jet air stream and they twine over the hollow spindle. Those fibers are whirled around the fiber core and made into MVS yarn as they are drawn into the hollow spindle. The finished yarn is wound onto a package after its defects have been removed. Thus, the consolidation of fibers is achieved by applying a rapidly spiraling flow of compressed air at a non-rotating spindle tip in the air nozzle.

The above mechanism provides better wrapping effect over the conventional MJS system. However, this effect alone would not be sufficient to produce a 100% cotton yarn, particularly if carded yarn is the target. The reason for that is the presence of short fibers, which provide ineffective wrapping effect by virtue of their limited length. This problem is overcome through control of the distance between the nip of the front roller and the tip of the spindle (distance L in Figure 3). The larger this distance, the more the “upper portion open” fibers, resulting in a yarn of characteristics similar to those of truly-twisted yarns. Also, the larger this distance, the greater the short fibers removed as waste from the main fiber stream. Murata suggests a distance that is slightly shorter than the average length of fibers.

The MVS development has resulted in a yarn that can truly compete with rotor-spun yarn at its coarse to medium yarn count range and with ring-spun yarn at its medium to fine range (up to 40’s). This point is illustrated in Figures 4 through 6, which are based on data presented by Murata in ITMA-99 Paris. MVS yarns were also found to have a relatively better surface definition and appearance (luster and uniformity) than conventional air-jet spun yarns and rotor-spun yarns. It was also found to exhibit slightly less torque or skew than ring-spun yarn, but similar to rotor-spun yarn.

The Corrective Approach

In the corrective approach, short fibers are handled by accommodating them in the fiber stream in such a way that provides minimum adverse effects on yarn quality and spinning performance. One of the methods that have been successfully implemented in the U.S. is judicious fiber selection. The majority of U.S. textile mills have used the powerful Engineered Fiber Selection (EFS®) system produced by Cotton Incorporated since the early 1980. This system uses practically proven scientific techniques to search through millions of different cotton bales and select cotton mixes that are consistent on day-to-day basis.

In the context of short fibers, the EFS® provides ways to control short fiber content in the cotton mix, through proper accounting of the probability of their representation in the spun yarn. The principles of some of these methods were discussed in other papers by the present authors. A key point in this regard is that short fibers, particularly of low Micronaire, have a much greater chance of being represented in the micro-sections, and the macro-sections of the spun yarn.

In line with the corrective approach, one of the most significant developments is the introduction of Compact or Condensed Spinning. In contrast with the MVS discussed earlier, which is based on a partial fiber divergence to produce a spun yarn, Compact spinning produces a unique yarn structure through substantial elimination of fiber divergence.

Compact or condensed spinning is a new concept of yarn forming. It represents a fundamental modification of the conventional ring-spinning system that aims at producing a better surface integrity of spun yarns and maximizing the fiber contribution to yarn strength. The idea stems from the necessity of controlling the dimensions of the spinning triangle to improve yarn strength and reduce yarn hairiness.

In simple practical terms, it is well known that one of the feature of the conventional ring spinning is that the width of the fiber strand undergoes dynamic changes as fibers flow from the drafting zone to the twisting zone. In the drafting system, the width of the fiber strand (W_F) is large. As the fibers emerge from the nip of the front drafting rollers, the width decreases to the width of the spinning triangle (W_T). Finally, as the fibers enter the twisting point, the width of the strand is reduced further to the thickness of the yarn being formed (see Figure 7). The continuous change in the width of fiber strand associated with the tension differential across the fiber flow results in a divergence of some fibers (particularly, the outer fibers) from the main fiber stream. This prevents some fibers from being fully incorporated in the yarn structure. Those fibers will not fully share the loading of yarn under tensile stresses, leading to a loss in yarn strength. Furthermore, they are likely to form protruding hairs that can be stimulated further by the ring/traveler system. A significant portion of the diverged fibers is that of short length. Very short fibers enter the spinning triangle in a largely random fashion and they are likely to float in this critical zone (not gripped by the twisting point or the front roller nip). Some long fibers may also diverge if they exhibit free ends in the spinning triangle zone.

The idea of compact or condensed spinning is to minimize the change in the width of fiber strand through the introduction of a compacting media (air), and a substantial reduction (almost elimination) of the spinning triangle. This is achieved using an air-suction system and a perforated surface mounted in the fiber flow line.

In ITMA 1999, Paris, three condensed spinning systems were introduced. These are:

- Rieter Com4® system.
- Zinser AIR-COM-TEX 700® system.
- Suessen EliTe® system.

The early development of the Rieter Com4® system was called the "Compact" spinning. This system was conceived by Dr. Ernst Fehrer, the founder of friction spinning, and later developed by Rieter. Figure 8 shows the drafting system of the Rieter Compact spinning system. This system consists of 3/3 roller drafting in which the bottom delivery roller is a hollow, perforated drum with a large diameter. Using a suction system, airflow is sucked from the outside to the inside of the drum. Under this air suction, fibers merging from the delivery nip of the drafting unit are held against the drum surface and moved at the same circumferential speed as the drum surface. A second top roller pressing against the drum is also used to create a nip between the drum and the top roller that acts as twist stop. This leads to a yarn formation immediately after this nip (i.e. no triangle). The condensation of fiber flow takes place in the intermediate zone between the two top rollers sitting on the perforated drum.

The Zinser AIR-COM-TEX 700® system also works on the basis of eliminating the spinning triangle. This system uses a conventional 3-cylinder drafting system. The fibers emerging from this drafting system are taken by an air flow, and condensed under suction on a perforated belt surface (see Figure 9). The condensed fiber strand thus undergoes a substantial reduction in width prior to twisting. This, in turn, reduces the difference between the width of the fibers emerging from the drafting system and the yarn diameter (i.e. total elimination of the spinning triangle).

The Suessen EliTe® system is a spinning module that can be attached to an existing ring-spinning machine (see Figure 10). It consists of a tubular profile, subjected to negative pressure and closely embraced by a lattice apron. The delivery top roller, fitted with rubber cots, presses the lattice apron against the hollow profile and drives the apron, at the same time forming the delivery nipping line.

The tubular profile has a small slot in the direction of the fiber flow, which commences at the immediate vicinity of the front roller nipping line and ends in the region of the delivery nipping line. This creates an air current through the lattice apron via the slot towards the inside of the profile tube. The air current seizes the fibers after they leave the front roller nipping line and condenses the fiber strand, which is conveyed by the lattice apron over a curved path and transported to the delivery nipping line. As the slot, being under negative pressure, reaches right up to the delivery nipping line, the fiber assembly remains totally compacted. This results in a substantial disappearance of the spinning triangle.

The suction slot can be arranged at an angle to the direction of fiber flow, especially when processing short fibers. This ensures that the fiber ends, during their transport from the front roller to the delivery nipping line, are well bound into the strand. It also creates a cross-directional force during the fiber transport, which in turn causes the fiber assembly to rotate around its own axis so that the fiber ends are closely embedded into the fiber assembly.

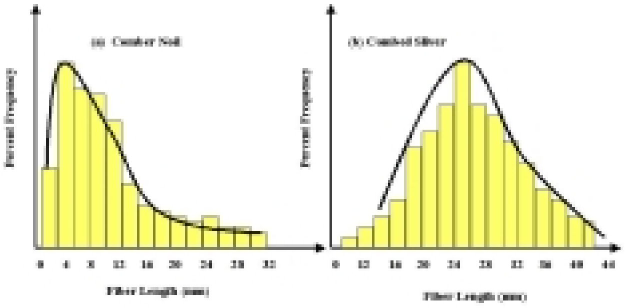

Figure 1. Typical fiber length distribution in the comber noil and the combed silver.

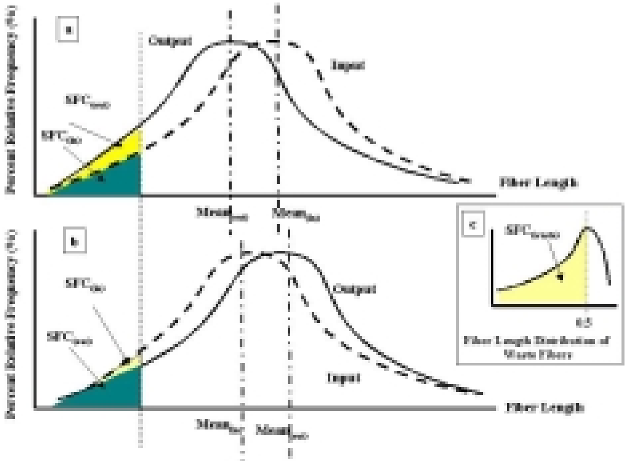

Figure 2. Possibilities of change in short fiber content upon cleaning.

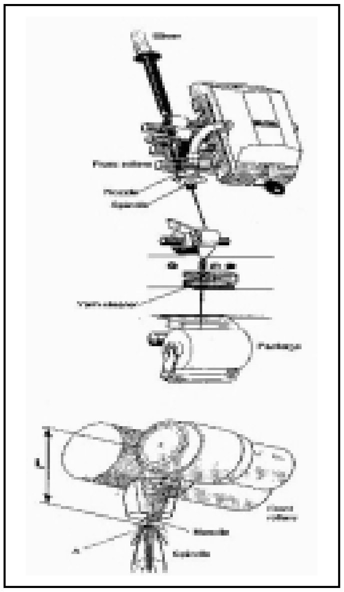

Figure 3. Murata vortex spinning(MVS®)

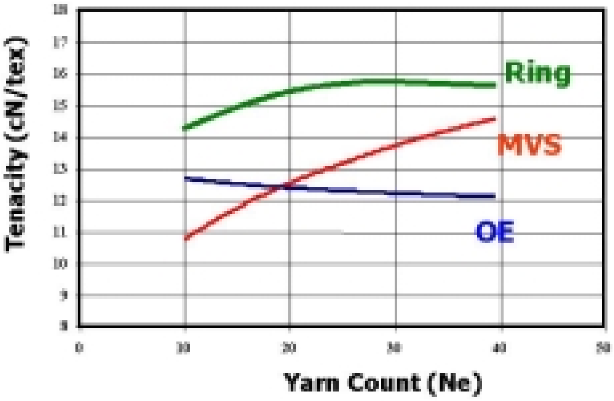

Figure 4. Comparison of Yarn Tenacity [ITMA-99-Paris].

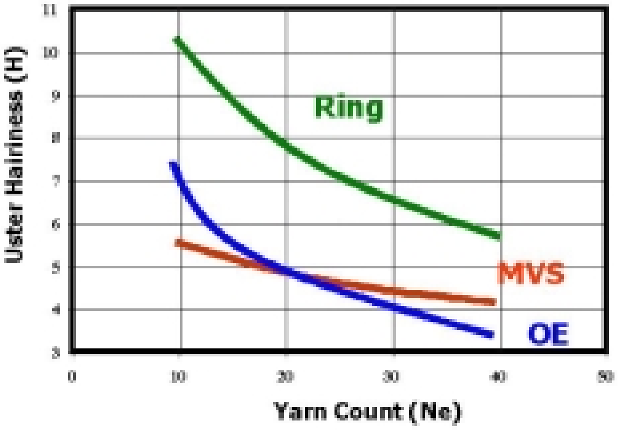

Figure 5. Comparison of Uster Hairiness [ITMA-99-Paris.

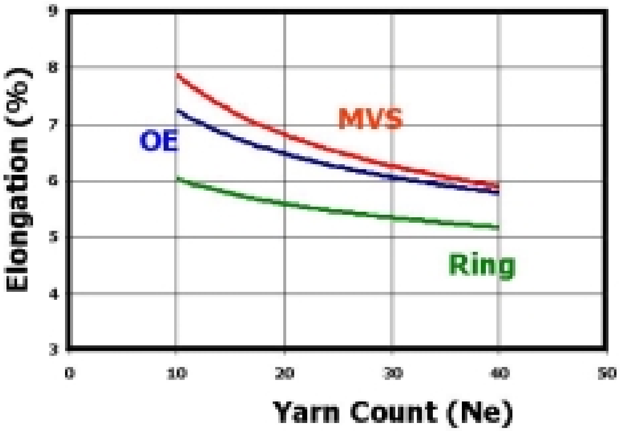

Figure 6. Comparison of Yarn Elongation [ITMA-99-Paris].

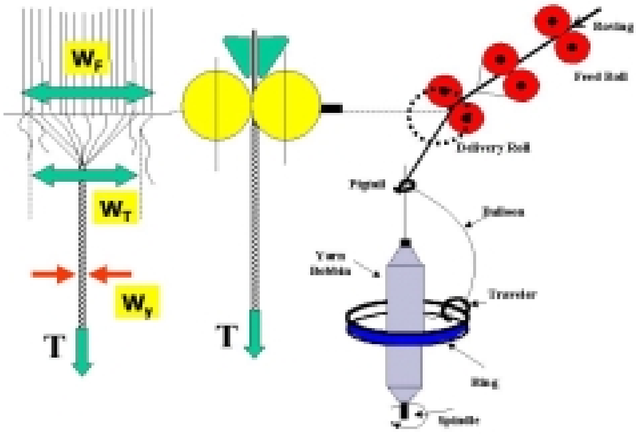

Figure 7. The concept of compact spinning.

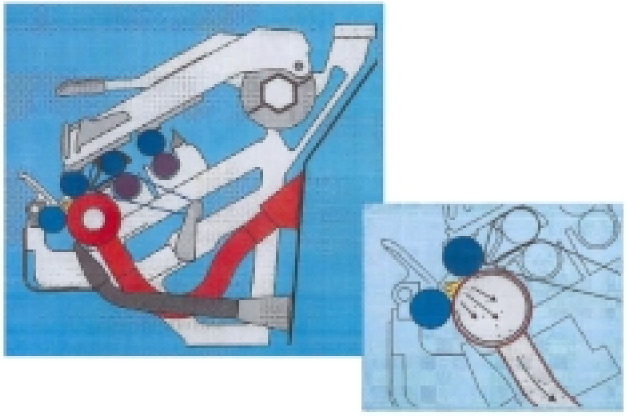

Figure 8. RIETER COMFORSPIN® MACHINE.

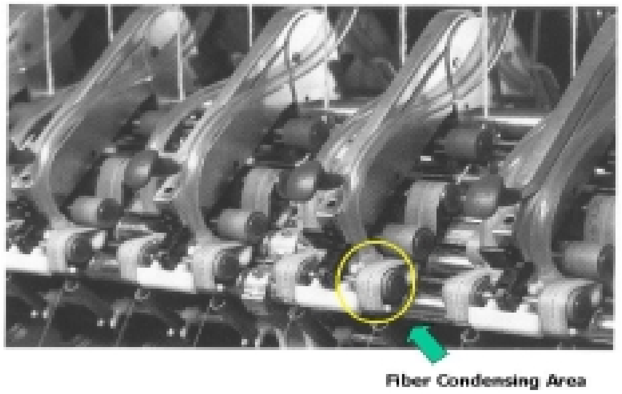

Figure 9. Zinser AIR-COM-TEK 700® condenser ringspinning.

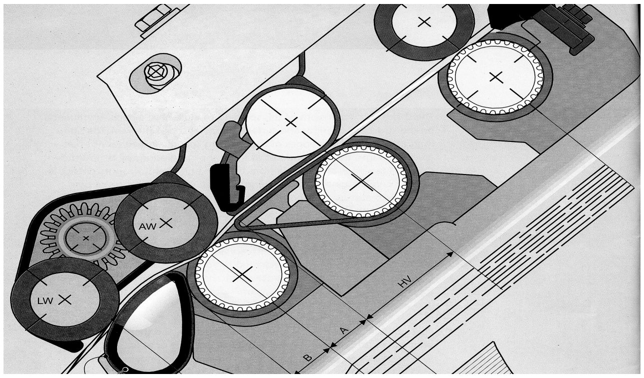

Figure 10. Suessen Elite® spinning system.