ADAPTING AND TUNING QUALITY MANAGEMENT IN SPINNING INDUSTRY

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Abstract

The Egyptian government has shown substantial consideration regarding the rehabilitation and restructuring of inefficient companies in the public sector with regard to converting them into profitable companies which will be ready for privatisation. Furthermore, textile manufacturing can be considered as one of the biggest industries in the public sector. So, the idea of showing how textile manufacturers in the public sector can be developed to meet the requirements of marketing and product strategies has been initiated.

This study has been prepared to assist in developing one public-sector textile manufacturer to meet the requirements of a quality management system, which in turn reflects on improving the mill performance. Applying the technical means of quality management in the spinning industry, preparing the spinning industry for quality agreements, requirement profiles for different yarn quality characteristics and types, spinning quality problems and solutions, and optimum yarn quality at optimum costs are the key areas which are covered in a unique manner.

Key words:

quality management, spinning industry, quality characteristics, reference values, requirement profile

Introduction

Quality is one of the key factors for the Egyptian textile industry's success. The image of Egyptian cotton is strongly linked to quality products worldwide. To take full advantage of this image, Egyptian textile manufacturers need to maintain a high standard of quality. Unfortunately, a great decrease in quality level has arisen, which in turns seriously affects the level of production in such a way that threatens the future of the workers in this industry.

El-Minia spinning mill may be considered as one of areas which is most at risk;it lacks management which is appropriate for a public-sector body. The key factors that are lacking in the management of the mill can be broadly categorised as follows:

- lack of quality systems and quality ethic;
- ineffective maintenance systems, and the lack of the wherewithal to carry out essential or preventive maintenance;
- lack of understanding of the customer's needs, and no determination to meet these needs.
- ineffective process and operational control;
- ineffective investment and replacement policy;
- lack of control of the workforce and workforce deployment.

This paper is aimed at assisting in developing one public-sector textile manufacturerto meet the requirements of the quality management system in the spinning industry.

Technical means for quality management in the spinning industry

To be able to make agreements, accurate values which characterise quality are required. Fifty years ago, there was no data available in the spinning mill for the objective assessment of the quality of a product. Today, such data are provided by laboratory testing instruments, for example, for assessing the quality of fibres, slivers, rovings and yarns [1,2,3,4,5,6,7].

Without the availability of such reliable values, it would be extremely difficult or even impossible to form the basis for a dialogue with the modern textile world. Therefore, great importance is attached to the accuracy and reproducibility of the quality-determining values.

The limits of accuracy have not yet been reached. As far as elongation, thick places and neps are concerned, the measurement system is considerably more accurate than the results would suggest. It is more a question of the textile-technological as well as statistical problems which will have to be solved within the next few years.

Also, with respect to raw material testing, great achievements have been made during the past few years. Table 1 shows the results of inter-laboratory tests taking into consideration the round tests undertaken by Zellweger Uster®, the Bremen Cotton Exchange and by the United States Department of Agriculture (USDA) [8].

Table 1. Yarn quality characteristics and inter-laboratory variations

Quality characteristics	Inter-laboratory variation CV
Count	< 1.0 %
Twist	< 2.5 %
Mass variations CV (evenness)	< 1.0 %
Hairiness H	< 3.5 %
Hairiness variation sh	< 3.0 %
Tensile force Fmax	< 3.5 %
Elongation E Fmax	< 7.5 %
Thin places*	< 10 %
Thick places*	< 10 %
Neps*	< 10 %

** for counting of over 30/1000 m yarn test lengths*

Table 2 shows the fibre quality characteristics. As limited experience of raw material testing is available, an improvement in these values can be expected within the next few years. As with yarn testing, the elongation value shows a relatively high variation in spite of the fact that in both cases the measuring system is extremely accurate. A thorough investigation of inter-laboratory variation has shown that the following causes may be responsible (Figure 1): The variation can be influenced by the variation between the textile samples. Often, this variation is responsible for a major part of the inter-laboratory variation. In addition, there are differences between instruments with regard to sensor calibration and accuracy. Furthermore, different environmental conditions such as room temperature and humidity can have an impact on this variation.

Table 2. Fibre quality characteristics and inter-laboratory variations

Fibre Testing / Inter-Laboratory Variation		
Quality characteristics	Inter-laboratory variation	Measuring system
Fibre fineness (Micronaire)	< 2.5 %	HVI
Fibre length (50% span length)	< 2.5 %	HVI
Fibre length (2.5% span length)	< 1.2 %	HVI
Coefficient of variation of the fibre length (uniformity ratio)	< 2.0 %	HVI
Fibre tensile force	< 4.5 %	HVI
Fibre elongation	< 9.5 %	HVI
Nep count in raw cotton	< 10 %	AFIS

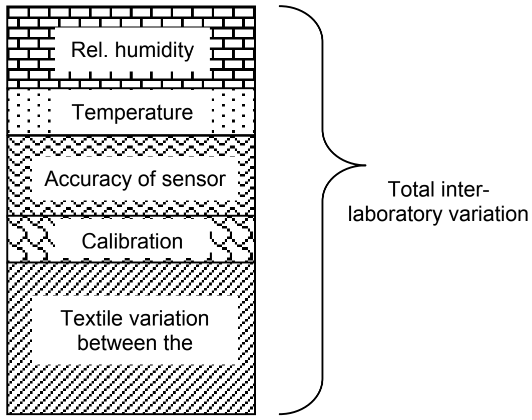

Figure 1. Factors influencing inter-laboratory variation

A quality management system requires reference values in order to assess quality levels for yarns and fibres. These will facilitate the devising of agreements via the interfaces of the textile chain.

Reference values within the framework of the Uster® Statistics [3,4] are available for the following quality characteristics, as indicated in Table 3.

The expert know-how which has been collected in the textile industry during the course of many years must also not be underestimated. On the one hand, it helps to ensure that the machines in the entire mill are kept in good condition; on the other, to provide a means of manufacturing good-quality yarn from a fibre which is as inexpensive as possible. Much has also been done by the testing instrument industry to facilitate the interpretation of quality data.

Table 3. Reference values for on-line and off-line control

Off-line values	**On-line values**
Count variation	<u>Ring Spinning Machine</u>
Mass variation (0.01m)	Actual efficiency value
Mass variation (0.01…. 100m)	Production per spindle hour
Mass variation between bobbins	Yarn breaks /1000 spindle hr.
Index of irregularity	Production loss due to yarn breaks
Thin places	Break-free yarn length
Thick places	Mean yarn break duration
Neps	Exception spindles
Hairiness	
Hairiness variation	*<u>Rotor Spinning Machine</u>*
Hairiness variation between bobbins	Production per rotor hour
Tensile force	Yarn break frequency
Tensile force variation	Break-free yarn length
Elongation	Mean yarn break duration
Work done to break	Yarn faults per 1000 km
Classimat values	
Nep content in cotton fibres	*<u>Cone Winding Machine</u>*
	Splice and knot frequency

Preparing the spinning mill for quality agreements

In the last two decades, spinning mills have begun to experience a quite distinct intensification of business pressures, particularly in the industrialised countries [8,9,10].

The international yarn trade tends to give preference to the producers of better and cheaper products, and there are many producers who can offer yarn of a satisfactory quality. The reaction time (quick response) is being given higher priority. The yarn quality has to be accurately adapted to the conditions of further processing and the end product. In order to be able to compete, one must continuously invest. Although there is a certain amount of unemployment, there is an absence of competent technologists with good knowledge of the complete textile process.

In order to satisfy the expectations of the customer, the quality of the raw material and of the yarn, in many cases, is considerably over-dimensioned, for safety reasons, and also on the basis of the motto “Quality is when the customer returns and not the goods”. Quality, however, can be achieved with an efficient quality management system.

However, a successful quality management system, pre-supposes a communication between the supplier, the producer and the end-user. For the spinning mill this means that a partnership with subsequent interfaces such as the weaving and knitting mill, as well as with the producer of the raw material or his local agent, has to be established in order to be able to produce a certain quality successfully and with acceptable manufacturing costs. The agreement between the weaver or knitter and the spinner based on yarn quality certificates can help to reduce the raw material costs and improve the quality of the yarn.

Changes in the spinning process

Within the spinning process, the limiting conditions have changed during the last few years:

- Personnel have less knowledge about the raw material than was earlier the case. Furthermore, particularly with cotton, the spinning value is often much worse than previously; alternatively, many important factors necessary for yarn manufacture are not taken into consideration during classification.
- New machines in the spinning mill run quicker, produce more, and stress the fibre much more than was previously the case.
- The spinning process is shorter, and the number of fault-reducing doublings is much less.
- The yarn processor requires a much longer fault-free length of yarn or a better quality of yarn.
- Competition has a negative effect on profit margins. As raw material prices reach approximately 50% to 70% of the overall yarn production costs, the spinning value of a raw material and variations in the raw material have to be regarded as much more important.
- The yarn buyer not only demands a yarn quality adapted to the requirements of further processing and the appearance of the end product, but he is also interested in close tolerances and a reduction in the number of so-called ‘rogues’. In other words, his aim is zero defects for a batch delivery according to specification.

Changes in the weaving process

In the last 20 years, there has been an increase in production of 2 to 3 times the area of woven cloth per weaving machine as a result of increases in weaving machine speed and fabric width.

The weaving speeds that were previously considered Utopian have become normal production conditions within only a few years. However, high production alone is no guarantee of economic conditions and product quality. Unproductive downtimes, such as stops due to end breaks, are of fundamental importance in terms of manufacturing costs, as “material structure and short stops at weaving determine the productivity at a weaving machine and not the maximum and theoretically possible machine speed”.

In order to keep up with the production development in weaving, it is necessary to be able to produce under better economic conditions. Here, more than ever, the law of any business undertaking is applicable: “Not taking a step forward is in fact the same as taking a step backward”. If the rate of weft insertion of a weaving machine is doubled, then the yarn will have to contain half the number of weak places than was previously the case, in order to achieve the same weaving efficiency. Various investigations carried out during the last few years [2,3,4,5,8,11] have been concerned particularly with the problem of weak places, i.e., those weak places that will later produce stops at weaving and knitting machines. However, in many cases, weak places only exhibit a certain percentage of the mean breaking force of a yarn.

Considered statistically, weak places in yarns are rare events. Nevertheless, they are gaining more and more importance in high-production spinning and weaving mills, for the following reasons:

- Acceptable mean yarn tensile force and elongation values cannot guarantee acceptable running conditions of high production machines.
- It is particularly the weak places that, as rare events, produce end breaks, which can negatively influence the running efficiency.
- Weak places are nevertheless only determined by chance with normal laboratory sampling, and cannot therefore be statistically determined with a degree of reliability.

When making a forecast of machine stops as a result of weak places, the following must be taken into consideration:

- Tensile tests in the laboratory are carried out under different conditions than those which are encountered during weaving and knitting.
- The measurement of maximum tensile loading of the yarn at weaving and knitting machines is extremely difficult.
- Yarns can break during subsequent processing as a result of package defects, poor winding conditions, clinging of two threads, poor warping and beaming conditions, unsuitable sizing, too much yarn hairiness, too many thick and thin places and neps, poor splices or knots, etc.

A large number of tensile tests have to be undertaken in order to be able to determine a statistically-representative distribution of the weak places. The comparison of two trials shows that with 1300 tests, only 2.23 % of all values were below 160 cN (overall mean value of max. breaking force = 208 cN). With 46,000 tests, on the other hand, 6.05% of all values referred to weak places below 160 cN.

Experience values for weft yarn stops

For every yarn processor, the number of stops is one of the most important factors for assessing the quality of a batch of yarn. An attempt was made by Zellweger Uster® [8] to provide experience values for stop frequencies and, based on these, requirement profiles for yarns, which was based on the experience obtained so far.

Analyses of the requirements of the weaving mill show that no more than one stop per 100,000 m of weft yarn should occur. As soon as two or more stops per 100,000 m of yarn are available in the high production weaving mill, costs will increase as a result of a reduction in efficiency.

If one takes as an example a ring-spun yarn with a yarn count of 20 tex (Ne 30) and a cop weight of 50 g, then at the most one weak place every 41 cops (which could result in a stopping of the machine) would be acceptable.

Requirement profile of cotton weft yarn

In contrast to earlier considerations, a weft yarn today must have a requirement profile as high as that of a warp yarn in order to satisfy the requirements of high-production weaving machines. According to the scientifically-based investigations carried out by various literatures [2,3,4,5,8], a weft yarn must exhibit at least the following quality characteristics as indicated in Table 4. It can be concluded from the above that the previously-used 'mean breaking length' for forecasting the running conditions in the weaving mill is no longer sufficient. What has become particularly important, for instance, is the yarn elongation as well as the variations in breaking force and elongation. The Classimat faults can also be considered as weak places, because a thick place fault usually contains less twist than the rest of the yarn, and can easily break when a tensile force is applied. It should be mentioned here that, with a higher variation (i.e., a higher coefficient of variation value of breaking force or elongation), this can only be compensated by a higher breaking force or elongation at break value in order to achieve equivalent running conditions. In terms of the spinning process, this means "Better raw materials, higher yarn twist, etc..., certainly result in increased yarn manufacturing costs".

Experience values for stops during beaming

The yarn is placed under stress not only during weaving but also during weaving preparation such as warping, beaming and sizing, which is particularly true in terms of yarn elongation.

Beaming machines operate today with drawing-off speeds of up to 1,200 m per minute.

Only with an end break frequency of less than 0.4 end breaks per 1,000,000 m are conditions considered as very good when beaming a combed ring-spun yarn, and conditions of less than 0.8 end breaks per 1,000,000 m are considered as very good when beaming a carded ring-spun yarn.

Table 4. Requirement profile of cotton weft yarn

Count variation CVt, cut length 100m	< 2.0 %
Breaking tenacity [Fmax/tex]	> 11 cN/tex
Breaking force variation [CVFmax]	< 10 %
Elongation at breaking force [EFmax]	> 5%*
Variation in elongation at breaking force [CVEFmaxl	< 10 %
Weak places**	< 1 per 100,000 m
Hairiness H	to be agreed upon between the partners based on the requirements of the weft insertion system and the end product [e.g. < 50% value of the Uster® Statistics]
Hairiness variation between packages H***CVb	< 7 %
Seldom-occurring thick and thin place faults (CLASSIMAT values)	< 50 % value of Uster® Statistics

* *1 % losses in elongation can be compensated by an increase in breaking tenacity of 2 cN/tex*
** *Definition of a weak place: < 60% of the mean breaking force*
*** *Variation between packages. Higher values can lead to stripiness with single-coloured materials.*

Experience values for warp stops

Today, less than 0.4 stops per 1,000 warp threads and 100,000 picks are considered acceptable.

Only when one considers that (in each case according to the style) 20,000 m of yarn can be available in the weaving zone for 5 to 10 minutes, does the severity of this requirement really become comprehensible.

Yarn hairiness, an important warp characteristic, has always been a factor which has influenced the appearance of the cloth, which was true even long before it could be measured. Varying yarn hairiness, e.g., from package to package, results in weft stripes in a woven fabric, or a cloudy appearance in a knitted fabric. Hairiness is also increasing in importance with respect to the running conditions at all processing stages subsequent to spinning.

A high amount of hairiness of the warp yarns can negatively influence the movement of the weft yarn through the shed with air-jet weaving machines, and the weft transfer with rapier weaving machines. The result is usually a stop as a result of a warp. Hairy yarns and structure faults in the yarn, such as neps, often produce threads which cling to each other, particularly with the much smaller shed openings in modern weaving machines. If one increases the warp tension in order to avoid these clinging fibres, more end breaks can result due to weak places. The result of this is that hairiness, as well as hairiness variation and particularly periodic hairiness variation, is of increasing importance with warp yarns, especially with respect to their application on high-production weaving machines.

Requirement profile of cotton warp yarn

In contrast to a weft yarn, the cyclic loading of a warp yarn is an important quality characteristic. This is the case with weak places which slip apart due to too little twist, as for instance with a slub-type yarn fault. Furthermore, with warp yarn, hairiness is becoming increasingly important, i.e., there should be little hairiness and it should be evenly distributed. The requirement profile of a cotton warp yarn is indicated in Table 5.

Table 5. Requirement profile of cotton warp yarn

Count variation CVt, cut length 100m	< 2.0 %
Breaking tenacity [Fmax/tex]	> 11 cN/tex
Breaking force variation [CVFmax]	< 10 %
Elongation at breaking force [EFmax]	> 5%
Variation in elongation at breaking force [CVEFmax]	< 10 %
Weak places*	< 1/100,000 m
Hairiness H	to be agreed upon between the partners based on the requirements of the weft insertion system and the end product [e.g. < 50% value of Uster® Statistics]
Hairiness variation between packages H** CVb	< 7 %
Thin places/ thick places/ neps	< 50 % value of Uster® Statistics
CLASSIMAT values	< 50 % value of Uster® Statistics

** Definition of a weak place:<60% of the mean breaking force*
*** Variation between packages. Higher values can lead to stripiness with single-coloured fabric.*

Requirement profile of cotton knitting yarn

A knitting yarn (100% cotton) for high-production circular weft knitting should exhibit the quality characteristics as indicated in Table 6.

In contrast to weaving yarns, the yarn strength of knitting yarns is secondary, as the loading placed on the yarn during knitting is lower than that with a high-production weaving machine. However, the yarn must exhibit enough elongation and elasticity. There must be no weak places or thick places that can result in stop holes in the knitted material, or even broken needles. Particularly important is the ability of the yarn to pass easily through the various guide elements of the machine (low friction value). The moisture content of the yarn should be evenly distributed. Yarns in a ??[[clematises]] condition provide better running properties and a better appearance of the finished fabric. In most cases, a constant and high hairiness value with a low twist is required in order to achieve a soft fabric handle. However, this hairiness value must remain constant and be without periodic variations, and also be of a level suitable for the type of end product.

Table 6. Requirement profile of cotton knitting yarn

Count variation CVt, cut length 100m**	< 1.8 %
Count variation CVt, cut length 10m**	< 2.5 %
Breaking tenacity* [Fmax/tex]	> 10 cN/tex
Elongation at breaking force [EFmax]	> 5%
Yarn twist (α_m value)	Ring-spun yarn 94-110 (3.1-3.6 α_m value) / Rotor-spun yarn up to 25 % higher than ring-spun yarn
Paraffin waxing/surface friction value	0.15µ
Yarn irregularity**	< 25 % value of Uster® Statistics
Hairiness H***	[e.g. > 50% value of the Uster® Statistics]
Hairiness variation between bobbin H**** CVb	< 7 %
Seldom-occurring thin and thick place faults (CLASSIMAT values)	< A3/ B3/ C2/ D2 or D1 or more sensitive (Cleaning limit)
Remaining yarn faults (CLASSIMAT values)	A3 + B3 + C2 + D2 =< 5 / 100,000 m

** A low breaking force value must be compensated by a higher elongation at breaking force value*
*** Highest requirements with single jersey*
**** Higher, but constant hairiness as a result of the cloth appearance and handle. The minimum hairiness value must be set based on agreements between the partners*
***** Variation between packages. Higher values can lead to 'rings' with single-coloured fabrics*

Particularly important with single jersey materials are the yarn evenness and count variation. The short, medium- and long-term count variations lead to cloudy or stripy fabrics as soon as a certain mass variation level is overstepped. In addition, neps & vegetable matterand high dust content refer to the types of foreign matter that are particularly disturbing. These lead to wear of the needles, holes in the knitted material and, in many cases, to dyeing problems.

Yarn quality conditions

So far, the requirement profiles of yarns have been based on the laboratory testing of samples. However, the situation is often quite different, especially when the quality of a yarn has to be checked over days, weeks and even months. Three typical mill cases were analysed as follows:

Case 1: economic yarn quality

The yarn test values (yarn breaking force) were plotted as a function of time based on samples taken daily in the mill (Figure 2). As one can see, the yarn breaking force values are well above the maximum tension applied during weaving. The mean yarn quality is therefore well within the requirements of weaving.

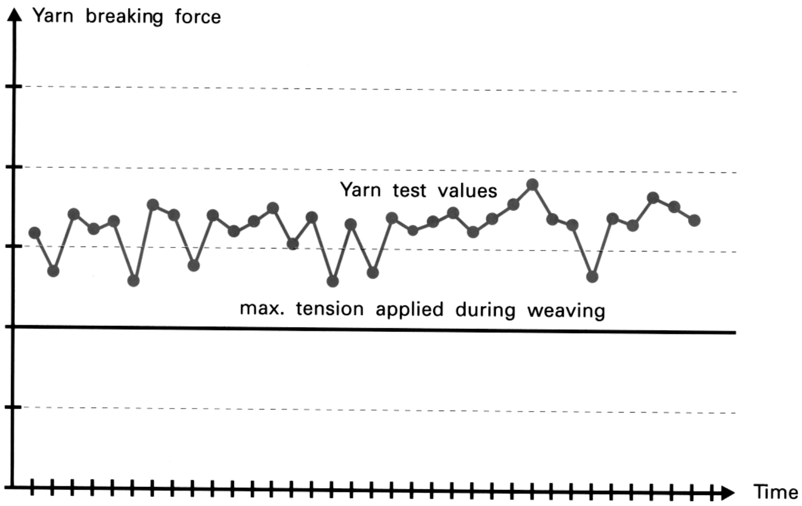

Figure 2. Economic yarn quality case

Now and again, however, the minimum values of yarn breaking force tend to approach peak load yarn tension values at the weaving machines. So, if the yarn quality satisfies the end product, then this poses a very economic solution for the yarn manufacturer. However, the fact that certain yarn breaking force values tend to approach maximum peak tension values in the weaving mill presents a certain risk of a loss in efficiency. By means of a small change in the raw material quality and/or achievement of optimum spinning conditions, the level of the number of weak places can improve (be lowered) with the advantage of reducing the loss-in-efficiency risk at the weaving machine.

Case 2: 'over-dimensioned' (safe) yarn quality

In the second case, both the level and the variation in the yarn breaking force values are excellent, compared to the maximum tensile loading of the yarn during weaving (Fig. 3). As long as the end product necessitates such quality, a free-of-risk (safe) processing in the weaving mill with a high efficiency value will be available. In this particular case, however, the cost of the yarn to the weaver was much too high and, as a result, no longer economic. The weaver changed to another yarn manufacturer who could offer a cheaper yarn of suitable quality.

As a conclusion, because there was no agreement between the spinner and the weaver, the yarn was very much, 'over-dimensioned' and, in spite of the excellent quality achieved by the spinning mill, the yarn was uneconomic for the weaver. By using a cheaper raw material, a cheaper yarn could have been produced which would have amply satisfied the requirements of the weaver.

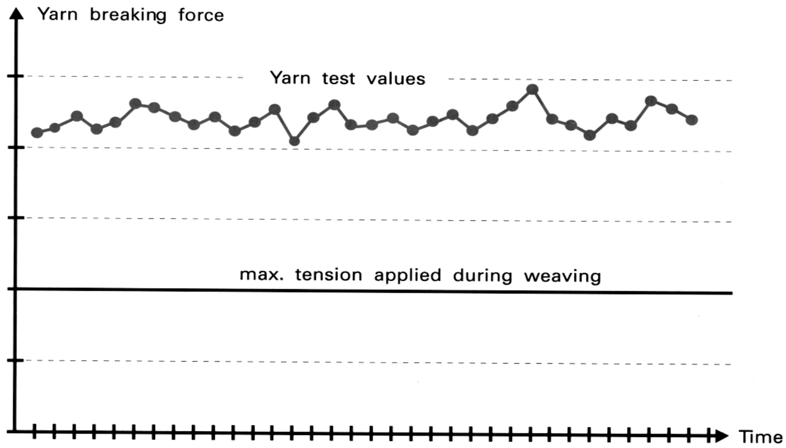

Figure 3. Safe yarn quality case

Case 3: unacceptable, low quality yarn

The third case is frequently the reason for complaints, dissatisfaction and even a discontinuation of business relationships. Based on a sample provided prior to delivery, the weaver was very satisfied with the quality of a certain yarn, so that a large contract was signed. As one can see from the graphical representation (Figure 4), the average yarn quality is well above the maximum peak tension recorded in the weaving mill.

Nevertheless, with certain deliveries of the same yarn, the weaver experienced losses in efficiency as a result of 'rogue' weak places, which also resulted in weaving faults and downgraded material. An analysis of the situation showed that the spinning mill was not under control and that there was no quality management system in place.

Non-homogeneous raw material mixes, lacking thequality consciousness of the mill personnel (cleaning, maintenance of the machines care during material transport, etc.,), poor card clothing (to a certain extent) and an unsatisfactory condition of the spinning elements can be reasons for those short-term periods during which poor-quality material is produced.

By means of applying supervisory systems, it can be determined whether each machine or the complete spinning process produces constant quality, or whether there are exceptions or 'rogue' production positions. Also, an assessment of the suitability of the raw material, and the control of variations within this raw material, must be a task of quality management. Good quality also means consideration of the ambient conditions. Quality cannot be tested into a yarn, but must be planned and produced. For this purpose, a quality philosophy is necessary at all stages and with respect to all aspects of yarn production.

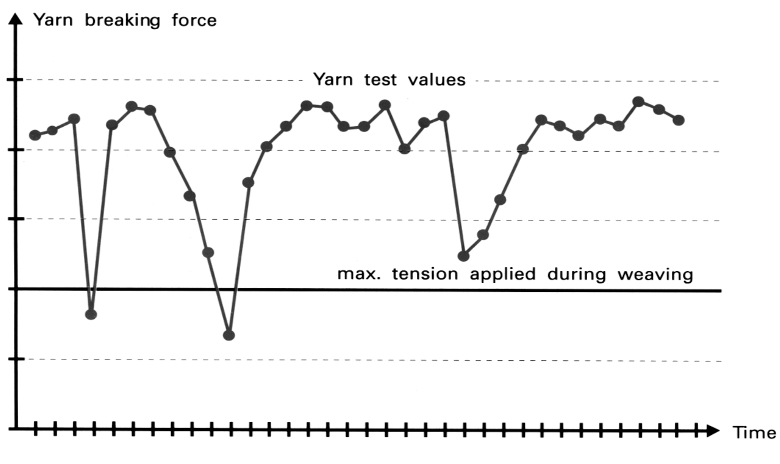

Figure 4. Low yarn quality case

Reasons for quality problems

If one summarises the results of the practical cases as referred to above, the problems in general would seem to be caused by the following factors:

Unsuitable quality level

Correction by means of better raw materials, re-arrangement of the sequence of processes, better machines and optimum machine operating conditions from the bale material to the spun yarn.

Large quality variation

Correction by means of checking the raw materials (particularly with respect to variations in the fibre characteristic values), introduction of measures to keep the processes constant by means of on-line supervision & off-line testing in the laboratory, and improvement of all ambient conditions.

Unexplained quality exception ('rogues')

Correction by means of on-line control and an improvement of all ambient conditions, i.e., the introduction of a quality management system at all levels of management in the spinning mill.

Measures to produce better yarns

Better yarn properties do not necessarily result in increasing costs, but in the long-term they usually provide a reduction in costs.

The following possibilities are introduced by some investigators [2,3,4,5,6,8,11,12, 13,14,15,16,17,18,19,20]:

- Detection of raw material variation and its reduction (a basic and fundamental requirement).
- Reduction in the coefficient of variation values of the yarn quality characteristics (and this primarily).
- Elimination of rare yarn faults (weak places), which is becoming more and more important.
- Increase of the yarn breaking force and elongation at break.
- Application of high-quality preparation machines and spinning units (or improvement of those available).
- Supervision and control at all the spinning processes (also a basic requirement).
- Obtaining optimum conditions with all machines.
- Use of automation (according to existing mill conditions).
- Elimination of any negative ambient influences.

Optimum quality and cost conditions

The measures undertaken on the basis of a quality management system serve not only as a means of obtaining optimum quality conditions, but also of ensuring optimum cost conditions, and thereby the ability of a textile operation to continue functioning. For the spinning mill, at least three of the following areas of application of a quality management system should be taken into consideration:

Bale management

Due to the absence of suitable and quickly-operating fibre testing methods, too little has been known in the past about raw material characteristics, their variations and their influence on the various parameters of the spinning process and yarn quality. As a result, and for safety reasons, a higher quality raw material than necessary was often used in order to guard against complaints. Although these preventive measures seemed to be the best compromise, they cost money. Such high costs can only be avoided if agreements with the raw material supplier (or even with the mill's own purchasing department) can be reached.

In order to improve this situation, a sorting of the bales was undertaken. The new generation of fibre testing instruments such as the HVI, AFIS, QUICKSPIN, etc., make a much more comprehensive and quicker means of testing the raw material possible than has previously been the case [3,4,11,12,13]. Bale management covers:

- measuring of the more important fibre properties per bale or per series of bales;
- separation of these bales into classes;
- arranging those bales in a store which hassimilar fibre properties and a defined variation of the more important fibre characteristics.

This results in a process-oriented bale mix and, accordingly, practically constant running conditions. It also results in yarn quality with little inter- and -intrabobbin variation.

Yarn engineeing

Many research works have been focused on yarn engineering [11,12,17,18,21, 22,23,24,25,26,27]. According to the literature, yarn engineering refers to the following:

- obtaining optimum conditions in terms of product quality, with respect to the yarn and the end product;
- optimum selection of the raw material for the required quality;
- increase of the added value by means of a better use of the raw material;
- pre-determination of the yarn properties based on raw material and process data, i.e., the quality data of the yarn and the end product are no longer to be considered as chance conditions;
- ensuring the quality level throughout the complete process;
- keeping constant quality in order to ensure long-term marketing conditions;
- reduction of manufacturing costs by increasing efficiency.

It is not difficult to imagine that, for the tasks referred to above, experienced specialists with an excellent fundamental knowledge of textile spinning would be necessary in order to implement the interfaces already referred to. These specialists must not only be good technologists, but must have knowledge of cost accounting in order to be able to solve problems in their correct sequence and in terms of their cost effectiveness.

Process management

With process management, not only is each individual machine in the spinning mill to be run under optimum conditions, but also each separate processing stage is to be exactly tuned to the other processing stages in order that a reasonable and process-oriented compromise can be arranged with respect to quality and costs [11,21,22,23,24,25,26,27]. For this purpose, the following is necessary:

- testing of the fibre properties before and after each important processing stage;
- correct settings, in order to achieve optimum conditions at all machines, taking into consideration the yarn as the end product;
- determination of the most suitable machine equipment;
- arranging optimum conditions for machine maintenance, so that there is no reduction in quality as a result of long-term running of the machine;
- introduction of early warning systems.

Only after process management has been introduced can the advantages of an engineered raw material mix be assessed and improved.

With varying raw material properties, it is extremely difficult to institute process management; in general, process management does not result in the required success. In the spinning mill, it is never advisable to obtain maximum conditions based on one single quality characteristic alone. Success always lies in a balanced compromise. What is the use, for instance, of a nep-free yarn whose fibres during carding are so stressed that yarn tensile force and elongation are reduced as a result of the increase in short-fibre content? For this reason one should always assess the complete process, and not try to obtain maximum conditions on a single machine. Zellweger Uster® have made some trials [8] to manufacture a yarn which is as free of neps as possible, and this without damaging the fibre. Figure 5 indicates the process analysis in a spinning mill.

However, because neps may consist of fibres or seed coat fragments, it is important that the vegetable matter content, the fibre neps and the short fibre content should be reduced, so that all of them are maintained in a balanced relationship. With the help of a single fibre-testing instrument, the USTER® AFIS, which has the testing modules for measuring neps, fibre length and trash particles, the raw material, the card feed material, the card and comber slivers as well as the roving were tested. By means of a measurement of these three parameters while attempting to obtain optimum conditions (in each case at the input and output of the processes referred to above), the spinning mill was able to attain a satisfactory compromise. As a result of an intensive opening and cleaning based on the available trash content, the fibre neps increased during opening and cleaning. This was because, with the type of vegetable matter present and the size of, for instance, the pulverised trash (pepper trash) and seed coat fragments, etc., any cleaning without an increase in the number of neps was found to be impossible. However, the short fibre content trace shows that the fibres were hardly damaged at all; with subsequent carding and combing, the number of neps that were produced could be practically reduced to well below the original value. Certainly, any remaining trash particles, and particularly most of the short fibres, would then be extracted at combing.

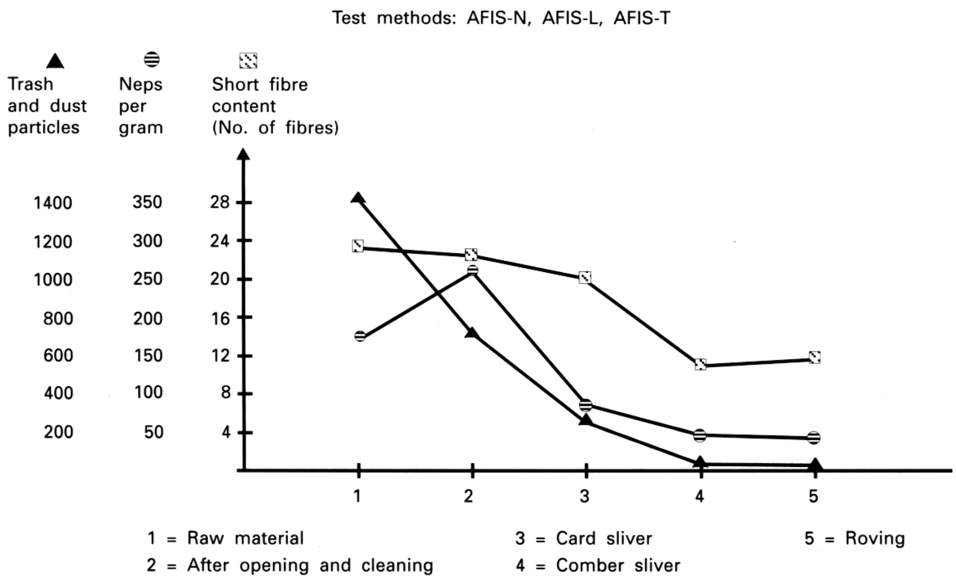

Figure 5. Process analysis in a spinning mill

Optimum cost conditions

A reasonable bale management and yarn engineering system, taking into consideration the interfaces between the raw material and subsequent processing, as well as a process management system, must be arranged with the purpose of reducing yarn-manufacturing costs. A reasonably priced manufacturing process for a yarn quality which is no more or no less than that required by the yarn processor is achieved by taking the following steps: using a reasonably-priced raw material with a good spinning value, maximum use of all the available manufacturing means, higher production, and fewer process disturbances, i.e., higher efficiencies, not only in the spinning mill but also, and above all, during subsequent processing.

Conclusion

Adopting a quality management system in spinning mills requires quality characteristics and reference values. The quality characteristics belong to the input and the output of this industry, which are textile fibre and yarn respectively, whereas reference values belong to the processing itself, whether it is on-line or off-line.

This work discusses both quality characteristics and reference values used in the spinning industry in order to assess quality levels for yarns and fibres.

Adaptive spinning quality system has shown inter-laboratory variations in both fibre and yarn quality characteristics. These variations could be influenced by variation between samples, measuring sensor calibration and accuracy, and the measuring environmental conditions.

The achievement of optimum conditions by determining the various fibres’ characteristic data in the raw cotton, and in the more important processing positions in the spinning mill, finally results in the best compromise.

From this study, it is quite obvious that the testing instrument manufacturer will be required to develop instruments that can test enough samples within a reasonable period of time.

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