Quickspin - a new method for evaluating cotton quality

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ABSTRACT

The raw material in the spinning mill represents the main component of the cost of the yarn production. For this reason, the raw material is an essential aspect in the economical operation of spinning mills and yarn quality, respectively. The QUICKSPIN process provides additional information on tendencies and influences regarding differences in raw material. A prognosis method includes raw material properties, such as cleanability, opening and processing behavior, fiber cohesion or stickiness - properties which can’t be determined by HVI or AFIS-measurements. QUICKSPIN can be characterized as a new tool for yarn engineering. The new QUICKSPIN process, a short-spinning process, meets the following requirements: Simulation of fiber opening (similar to carding) for the evaluation of cleaning and opening behavior, within a very short time and by means of only a small quantity of raw material with subsequent yarn formation at real twist and high spinning limits (fine yarn count). QUICKSPIN, moreover, allows the testing of raw material blends in respect of their specific spinning behavior, providing also results for the respective trash and dust content and stickiness, respectively. QUICKSPIN can be divided into two process stages, two modules that are completely independent from each other. Module 1 is represented by the MDTA3 testing device, where the fibers are opened, cleaned and formed into a sliver. At the same time the fibers can be tested - due to centrifugal force - for stickiness. The rotor spinning system with integrated industrial rotor box forms module 2.

Introduction

Raw material cost represents the major percentage of the total cost of yarn preparation in the spinning mill. Depending on spinning method and yarn count, more than 50% of the cost of yarn production can result from raw material cost. Raw material therefore is a crucial aspect as regards the profitability of the spinning mill and yarn quality, respectively.

When cotton was exclusively hand-picked there were clear criteria for cotton classing. The non-lint content consisted of leaf, bark and seeds. Based on the amount of these non-lint particles the cotton classer assigned a cotton grade.

Starting in 1960, cotton production was drastically expanded due to the fast growing population. But only a limited gain in production area was possible.

For this reason cotton production was raised by the following measures:
- Improvement of the yield by:
  - Irrigation and fertilization
  - Breeding of new cotton varieties with higher yields
  - Use of more efficient pesticides, fungicides and herbicides
- Production increases by:
  - Mechanical harvesting
  - Increase of ginning throughput
  - Intensive separation of fibers from seed for improved fiber yield

The resulting problems are quite evident today in the spinning mills. In ginning, many seeds are smashed producing seed coat fragments. Moreover, the aggressive ginning process stresses the fibers much more, and fragments the vegetative non-lint content into dust and particles of different, often very small sizes.

The most important consideration in selecting a raw material supply is to be able to produce the required yarn quality at lowest cost. A wide range of cottons from different origins and different fiber properties is available worldwide – cottons the prices of which are often subject to sudden change. The spinning mill must be able to respond to these extremely rapidly changing raw material situations. This means that in such cases raw material know-how gained from past experiences is not applicable. On the other hand, changes in the growing methods, crops and ginning processes within a given cotton growing area can result in permanent changes in fiber cost and properties. Nevertheless, every spinning mill needs a high degree of security in selecting the appropriate raw material. In many cases, only small samples are available for the selection of the suitable cotton to be purchased. In general there is evidence of a tendency towards defining the raw material by objective measurement methods in order to be independent from subjective classification methods.

However, at present, both techniques are still used for the necessary information. High Volume Instruments (HVI) and AFIS testing equipment have been established worldwide for the quick evaluation of cotton properties. AFIS and HVI equipment for testing raw material, classification and evaluation appear to be absolutely necessary, ensuring a guaranteed raw material purchase and the reduction of raw material variations. From this follows that it is still necessary for the spinning mill to have a good understanding of the raw material to optimize its use according to spinning method, yarn count and yarn application.

However, in addition to this, the spinner needs a method that allows him to forecast yarn properties and processability by means of small fiber samples. This process of calculated yarn construction can be described as ‘yarn engineering’. This means that for a given ap-
plication the suitable combination of raw materials has to be selected. It is in this situation that ‘yarn engineering’ becomes essential, raw material know-how being of greatest importance.

QUICKSPIN provides unique and valuable information regarding tendencies and influences resulting from different raw materials. Moreover, it also provides the information concerning processing behavior cleanliness and stickiness of the fiber material. The QUICKSPIN process also offers a method of forecasting yarn properties – a method which does not rely on mathematical models or regressions, but a method which deals with real yarn properties.

Therefore, the intention was to find a method that provides the spinning mill expert with a reliable and quick prognosis of anticipated yarn quality, based on the use of a small sample of raw material. A prognosis method should also include fiber properties that cannot be determined by HVI measurements. Such properties are:

- Cleanability
- Opening behavior
- Fiber cohesion
- Processing behavior
- Stickiness and so on.

It should be clear, that the closer the measuring criteria approach the actual yarn, the more reliable the prognosis becomes. Thus was born the idea to predict real spun yarn properties from model yarn properties. The use of shortened spinning methods is old and they have been applied for some time. These methods, however, are time-consuming and costly, for example the conventional Platt short spinning method that comprises mini-card, mini-drawing frame and ring spin tester.

A new short spinning method and the QUICKSPIN method, respectively should meet the following requirements:

- Small fiber sample
- Short testing time
- Simulation of fiber opening, similar to carding – for cleaning and opening behavior evaluation
- Yarn formation with real twist
- Relatively high spinning limits for fine yarn count
- Possibility to also test raw material blends
- Data collection regarding spinning behavior, trash and dust content.

**Experimental procedure**

The method developed for producing a model yarn is known as ‘QUICKSPIN’. It comprises two process stages, that is, two modules, which are completely independent of each other.

**QUICKSPIN - Module 1 - MDTA 3**

A fiber sample is put on a conveyor and transported with unidirectional feed (gentle fiber opening) to the opening roller. This opening roller is equipped with a saw tooth wire to comb out the fiber beard. Dust particles and fiber fragments are separated from the fibers and sucked into the dust channel by vacuum (Figure 2). By means of two filters with different pore sizes the particles are separated into dust and fiber fragments and gravimetrically measured. Heavier trash particles are separated from the fibers by means of a separation knife placed under the opening roller. So these particles are ejected by centrifugal force into the trash drawer. The remaining fibers are sucked into the rotating rotor. The rotor has a diameter of 300 mm, producing a sliver length of approx. 1m. By means of a high doubling rate, an excellent fiber blend is achieved. Figure 3 shows the MDTA 3 testing equipment - with rotor ring. To categorize the trash and dust results the ITV Institute of Textile Technology and Process Engineering Dekendorf recommends the following categories (Figure 4). For fiber fragments, there exists no categorization. A high fiber fragment content is an indication of fiber damage during processing, often after re-wiring of cleaning elements; it can also be an indication of a sensitive fiber. In both cases there exists the possibility of problems in downstream processing, such as increased dust and fly.

**QUICKSPIN - Module 2 – Spinning unit**

The rotor-spinning unit is identical to that used in modern rotor spinning machines. Several spinning elements can easily be removed for the purpose of simulating the production of different yarn structures and applications. The delivery speeds, feeding and winding tension are continuously adjustable. Furthermore, the rotor speed and opening roller speed can be varied independently (Figure 5). The sliver produced on the MDTA 3 testing unit is fed into the rotor while pressing the sliver feed button. The start-up begins immediately after rotor cleaning and the preparation of the yarn package for piecing. The spinning elements are accelerated to full speed within approximately 8 seconds. Depending on the draft, the spinning procedure of the QUICKSPIN yarn itself takes 2 to 4 minutes. When testing different cotton types, the spinning mill expert will realize that cleaning is not completed after the first passage of the MDTA 3. In the sliver there still remains - depending on cotton origin - a varying amount of contamination. This is similar to what happens with raw material in the blow room. This effect is used to determine the cleanability of cotton. The sliver will be cleaned further by means of a second and third passage. The resulting sliver is somewhat like a card sliver with respect to cleanliness.
Results

Raw material and quality management - calculations related to cleaning behavior

Figure 6 shows the cleaning characteristics of cotton from three different origins, which exhibit different cleaning behavior. One can see the different cleaning behavior of these cottons. For a cotton with a high cleanability, almost 90% of the trash is removed during the first passage, whereas only 60% is removed with material in the love of a cotton with low cleanability. Furthermore, it can be seen that there is almost complete cleaning after the third passage. All this corresponds to normal practice in the blow room. Usually there are two cleaning machines in addition to the card, resulting in three stages of cotton cleaning. The QUICKSPIN equipment was designed in such a way that cleaning of almost 100% is not achieved after the first passage. Since, it wouldn’t have been possible to determine the degree of cleanability of a given cotton in such a dose.

Cleaning degree of raw material

By means of the trash values obtained, the cleanability of the raw material can be quantified. It has been defined in the following equation and can be quickly calculated by the mill expert using the two trash values.

\[
\text{Cleanability (CL)} = \frac{T_1}{T_{\text{Total}}} \times 100\%
\]

where \(T_1\) = trash after first passage, \(T_2\) = trash after second passage, etc. and

\[
\text{Total trash content (TT)} = T_1 + T_2 + T_3
\]

This means that if a relatively large amount of trash - compared to the total trash content - is separated during the first passage on the MDTA 3, there is good cleanability of the fibers (Figure 7).

Figure 8 shows the measurements of total trash content as well cleanability for 34 different cotton types. If one ranks these fibers according to trash content and according to cleanability one sees that there is no correlation between total trash content and cleanability. Thus, it is evident that cleanability is a completely separate fiber property, which is of major importance in the processing of fibers. Very often those cotton bales, which seem to be relatively clean, cause the greatest problems. With these fibers, the trash consists mostly of ‘seed-coat fragments’. These cannot be separated at all or only with difficulty. If a high trash content in cotton consists primarily of leaf particles, it can be easily cleaned. According to experience, raw materials can be classified by testing with the MDTA 3 as follows (Figure 9).

By means of this classification, a coarse ranking of raw materials with respect to cleanability is given. Both values are of extreme importance to the spinning mill.

Cleaning efficiency of machinery

The cleaning efficiency of opening/cleaning equipment, of cards or of an entire cleaning line, doesn’t only depend on the raw material processed, but also on the type of machinery, maintenance condition of the equipment and processing parameters, such as a machinery setting and roller speeds.

In addition to the trash separation, the loss of usable fibers can be calculated as follows:

\[
RG_M = \frac{T_{\text{input}} - T_{\text{output}}}{T_{\text{input}}} \times 100\%
\]

where \(RG_M\) = Cleaning efficiency of a machine, \(T_{\text{input}}\) = Trash content of material input measured after 1 processing stage on MDTA 3 and \(T_{\text{output}}\) = Trash content of material output measured after one processing stage on MDTA 3. Theoretically the cleaning efficiency can take any value between 0 and 100%. For statistically significant results several tests are necessary.

The QUICKSPIN system is very helpful in the area of raw material and quality management concerning quality planning and process optimization.

Quality planning

- Prediction of yarn quality characteristics of ring and rotor yarns regarding;
  - Appearance (black/white yarn boards)
  - Strength and elongation
  - Hairiness
- Determination of cleaning efficiency and cleaning effort for a raw material as well as of the gravimetric content of trash, dust and fiber fragments, including visual assessment of these disturbing particles.
- Simulation and optimization of blends of different cotton types with regard to price and yarn properties.
- Simulation and optimization of added re-processed waste with regard to price and yarn properties.
- Process optimization
- Simulation of an opening/cleaning line by establishing a cleaning profile and by assessment of cleanability behavior
- Optimization of opening and cleaning equipment based on trash and dust content of processed cotton
- Observation of the formation of processing nepes by several steps on the MDTA 3 with subsequent testing of the sliver on the USTER® AFIS
- Direct spinning of production card slivers to monitor quality of carding process.
**Definition of trash and dust**

ITMF (International Textile Manufacturers Federation) has worked out a definition for trash, dust and micro dust based on particle size. The MDTA 3, test unit is in accordance with this definition. On the MDTA 3 the category ‘dust’ which ranges between 15 and 500 µm is split further into dust (up to 250 µm) and fiber fragments (250 µm to 500 µm, Figure 10).

For yarn processing on circular knitting machines, knowledge about dust and fiber fragment content becomes important with regard to defects in the knitted product. During yarn production on the rotor spinning machine, the fine dust often increases wear on machinery elements in contact with the yarn. Also on ring spinning frames, a high dust content often leads to processing problems due to increased dust and fly deposits on the machine and even wear of the ring traveler.

It has to be pointed out that dust and fiber fragments are independent quality characteristics. There is no correlation between the results for trash, dust and fiber fragment measurements. There are cotton bales with high trash and low dust content or vice versa. Figure 11 shows a typical result of the three components of contamination determined by means of the MDTA 3 test.

**Prediction of yarn properties**

In order to confirm the ability of the QUICKSPIN process to predict yarn properties, a sliver from the first module, MDTA 3, was spun on the QUICKSPIN tester, module 2, under QUICKSPIN conditions. QUICKSPIN conditions mean that the yarn is spun at a fixed machine setting - for purposes of comparison. For comparison purposes, six types of cotton were spun conventionally using ring and rotor spinning methods. The trash content of all yarns was measured opto-electronically. Figure 12 shows the number of trash particles in the QUICKSPIN yarn relative to the conventional ring spun and open-end spun yarn. Thus, it has been shown that the knowledge of the trash content of QUICKSPIN yarns makes it possible to draw highly reliable conclusions regarding the trash content of real spun yarn. The correlation coefficient between the trash content of QUICKSPIN yarn and rotor-/ or ring-spun yarn is about 95%. This, in fact, is an excellent correlation. The second criterion of yarn engineering applies to an optimal and quick selection of raw material with regard to yarn strength. A prognosis of yarn strength based on HVI or AFIS-values is very difficult. Yarn strength is a function of many fiber properties including:

- Fiber length
- Fiber strength
- Fiber fineness
- Fiber surface etc.

The production of yarns from fibers according to the three methods QUICKSPIN, rotor spinning and ring spinning answers the question whether it is possible to forecast the strength of industrially spun yarns based on the average strength of QUICKSPIN yarns. Figure 13 demonstrates that the strength of QUICKSPIN yarns highly correlates with that of rotor spun yarns and ranks the ring spun yarns in the proper order. The main purpose of the QUICKSPIN method is ‘raw material evaluation’ and this could be clearly shown. The results from 17 different raw materials indicate that the correlation of the yarn strength of QUICKSPIN yarn with ring spun yarn and rotor spun yarn is more than 95% in each case. Thus, it is demonstrated that it is possible to forecast yarn strength on the basis of QUICKSPIN yarn.

**Determination of stickiness of cotton**

With current test methods, the stickiness behavior of fibers is determined under conditions, which normally have nothing to do with conditions of processing. The sugar content of cotton is determined by chemical methods (Orcin-/Benedict-/Clini-test). All these tests show a different reaction depending on the type of sugar. However, the mini-card test - which simulates the opening process of the blowing room - seems to be practical. Here, the fibers - because of their sugar content and oily capsule particles - stick to the roller. The total number of sticky places is determined with this test. Today, however, there exists only a few mini-cards, as they haven’t been manufactured for a long time. With the traditional thermo-detection method (SCT) or the high-speed stickiness detector (H2SD) the fiber is heated to more than 80 °C between heated plates heated. This test method also doesn’t correspond to the real stress which fibers experience during the spinning process because the temperatures and times, respectively, are unrealistic. While conducting trials with the MDTA 3 unit it was observed from time to time that it was difficult to remove the fiber ring from the rotor. Fibers and trash particles sticking to the rotor wall were the reason for this problem. Some closer follow-up investigations – conducted with a foil placed in the rotor – revealed that the sticky places on the foil were identical to small honeydew drops. Afterwards, the foils with the sticky places were investigated photographically. Before the photos were taken the sticky places were exposed to heat treatment. Thermal treatment leads to the so-called caramelization of honeydew (Figure 14). Oily trash particles, too, can lead to bonding surfaces (Figure 15). The MDTA 3 unit opens and cleans raw cotton in a fashion similar to the processes in the blow room and the card. After having been opened, the fibers come into contact with the rotor wall, the contact pressure of the fiber against the wall. From this it follows that the sticky substance is subject to high contact pressure against the rotor wall caused by the high centrifugal force. The sticky effect therefore develops quickly. Figure 16 shows fibers sticking to the rotor wall. For the purpose of better evaluation the rotor has been anodized (darkened) so that the rotor ring (sliver) can be removed while all adhering fibers and fiber bundles - remaining in the rotor - are clearly visible.
The general method for the determination of stickiness tendency is to count the sticky places on a given heated surface. According to this method the number of sticky places on the rotor wall has been determined. The result is a correlation of nearly 100% between the ITV-method and the H2SD-test. There is only a difference regarding the absolute values (Figure 17) and it has to be mentioned that in the heat test the rotor has not been artificially heated. It is understandable that pests (e.g. whitefly) are never evenly spread within a certain cotton area. Gins normally process cotton within a certain region. Therefore, it is advisable to test the cotton before ginning, thus, being able to eliminate sticky cotton. It may happen that because of localized attack a total region is affected by blending in the ginning mill.

In order to guarantee certain reproducibility, the samples should be treated under standard climatic conditions. On the other hand, the test itself should be carried out under climate conditions, which are somewhat constant. There is a considerable influence of conditions concerning the test results. Repeat tests after a certain time may lead to completely different results because of reduced stickiness. So, it can be stated that the MDTA 3 unit has proved to be very suitable for the detection of sticky cotton. This opens up new possibilities to eliminate critical cottons before being processed. And, it can be assumed that the detection of some single fibers sticking to the rotor wall will probably cause trouble in processing.

The QUICKSPIN process can be also specially helpful and meaningful in the area of research on new cotton varieties. In this case QUICKSPIN appears to be very useful as there are only small quantities of fibers available for evaluation. Meanwhile considerable data has been collected as a result of co-operation with some cotton breeders from all over the world by comparing new seeds (fibers) from an early stage via yarn properties.

Figure 1. Definition of components of MDTA 3.

Conclusion

The QUICKSPIN system enables the quick and simple processing of raw material samples into yarn to assess the raw materials prior to purchase. The QUICKSPIN system permits an efficient forecast of yarn characteristics, especially regarding yarn appearance and tensile properties (strength/elongation).

By testing a sample on the MDTA 3, the gravimetric content of trash, dust and fiber fragments is determined as well as the cleaning efficiency and cleanability calculated. These figures are indicators of the behavior of the tested cotton in opening/cleaning and carding.

Mixes and blends of cottons of different origins and of different raw materials can be simulated and optimized by means of the QUICKSPIN system. The production of color matching blends and samples is also much faster.

The economical aspects of the QUICKSPIN system are foremost in the field of selective raw material purchase and economical composition of mixes and blends.

Since the yarn manufacturer – for reasons of competitiveness - has to utilize raw material and operational means even more extensively in the future, QUICKSPIN forms an important and integral part of the raw material and quality management.

The degree of stickiness of cotton varieties can be determined under conditions similar to industrial terms – without heating.

The QUICKSPIN system has proved to be extremely helpful on developing new cotton varieties – due to the fact that only a small amount of fiber is generally available for assessment.
Figure 2. Trash, dust and fiber fragments.

<table>
<thead>
<tr>
<th>Trash</th>
<th>Fiber fragments</th>
<th>Dust on filter</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Image]</td>
<td>[Image]</td>
<td>[Image]</td>
</tr>
</tbody>
</table>

Figure 3. MDTA 3 with open box and rotor ring.

Figure 4. Dust and trash classification.

<table>
<thead>
<tr>
<th>Trash in cotton bale</th>
<th>Up to 1.2 %</th>
<th>Very clean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.3 to 2.0 %</td>
<td>Clean</td>
</tr>
<tr>
<td></td>
<td>2.1 to 4.0 %</td>
<td>Average</td>
</tr>
<tr>
<td></td>
<td>4.1 to 7 %</td>
<td>Trashy</td>
</tr>
<tr>
<td></td>
<td>Over 7.0 %</td>
<td>Very trashy</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Trash in card and draw frame sliver</th>
<th>Up to 0.05 %</th>
<th>Very clean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.06 to 0.10 %</td>
<td>Clean</td>
</tr>
<tr>
<td></td>
<td>0.11 to 0.15 %</td>
<td>Average</td>
</tr>
<tr>
<td></td>
<td>0.16 to 0.20 %</td>
<td>Increased trash</td>
</tr>
<tr>
<td></td>
<td>Over 0.20 %</td>
<td>Much trash</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dust content in card and draw frame sliver</th>
<th>Up to 0.01 %</th>
<th>Very low</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.02 to 0.03 %</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>0.04 to 0.005 %</td>
<td>Average</td>
</tr>
<tr>
<td></td>
<td>0.06 to 0.09 %</td>
<td>Increased dust</td>
</tr>
<tr>
<td></td>
<td>Over 0.09 %</td>
<td>Much dust</td>
</tr>
</tbody>
</table>
Figure 5.
Quickspin testing equipment.

Figure 6.
Cleanability.

Figure 7.
Total trash of different cotton origins.

Figure 8.
Cleanability of different cotton origins.
Figure 9.
Cleanability stages.

<table>
<thead>
<tr>
<th>Cleanability (%)</th>
<th>Class of cleaning (-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 70 %</td>
<td>Bad</td>
</tr>
<tr>
<td>70 - 80 %</td>
<td>Normal</td>
</tr>
<tr>
<td>&lt; 80 %</td>
<td>Good</td>
</tr>
</tbody>
</table>

Figure 10.
Definition of foreign matter in cotton fibers.

Figure 11.
Data sheet with evaluation: Trash, dust, fiber fragments.

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Staub und Trashprüfung

Antrag:  
Probe:  
Datum:  

Dust: 0,2133 %
Fiber fragments: 0,1038 %
Trash: 5,369 %
Cleanability: 89,3 %
Stickiness: none
Quickspin - a new method for evaluating cotton quality

Figure 12. Trash content in yarn.

Figure 13. Yarn strength.
Figure 14.
Honeydew converted into caramel.

Figure 15.
Sticky (oily) trash particle.

Figure 16.
Sticky cotton fibers in rotor of MDTA 3.
Figure 17.
Stickiness:
H2SD vs. ITV-method.