Holger Neubauer
Rieter Machine Works Ltd.
Winterthur, Switzerland

Harald Schwippl
Rieter Machine Works Ltd.
Winterthur, Switzerland

# Processing Indian Raw Cotton

Comparison of processing characteristics of cotton with a high short fiber content on Rieter's rotor and ring spinning system

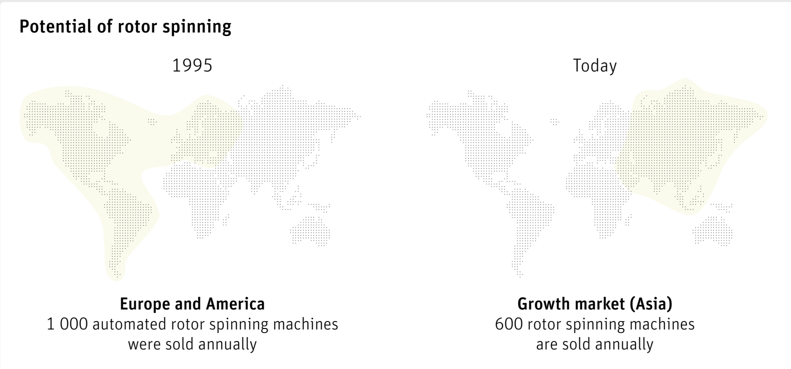



**Fig. 1**

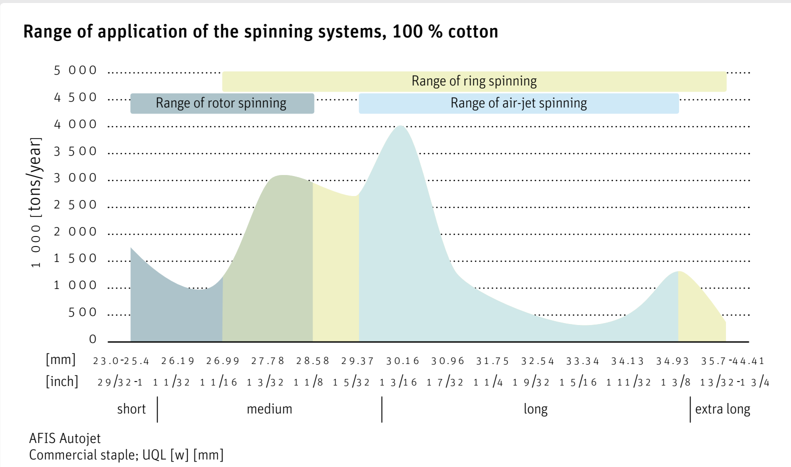



**Fig. 2**

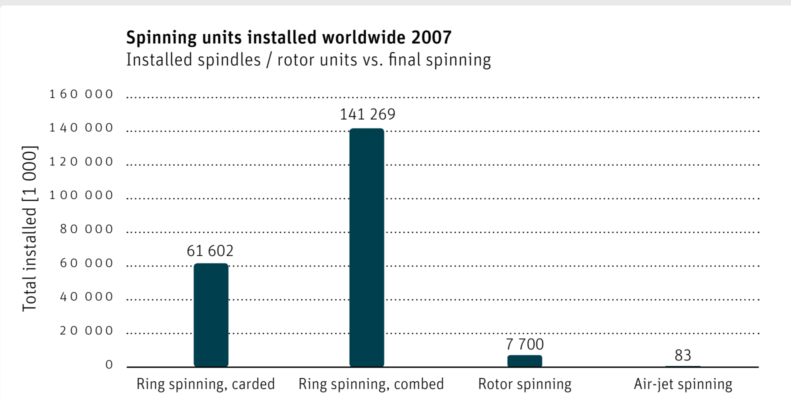



**Fig. 3**

## INTRODUCTION

The subject of this study is the processing of 1 1/16" cotton with a high short fiber content on Rieter rotor and ring spinning systems. The potential for processing 100 % cotton on rotor spinning machines is currently still far from exhausted in the Asian countries and enormous growth potential remains. Despite the increasing consumption of textiles worldwide, an average of 600 rotor spinning machines are being installed annually in Asia. This market is forecast to double (Fig. 1).

## RANGE OF APPLICATION OF THE DIFFERENT END SPINNING SYSTEMS

The range of application of the rotor spinning system in processing 100 % cotton is restricted on economic and qualitative grounds to cotton staple lengths from 1" to 1 1/8". Depending on the short fiber and trash content of the cotton, rotor spinning technology is often the only option for manufacturing yarns economically and at the same time in the required quality. The areas of application of the different end spinning processes can therefore be allocated as a function of the staple length of the cotton (Fig. 2).

7.7 million rotor spinning units were already installed worldwide in 2007. This number is small compared to the number of ring spindles installed. However, since the productivity of a rotor spinning unit exceeds that of a ring spinning unit by a factor of 6, this figure corresponds to some 30 % of total yarn output. In global terms the rotor spinning system is an established technology which fulfills the high requirements for yarns in downstream processing (Fig. 3).

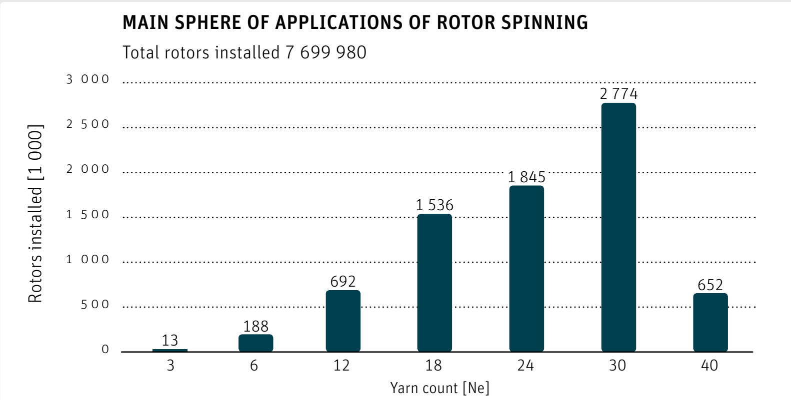



**Fig. 4**

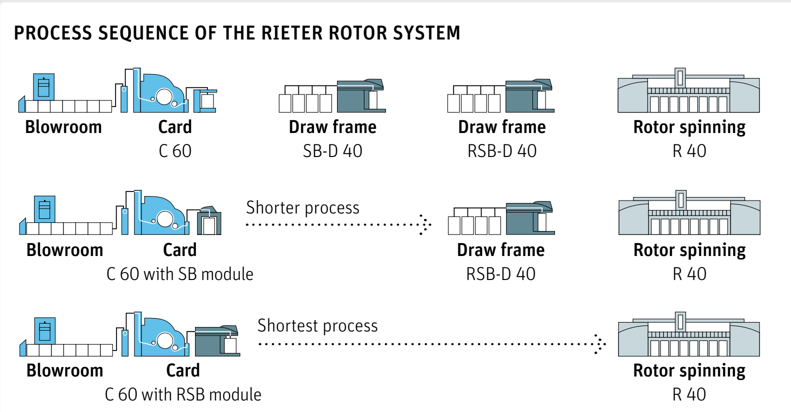



**Fig. 5**

The yarn count range of rotor technology is Ne 3 – Ne 40, with the typical and most frequently produced yarn count being Ne 30. Yarns in this count are processed mainly in circular knitting, but also in weaving (Fig. 4). Different process sequences can be chosen for processing the fibers in rotor spinning (Fig. 5). The choice of process sequence in rotor spinning depends on the yarn count being produced and the required yarn quality. When processing 100 % cotton in a yarn count of Ne 30, carding without a draw frame module and 1 or 2 subsequent drafting passages is appropriate (Fig. 6).

## TEST SETUP

In this trial, when processing 100 % cotton, the quality of the rotor-spun yarn is analyzed in direct comparison with a ring-spun yarn. In this case the choice of raw material had to meet the processing requirements of both spinning systems. Cotton with too short a staple length has an adverse influence on drafting action in the drafting system unit on the ring spinning machine due to poor fiber guidance ("floating fibers").

**Process coordination in rotor spinning, carded yarn, 100 % natural fibers**

| Raw material | Process version | Yarn count range Ne | Draft / Doubling | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Technologically recommended process | Draft SB / RSB-module | Draft SB / RSB 1. passage | Draft SB / RSB 2. passage | Draft SB / RSB 3. passage | Doubling | Draft final spinning |
| Cotton | Direct process without module | - | - | - | - | - | - | - |
| | Direct process with RSB module | 3-8 | 3-4.5 | - | - | - | - | 40-100 |
| | CBA + drafted sliver 1st passage | 9-20 | - | 4-6 | - | - | 4-6 | 80-200 |
| | CBA + drafted sliver 2nd passage | 9-40 | - | 6-8 | 6-8 | - | 6-8 | 80-400 |
| | SB module + drafted sliver 1st passage | - | - | - | - | - | - | - |
| | SB module + drafted sliver 2nd passage | - | - | - | - | - | - | - |

Recommended / Possible with losses

**Fig. 6**

### RAW MATERIAL PROPERTIES

| | |
|---|---|
| Cotton Shankar 6 – origin India | |
| Micronaire: | 3.86 (bale) |
| Commercial staple : | 1 1/16" |
| Mean fiber length (n): | 18.7 mm (Almeter) |
| Strength [g/tex]: | 28.4 (HVI) |
| Neps [1/g]: | 118 in bale (AFIS) |
| Seed coat neps [1/g]: | 14.2 (AFIS) |
| Short fiber content: | < 12.5 mm (n): 23.4 % (Almeter) |
| Stickiness: | not sticky (FCT) |

**Fig. 7**

### SPINNING SCHEDULE

Rotor-spun, carded [Ne 20 + Ne 30]:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| A 11 UNIfloc | B 12 UNIclean | B 7/3 UNImix | B 60 UNIflex | C 60 Card 100 kg/h | SB-D 15 | RSB-D 40 | R 40 Rotor |

Rotor-spun, combed [Ne 20 + Ne 30]:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| A 11 UNIfloc | B 12 UNIclean | B 7/3 UNImix | B 60 UNIflex | C 60 Card 100 kg/h | SB-D 15 | E 32 UNIlap | E 65 Combing noil 14 % | RSB-D 40 | R 40 Rotor |

Ring-spun, carded [Ne 20 + Ne 30]:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| A 11 UNIfloc | B 12 UNIclean | B 7/3 UNImix | B 60 UNIflex | C 60 Card 80 kg/h | SB-D 15 | RSB-D 40 | F 15 Roving frame | G 33 Ring |

Ring-spun, combed [Ne 30]:

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| A 11 UNIfloc | B 12 UNIclean | B 7/3 UNImix | B 60 UNIflex | C 60 Card 80 kg/h | SB-D 15 | E 32 UNIlap | E 65 Combing noil 16 % | RSB-D 40 | F 15 Roving frame | G 33 Ring |

**Fig. 8**

In order to establish how the two spinning systems react to a higher short fiber content, an Indian Shankar 6 cotton with a relatively high short fiber content was used for the study. The exact raw material specifications are listed below (Fig. 7).

The yarns were processed to a yarn count of Ne 20 and Ne 30 using carding and combing processes. The influence of the short fiber content on the yarn values of both yarn types was also studied. For this purpose 14 % noil was extracted from the raw material in the case of the rotor spinning process and 16 % in the case of the ring spinning process. Card output was adjusted according to the final spinning system; 100 kg/h for rotor spinning and 80 kg/h for ring spinning. The yarns are comparable on the basis of these appropriate adjustments (raw material, spinning schedule) (Fig. 8).

The influence of rotor / spindle speed and yarn twist was also studied on both spinning systems (Fig. 9).

### INFLUENCE OF ROTOR / SPINDLE SPEED

| Type of yarn | Yarn [Ne] | Nozzle | Speed [rpm] | Delivery [m/min] | Twist factor [$\alpha_m$] |
|---|---|---|---|---|---|
| Rotor-spun, carded | 20 | KS-NX | 120 000 | 189 | 109 |
| | 20 | $K_4$ K | 120 000 | 189 | 109 |
| | 20 | KS-NX | 120 000 | 178.7 | 115 |
| | 20 | $K_4$ K | 120 000 | 178.7 | 115 |
| | 30 | KS-NX | 110 000 | 142.7 | 109 |
| Rotor-spun, combed | 20 | KS-NX | 108 070 | 189.2 | 98 |
| | 20 | KS-NX | 120 000 | 189.2 | 109 |
| | 30 | KS-NX | 110 000 | 142.7 | 109 |
| Ring-spun, carded | 20 | - | 14 000 | 22 | 109 |
| | 20 | - | 18 000 | 27 | 114 |
| Ring-spun, combed | 30 | - | 15 000 | 19.5 | 109 |

**Fig. 9**

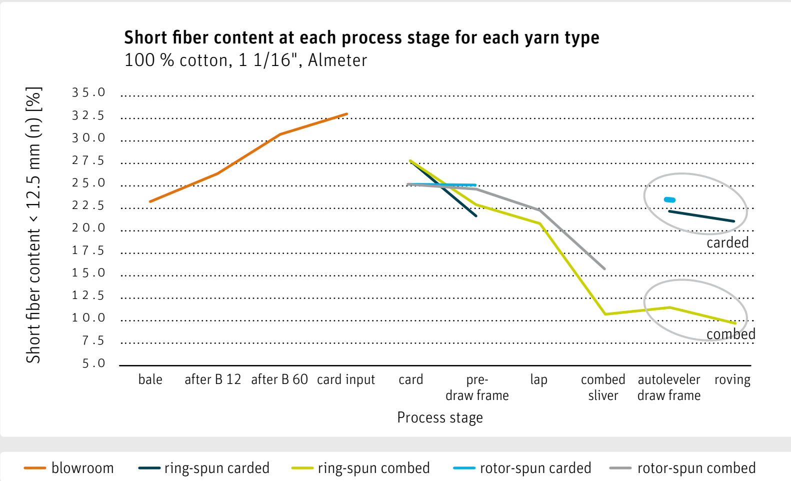



**Fig. 10**

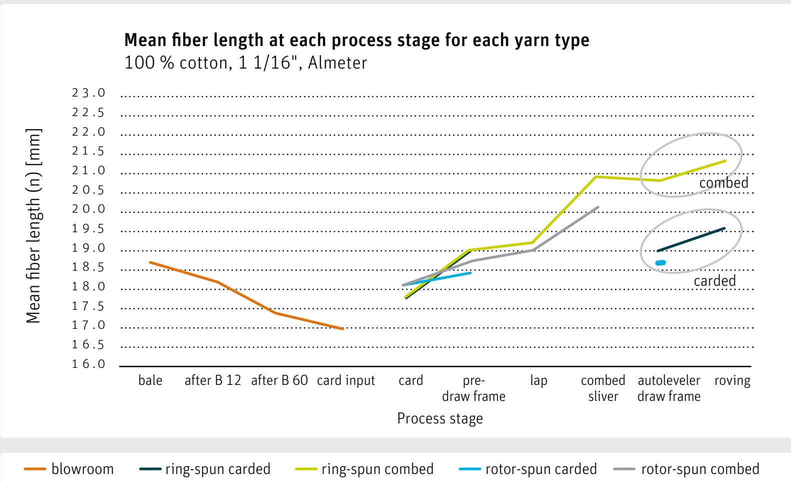
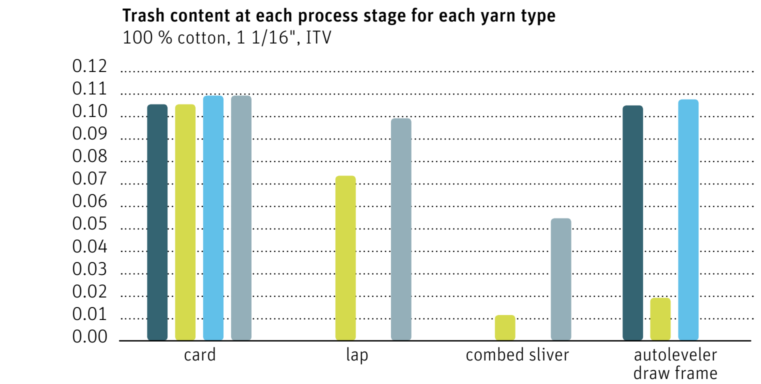



**Fig. 11**

## RAW MATERIAL RESULTS

The short fiber content of the cotton is relatively high at 22 %. Short fiber content measurements rise as a result of fiber turbulence during the cleaning stages in the blowroom. This does not reflect actual shortening of the fibers. The reason is that existing measuring technology also interprets fiber turbulence as shorter fibers. The fibers are parallelized again during the carding process. The short fiber content measured in the bale should still be the same after gentle cleaning, carding and fiber parallelization by the drafting passages. This is confirmed by the fiber measurements made during the study. The short fiber content after noil extraction is 10 % for the ring spinning process and 15 % for the carded rotor spinning process (Fig. 10).

The short fiber content has an impact on the mean fiber length and thus – besides fiber count – also on spin-out limits and yarn quality. The mean fiber length is 19 mm in carded applications and 20 – 21 mm in combed applications, depending on noil extraction (Fig. 11).




| | | | | |
|---|---|---|---|---|
| Ring-spun carded | 0.105 | Process stage | | 0.104 |
| Ring-spun combed | 0.105 | 0.073 | 0.011 | 0.019 |
| Rotor-spun carded | 0.109 | | | 0.107 |
| Rotor-spun combed | 0.109 | 0.099 | 0.054 | |

**Fig. 12**

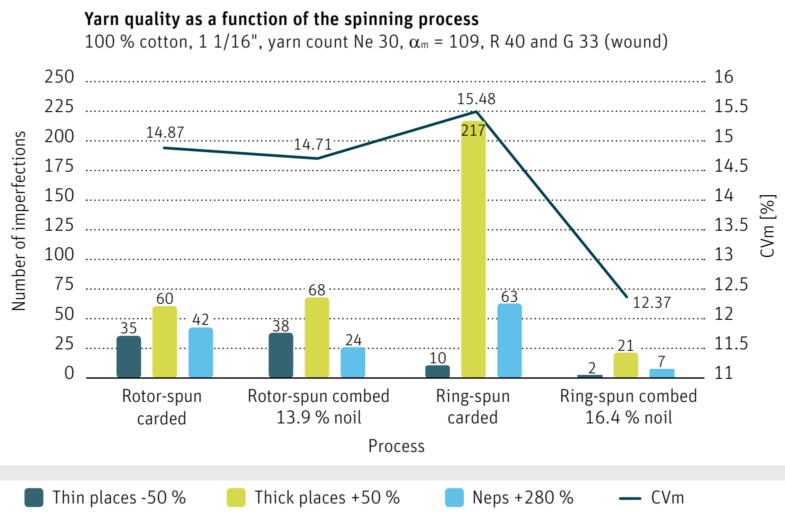



**Fig. 13**

The residual trash content in the feed sliver on the rotor spinning machine is an important criterion for the operating reliability of a rotor spinning machine. Contamination of the rotor groove when the trash content is too high results in ends down. Experimental evidence shows that the residual trash content of the feed sliver for the rotor spinning process should be no higher than 0.07 – 0.1 % in Ne 20 – Ne 30 yarns. This requirement is just barely met by the Shankar 6 cotton in the carded application with 0.107 %. With the combing process the trash content is generally reduced within a range of 60 – 85 % (Fig. 12). Combing can thus be technologically appropriate for rotor spinning with a low noil extraction rate.

In general, the adverse impact of raw material properties such as
• high short fiber content
• short mean staple length
• trash content of the cotton
is much lower in rotor spinning than in ring spinning.

## YARN RESULTS

### IMPERFECTIONS (IPI) AND YARN IRREGULARITY

Combed and carded rotor-spun yarns are at a similar level in terms of total imperfections with = 109 ($\alpha_e$ = 3.6). A reduction in imperfections in combed rotor-spun yarn is apparent with lower twist factors and declining rotor speeds, i.e. a constant delivery speed of 189 m/min. The number of imperfections in carded ring-spun yarn is considerably higher than in rotor-spun yarn, despite reduced card output of 80 kg/h instead of 100 kg/h (Fig. 13).

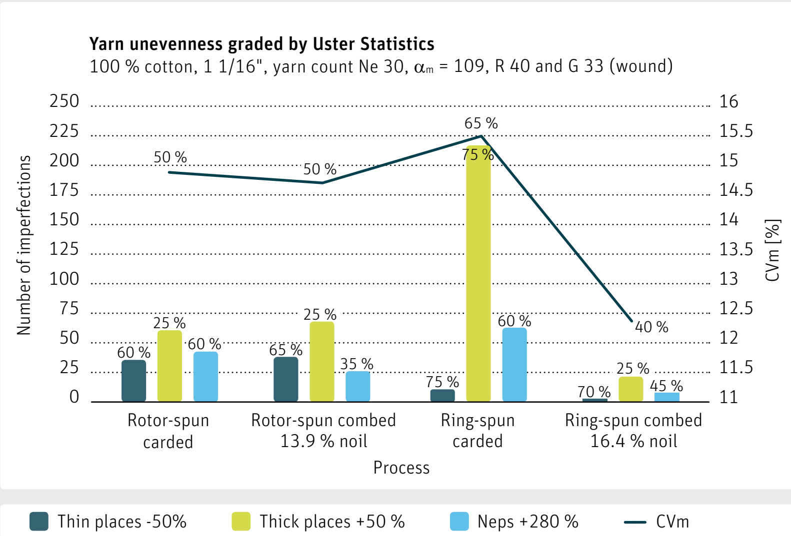



**Fig. 14**

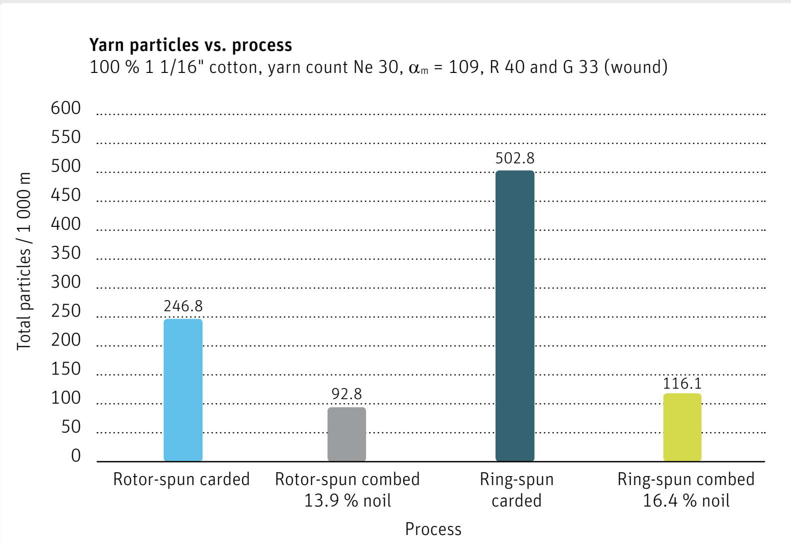



**Fig. 15**

The combing process, and thus the additional extraction of short fibers, brings no advantages in the rotor spinning line in terms of yarn regularity. This result is remarkable, since the short fiber content in the ring spinning process has, in contrast, a significant influence on yarn regularity. This means that short fibers can be guided much better through the fiber guide channel in the rotor spinning process than by the drafting system in ring spinning. This can also be demonstrated very impressively by the influence of the combing process on ring-spun yarn. For this purpose a combed cotton yarn with approx. 16 % noil extraction and a yarn count of Ne 30 was produced on the ring spinning machine. The measuring results show that – due to the combing process – a distinct improvement in yarn cleanliness is apparent compared to a carded ring-spun yarn. The yarn quality values are also better than those of a carded rotor-spun yarn. However, it must be borne in mind here that this improvement in quality of the ring-spun yarn could only be achieved with 16 % noil extraction from the cotton (Fig. 14).

In comparison (Uster Statistics), this means that the rotor-spun yarns are in a good range and the performance of carded ring-spun yarns is considerably poorer due to the specific raw material properties.

The residual trash content of a rotor-spun yarn is much lower than in a ring-spun yarn due to trash removal at the opening cylinder in the carded application. Only the combing process and the associated removal of trash particles then makes a very low trash content also possible in ring-spun yarn (Fig. 15).

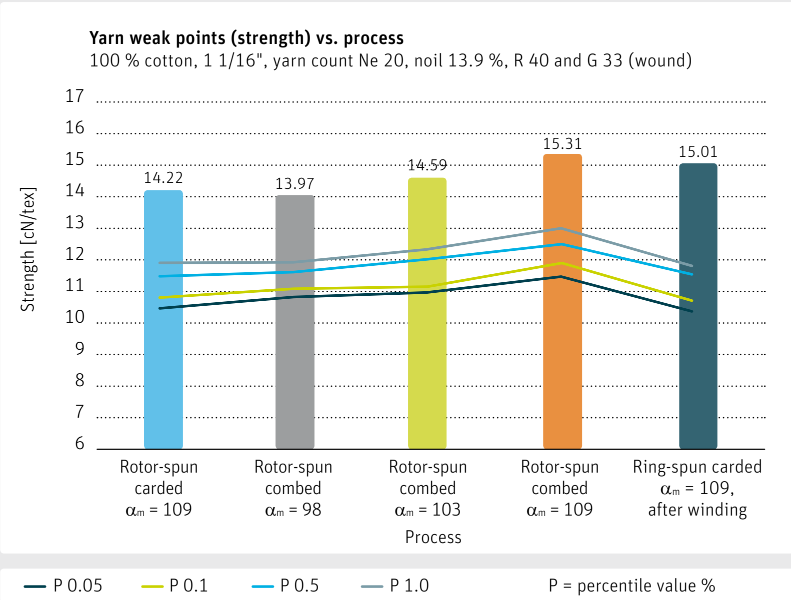



**Fig. 16**

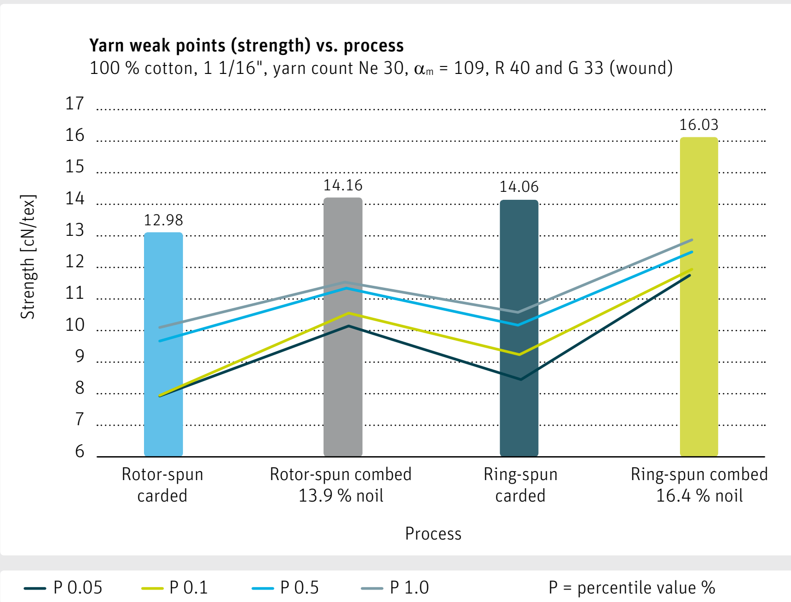



**Fig. 17**

## YARN STRENGTH AND ELONGATION

Compared to combed yarn, with an identical twist factor, the strength of carded rotor-spun yarn is approx. 1 cN/tex lower due to the shorter mean staple length. With an increase in twist factor from 98 ($\alpha_e$ 3.2) to 109 ($\alpha_e$ 3.6) an increase in yarn strength of more than 1 cN/tex is also apparent due to the improved integration of the fibers.

However, carded ring-spun yarn displays 0.8 cN/tex higher strength compared to carded rotor-spun yarn. It is generally known that ring-spun yarns display higher strength in direct comparison with rotor-spun yarns with the same raw material quality. This is related to the fiber orientation in the yarn structure, i.e. the structural assembly of the core and the covering fibers. Strength values of 10 cN/tex are normally adequate for applications in the knitting sector. The results for yarn weak points show that strength values of less than 10 cN/tex do not occur at any spin-out position (Fig. 16).

Fiber strength in the bale is approx. 28.4 cN/tex. Fiber substance utilization with a twist factor of = 109 is thus:
51 % in carded rotor-spun yarn
55 % in combed rotor-spun yarn
54 % in carded ring-spun yarn

Experience shows that substance utilization in carded rotor-spun yarn is approx. 5 % lower than in ring-spun yarn, due to the more random fiber orientation. Using the Ne 30 yarn count as an example, it is clearly apparent that strength increases by 2 cN/tex in absolute terms as a result of combing in the case of ring-spun yarn, and is thus higher than in carded and combed rotor-spun yarns (Fig. 17).

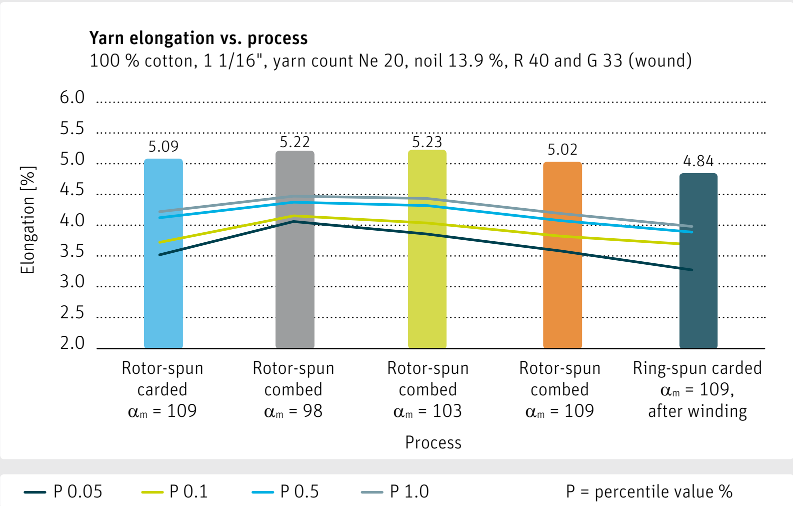



**Fig. 18**

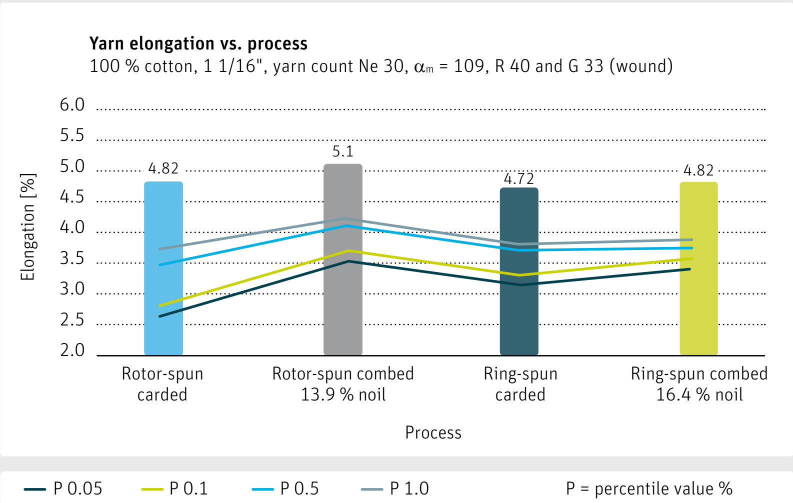



**Fig. 19**

The combing process does not have a positive effect on the elongation values of rotor-spun yarn. Carded rotor-spun yarn is at the same level as combed rotor-spun yarn. On the other hand, the values for ring-spun yarn are slightly poorer.

The minimum requirement for knitting yarns is normally approx. 5 % yarn elongation (Fig. 18). Due to the yarn structure, the good elongation values of rotor-spun yarns cannot be exceeded, even when combing is used with ring-spun yarns (Fig. 19).

Carded ring-spun yarn displays the lowest stretch recovery. The differences relative to carded rotor-spun yarn are small. Combed rotor-spun yarn with the same twist factor displays the highest elongation.

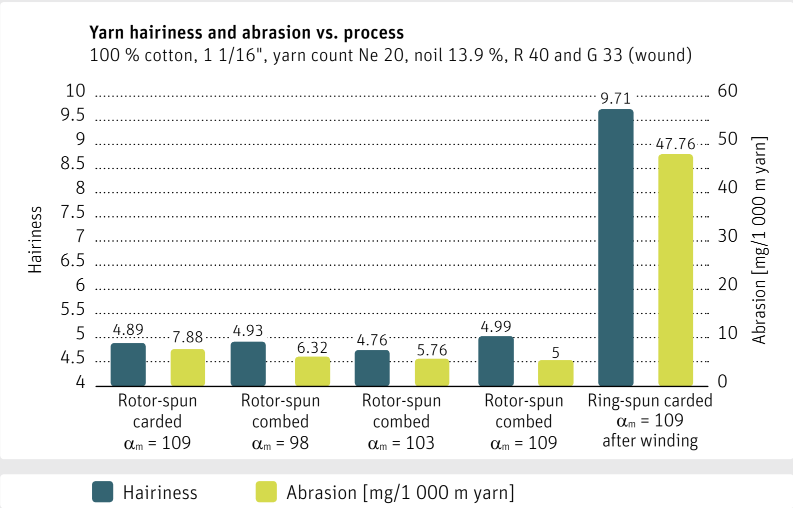



Fig. 20

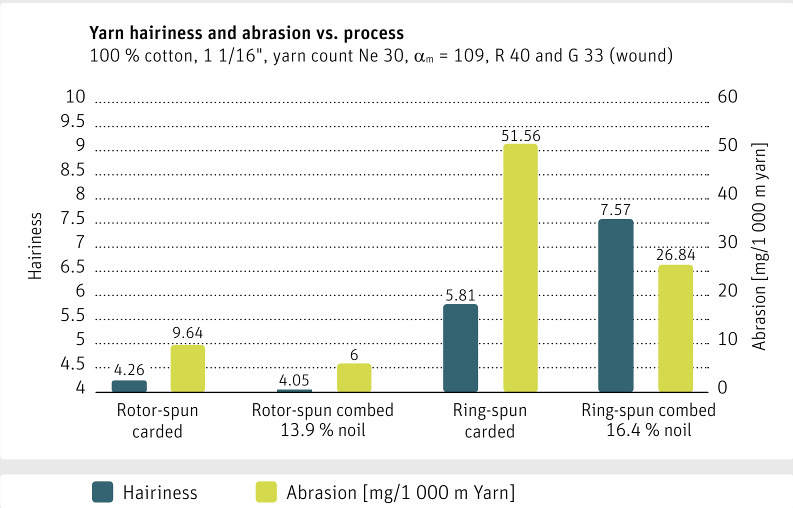



Fig. 21

## YARN HAIRINESS AND ABRASION

The yarns were processed on a circular knitting machine. The yarns were therefore waxed during the winding or rotor spinning process.

Ring-spun and rotor-spun yarns differ considerably in terms of hairiness. This difference is due to the differences in yarn structure between ring-spun and rotor-spun yarns. The yarn hairiness of carded ring-spun yarn measured with the Uster Tester 4 is almost twice that of rotor-spun yarn. The differences between carded and combed ring-spun yarns are minimal. The combing process has no effect on the hairiness values of rotor-spun yarn. The decisive factor for yarn hairiness in rotor-spun yarn is therefore primarily yarn structure rather than fiber length.

Rotor-spun yarns also display clear advantages in respect of yarn abrasion. The abrasion of ring-spun yarn is higher than that of rotor-spun yarn by more than a factor of 5. It is apparent that the combing process has a positive impact on the abrasion of rotor-spun yarn (Fig. 20 – 21).

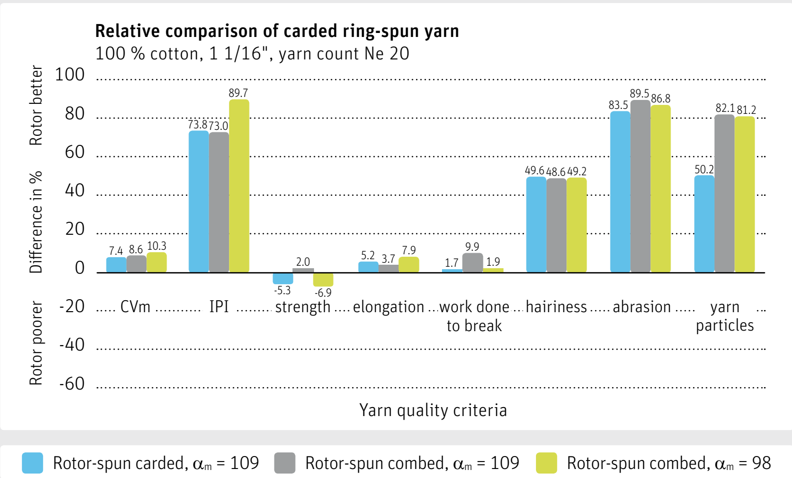



**Fig. 22**

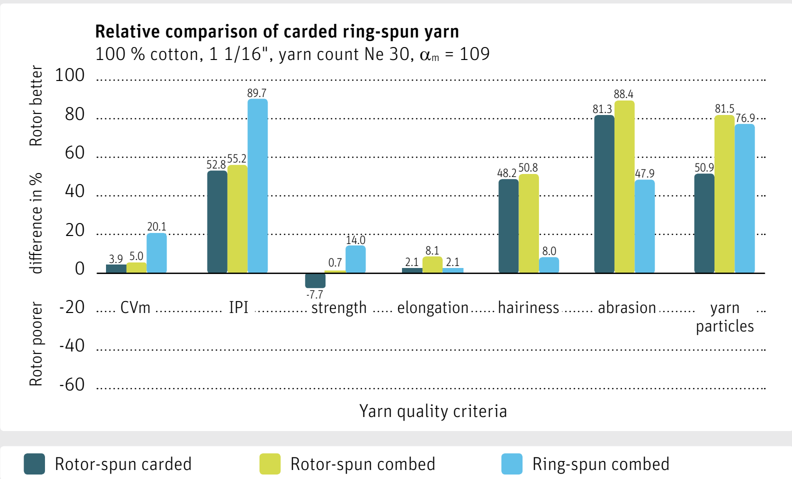



**Fig. 23**

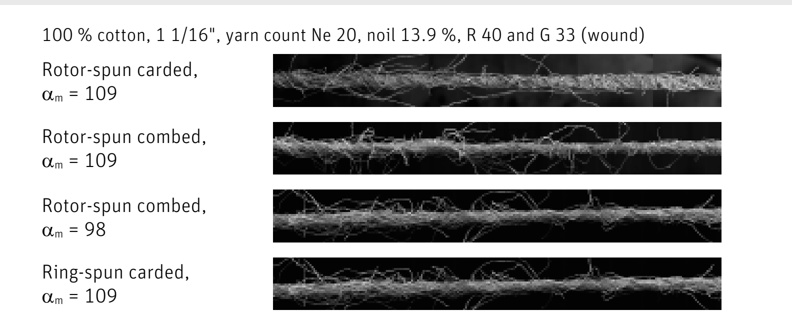



**Fig. 24**

The advantages of rotor spinning technology in processing Shankar 6 cotton with a relatively high short fiber content are impressive and can be summarized as follows:

- The quality values of rotor-spun yarn when processing Indian Shankar 6 cotton in a yarn count of Ne 20 are superior to those of ring-spun yarn (Fig. 22)
- The quality of ring-spun yarn can be improved significantly by combing and is only then superior to carded rotor-spun yarn, with the exception of hairiness and abrasion resistance (Fig. 23)
- Micrographs showed the typical structure of rotor-spun yarn with its belly bands compared to ring-spun yarn. The greater hairiness and the associated increase in volume of ring-spun yarn are clearly apparent in the micrograph. Rotor-spun yarn is normally distinguished from ring-spun yarn by a larger yarn diameter with the same yarn count. This results in a higher pile density in knitted fabric. However, it is apparent from these results that this effect can also be reversed as staple lengths become shorter in ring-spun yarn due to poorer fiber orientation and integration in the yarn structure (Fig. 24).

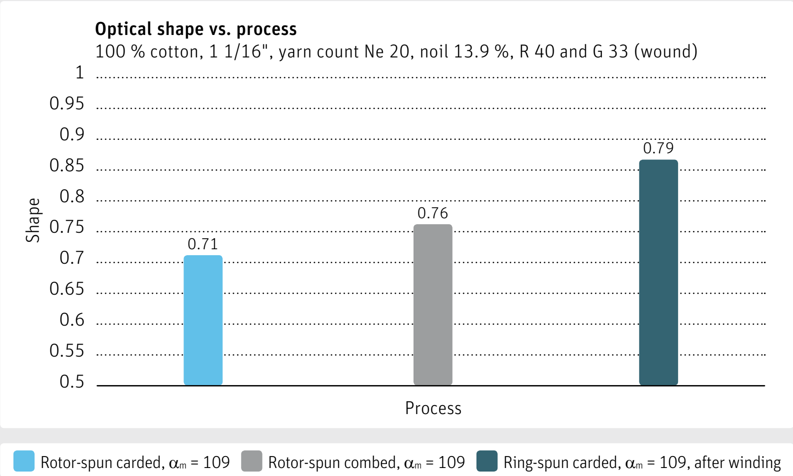



**Fig. 25**

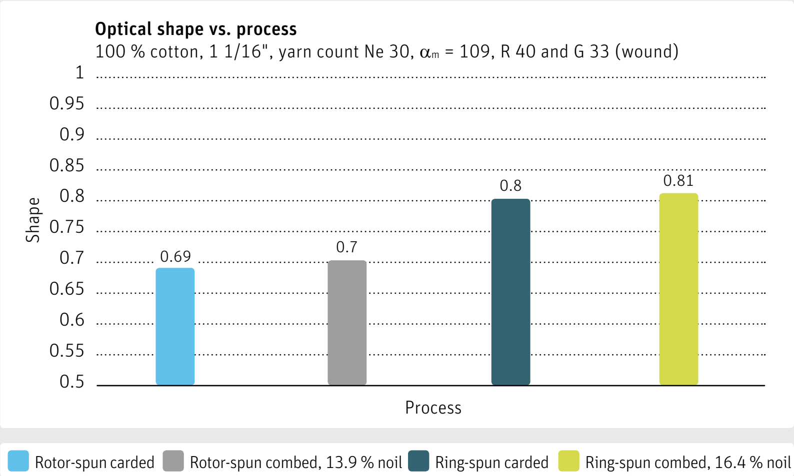



**Fig. 26**

## YARN SHAPE

In addition to the orientation of the fibers in the yarn structure, yarn shape also has an influence on the refraction of light in textile fabrics. Essentially, the rounder the structure of the yarn itself, the higher the brilliance in the fabric.

A ring-spun yarn is generally rounder than a rotor-spun yarn. Besides yarn structure, yarn roundness can therefore have a positive impact on the brilliance of a knitted fabric (Fig. 25 + 26).

## PROPERTIES OF KNITTED FABRICS AND FINDINGS

Besides the yarns, an appraisal of a knitted fabric before and after finishing should be conducted in order to compare the different spinning technologies. In this specific case the following typical criteria customary in practice were considered for assessing the knitted fabrics:

- fabric hand
- pile density
- uniformity
- pilling

The yarns were processed into a single jersey on an ORIZIO (John/C model) circular knitting machine with a gauge of E 24. The knitted fabrics were washed, bleached and dyed in the course of the finishing process.

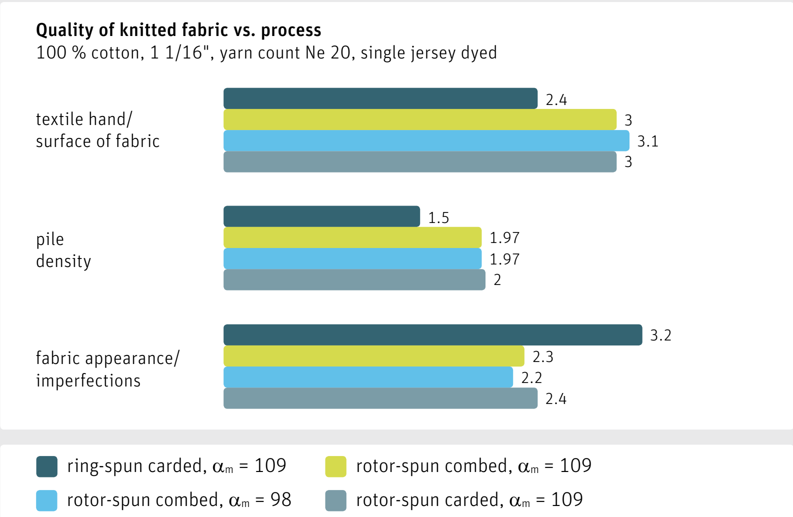



**Fig. 27**

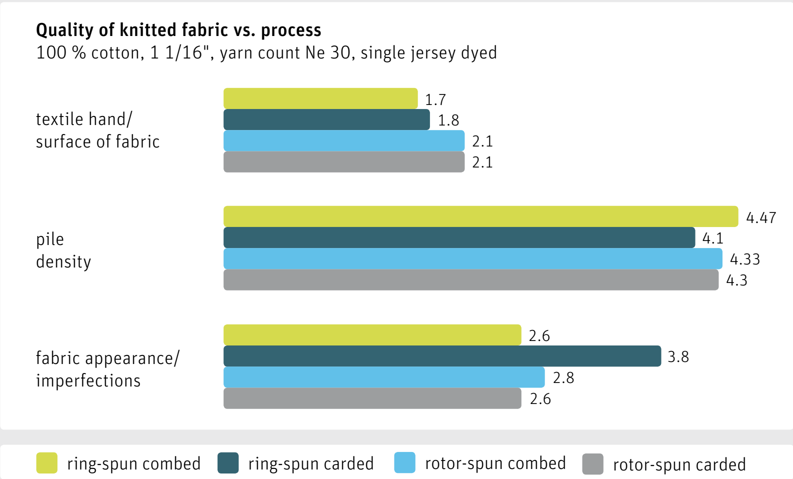



**Fig. 28**

## HAND, PILE DENSITY AND UNIFORMITY

Besides different yarn structures, the different spinning processes also display different yarn diameters and roundness. In addition to yarn structure, yarn diameter affects the optical uniformity of the end product. A larger yarn diameter with the same yarn count demonstrably has a positive impact on the optical uniformity of the end product.

As was to be expected, ring-spun yarn had a softer textile hand compared to rotor-spun yarn.

The greater pile density of carded ring-spun yarn compared to rotor-spun yarn is attributable in this case to its greater hairiness. This effect is also apparent in the fact that the pile density of ring-spun yarn deteriorates after combing.

Carded ring-spun yarn results in a much poorer fabric appearance compared to rotor-spun yarn. The fabric appearance of carded ring-spun yarn could only be improved by combing, after which it was in the same range as that of rotor-spun yarn.

No improvement in the knitted fabric was achieved by combing rotor-spun yarn. Reduction of the twist factor in combed rotor-spun yarn brought no improvement, either in textile hand or in the other assessment criteria (Fig. 27 – 32).

Rotor-spun carded, single jersey 100 % cotton, 1 1/16", yarn count Ne 30, nozzle KS-NX, 110 000 rpm, $\alpha_m$ 109

**Fig. 29**

Rotor-spun combed, single jersey 100 % cotton, 1 1/16", yarn count Ne 30, nozzle KS-NX, 110 000 rpm, $\alpha_m$ 109

**Fig. 30**

Ring-spun carded, single jersey 100 % cotton, 1 1/16", yarn count Ne 30, 12 200 rpm, $\alpha_m$ 109

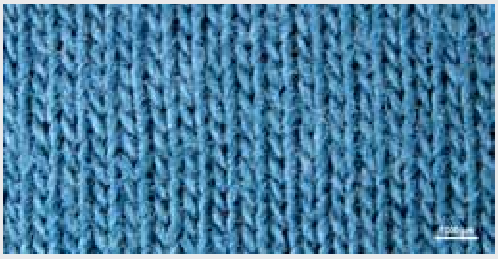


**Fig. 31**

Ring-spun combed, single jersey 100 % cotton, 1 1/16", yarn count Ne 30, 15 000 rpm, $\alpha_m$ 109

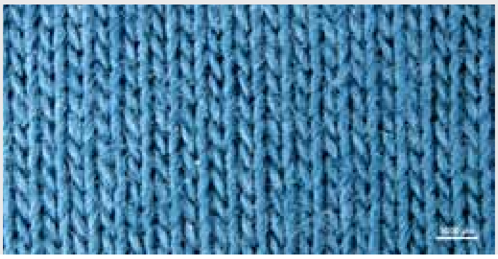


**Fig. 32**

**PILLING**

Most physical properties of an end product are attributable to the structure of the yarn being processed. Pilling behavior in the textile fabric, especially in knitted fabrics, is one of the most important quality criteria. End products which already form fiber pills on their surface after a short time due to stress reduce quality considerably and are unwelcome. Pilling is therefore a constant topic and can be significantly influenced and improved via low hairiness and the fiber integration structure (final spinning process).

Fibers protruding from the knitted fabric are formed into pills of various sizes by mechanical stress during wearing. These pills are clearly visible, depending on their size and frequency, and have a very negative impact on the appearance of the knitted fabric. Pilling measurement is therefore very important for the qualitative assessment of knitted fabrics. Ring-spun yarn displays the poorest pilling values in all knitted fabrics studied. Carded rotor-spun yarn has the lowest pilling values, i.e. the best scores.

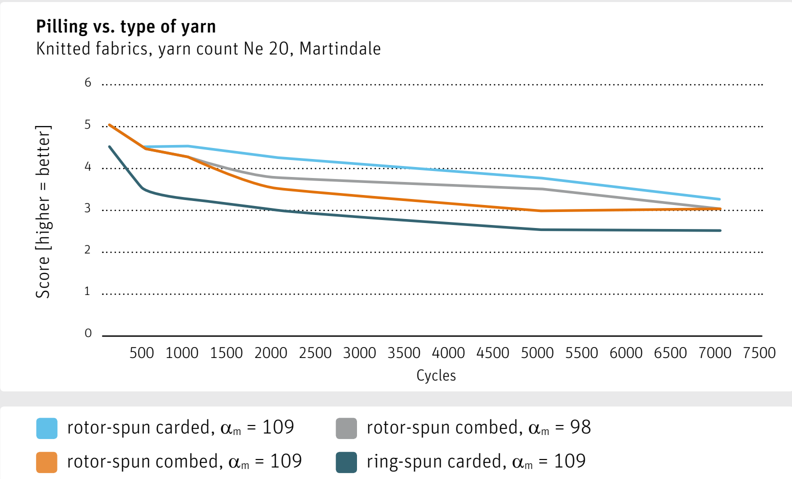



**Fig. 33**

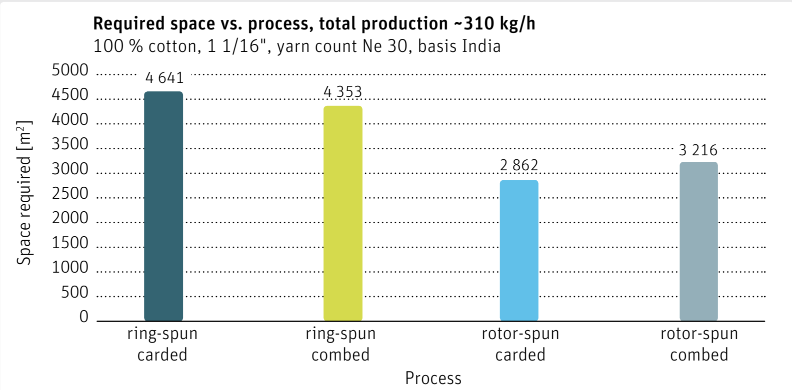



**Fig. 34**

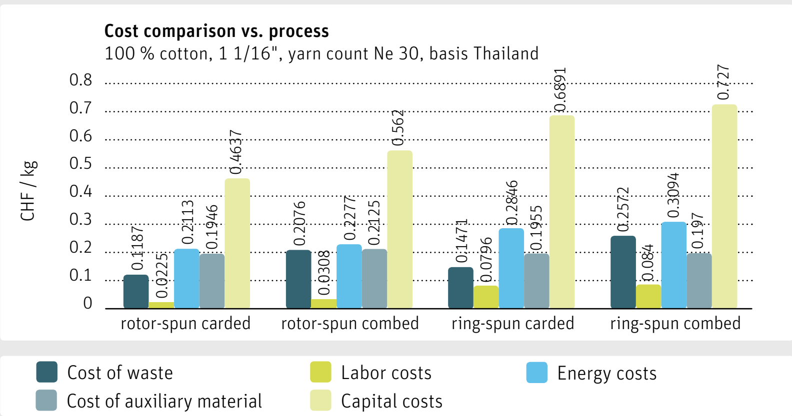



**Fig. 35**

The reason for the better pilling values of rotor-spun yarn compared to ring-spun yarn is to be found in its yarn structure with belly bands and less parallel orientation of fibers. The more random orientation of the fibers and the belly bands create resistance to the formation of pills. The results of the pilling test confirm this. It is clearly apparent that combed rotor-spun yarn displays poorer values than carded rotor-spun yarn. This can also be explained by the less random orientation of the fibers due to the different staple composition (Fig. 33).

## ECONOMICS AND SPHERE OF APPLICATION

The rotor spinning system requires 40 % less space than a ring spinning system. The yarn manufacturing costs of rotor spinning compared to ring spinning are significantly lower in the yarn count range up to Ne 30 (Fig. 34 – 35).

**SUMMARY**

The subject of this study was the processing of cotton with a high short fiber content on Rieter's rotor and ring spinning systems.

The trash content is reduced to a range of 60 – 85 % by combing. Combing can certainly be technologically appropriate for the rotor spinning process with a low noil extraction rate. In the case of the ring spinning process, combing is often necessary in order to achieve the required quality values.

The additional removal of short fibers is of no benefit to rotor-spun yarn as regards yarn regularity. This result is remarkable, since the short fiber content has a significant influence on yarn irregularity in the ring spinning process. This means that in the rotor spinning process short fibers can be guided better through the fiber guide channel than is possible in ring spinning by means of the drafting system. By comparison (Uster Statistics), rotor-spun yarns are in a good range and the performance of carded ring-spun yarn is much worse due to raw material properties and the process-related influence of the drafting system. Only the use of combing for manufacturing ring-spun yarn results in a good, improved classification of ring-spun yarn again.

Poorer raw material properties such as:

- high short fiber content
- low mean staple length
- trash content of the cotton

have a much less negative impact in the rotor spinning process than in ring spinning. Depending on raw material composition and the type of downstream processing, rotor spinning can be regarded as more economical. The quality values of carded rotor-spun yarn with a yarn count of Ne 20 are superior to those of ring-spun yarn when processing Shankar 6 cotton.

The quality of ring-spun yarn can be considerably improved by combing and is only then superior to carded rotor-spun yarn, with the exception of hairiness and abrasion resistance, in the case being studied. The greater hairiness and associated increase in volume of ring-spun yarn had resulted in better pile density in the knitted fabric. Rotor-spun yarn normally features a larger yarn diameter compared with ring-spun yarn with the same yarn count. This results in higher pile density in the knitted fabric. This effect can be reversed as staple lengths become shorter as a result of the poorer fiber orientation and integration in the fiber structure.

Ring-spun yarn has a softer textile hand compared to rotor-spun yarn. The combing process did not result in any improvement in the knitted fabric in the case of rotor-spun yarn. Nor does a reduction in the twist factor in combed rotor-spun yarn result in any improvement, either in textile hand or in the other assessment criteria. Ring-spun yarn had the worst pilling values in all knitted fabrics tested. Carded rotor-spun yarn had the best pilling values.

**Rieter Machine Works Ltd.**
Klosterstrasse 20
CH-8406 Winterthur
T +41 52 208 7171
F +41 52 208 8320
sales.sys@rieter.com
parts.sys@rieter.com

**Rieter India Private Ltd.**
Gat No 134/1, Off Pune Nagar Road,
Koregaon Bhima,
Taluka Shirur, District Pune
IN-Maharashtra 412216
T +91 2137 308 500
F +91 2137 308 426

**Rieter (China)**
**Textile Instruments Co., Ltd.**
**Shanghai Branch**
Unit B-1, 6F, Building A,
Synnex International Park
1068 West Tianshan Road
CN-Shanghai 200335
T +86 21 6037 3333
F +86 21 6037 3399



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