

Processing TENCEL® LF / cotton blends on Rieter's 4 end spinning systems

INTRODUCTION

Alongside the existing end spinning methods, such as ring spinning, compact spinning and rotor spinning technology, air-jet spinning was already gaining a market share in the US in the early 1980s. Modifications made in the late 1990s resulted in significant changes in yarn structure compared with the first generation of air-jet-spun yarns. This enabled twist to be imparted more effectively to the outer surface of the yarn which consequently increased the yarn tenacity. This also made it possible for the first time to process shorter staple lengths, such as 100 % cotton, in addition to manmade fibers and blends. This enabled the potential sphere of application for air-jet spinning to be widened significantly.

The specific structure of these yarns often displays particular advantages in the textile end product, which considerably expands the range of end products and their product characteristics.

Rieter already started to acquire technological know-how for the development of air-jet spinning processes some years ago. A start was then made later to develop a suitable machine concept for air-jet spinning.

EXPERIMENTAL SETUP

The following study was conducted in the context of a cooperative venture between Lenzing and Rieter. It seeks to establish the properties of yarns produced using the air-jet spinning process and compares them with those of yarns produced using established spinning methods. Characteristic differences in downstream processing of the yarns and in the textile fabric were measured in addition to yarn properties. Two different TENCEL® LF/cotton blends were used as the raw material. The definitions of the different spinning processes are explained briefly below:

Machine	Yarn	Process description	System
G 35 ring spinning machine	Com4®ring	Ring spinning	Ring system
K 45 compact spinning machine	Com4®compact	Compact spinning	Compact system
R 40 rotor spinning machine	Com4®rotor	Rotor spinning	Rotor system
J 10 air-jet spinning machine	Com4®jet	Air-jet spinning	Air-jet system

The schematic diagram of the different spinning processes clearly illustrates the spinning principle. (Fig. 1).

In the case of Com4®ring, Com4®compact and Com4®compact-twin yarns, twist is imparted by means of the rotating spindle. The fiber material is compacted further by a partial vacuum in the compacting unit in the drafting system, which drastically reduces the hairiness of the yarn and increases yarn tenacity. In the case of Com4®compact-twin yarn two rovings are fed in together and twisted into a compacted, spun-twisted yarn. This enables further reductions in hairiness and increases in tenacity to be achieved.

In the case of air-jet spinning, a fiber arc is created by means of an air current, and the yarn produced in this way is taken off via a fixed spindle. The twist factor in the covering yarn corresponds more or less to that of a ring-spun yarn. Assuming a yarn count of 20 tex (Ne 30), a twist factor of = 125 and a delivery speed of 380 m/min on the J 10 air-jet spinning machine, the rotation speed of the fiber arc can be calculated as follows:
rpm of the fiber arc = 380 m/min x 890 turns/m
of the covering fibers = 338 200 rpm.

On this basis it is clearly apparent that air is a suitable medium for generating such extreme rotation speeds (Fig. 2). The processing of man-made fibers assumes a significant role in air-jet technology. Manmade fibers produced from cellulose are especially suitable for processing on air-jet spinning machines. A brief summary of fiber volumes and their potential for downstream processing will therefore be given here.

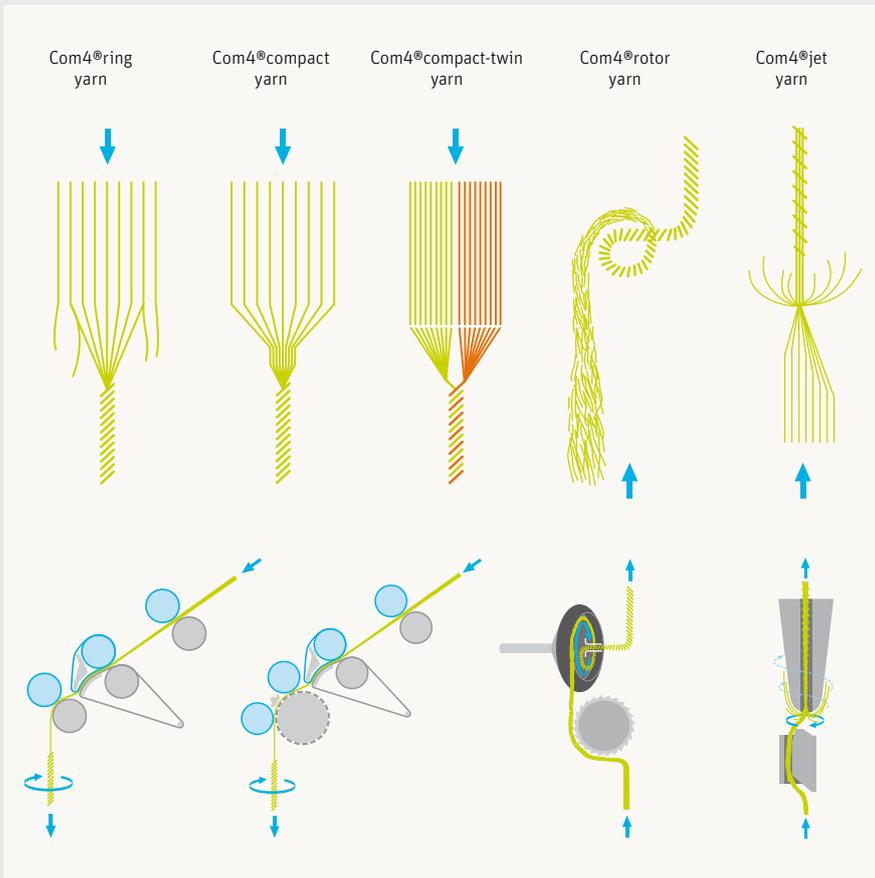


Fig. 1 Yarn process

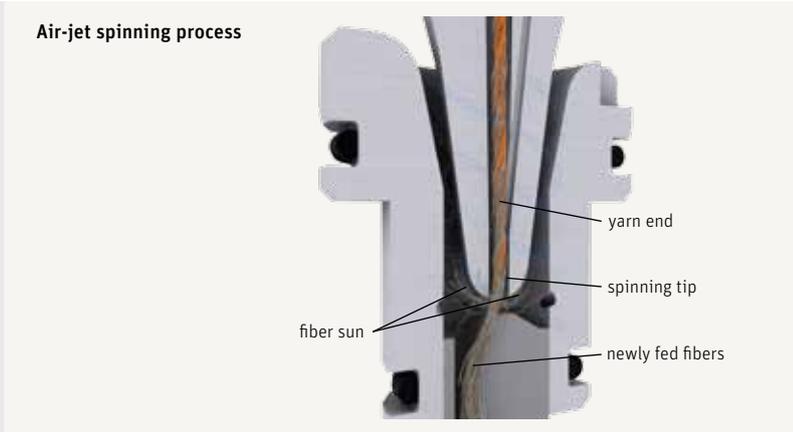


Fig. 2

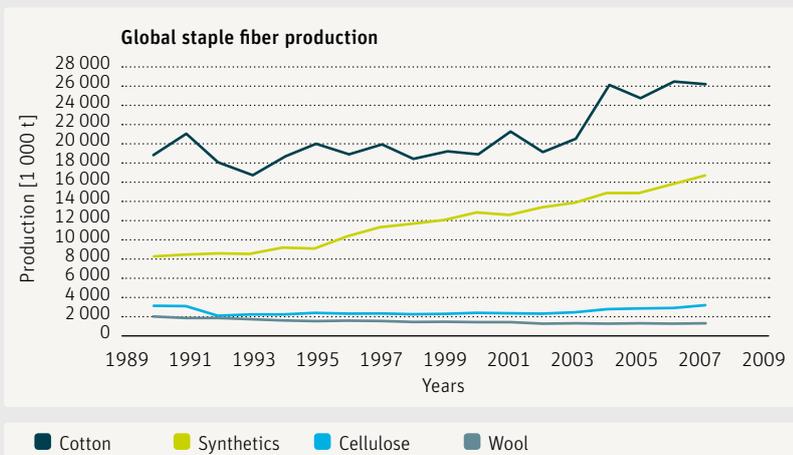


Fig. 3

Fiber specifications		Cotton (CO)	
TENCEL® LF		Yemen	
bright natural white			
Fiber count	1.3 dtex	Fiber count	4.3 Mic.
Commercial staple	38 mm	Commercial staple	1 1/8"
Tenacity	31.3 cN/tex	Tenacity	27.9 cN/tex
Elongation	7.9 %	Elongation	6.0 %

The image shows three microscopic views of fibers. The leftmost image shows TENCEL LF fibers, which appear as smooth, rounded, and somewhat irregular in cross-section. The middle image shows Cotton (CO) fibers, which are more elongated and have a distinct, slightly flattened, and somewhat irregular cross-section. The rightmost image shows a bundle of fibers, likely cotton, showing their natural texture and color.

Fig. 4

From 2005 the annual cotton production rose to a record level of 26 million tonnes. Cotton production is certainly of paramount importance. However, global growth in fiber consumption is satisfied primarily by the increasing use of manmade fibers. Within the group of manmade fibers, synthetic fibers occupy first place with more than 14 million tonnes/year. The manufacture of manmade fibers from renewable raw materials that come under the heading of cellulose raw materials already amounted to more than 3 million tonnes in 2007 (Fig. 3).

TENCEL® LF is an excellent alternative to cotton and plays a significant role in the textile market for fashionwear, bed linen, towels, etc. TENCEL® fibers display enormous advantages in adapting to the requirements of the end product both when spun pure and in various blends, especially with cotton.

Reflecting the expanding spheres of application of these fibers, 50/50 and 67/33 TENCEL® LF / cotton blends were used in this study (Fig. 4).

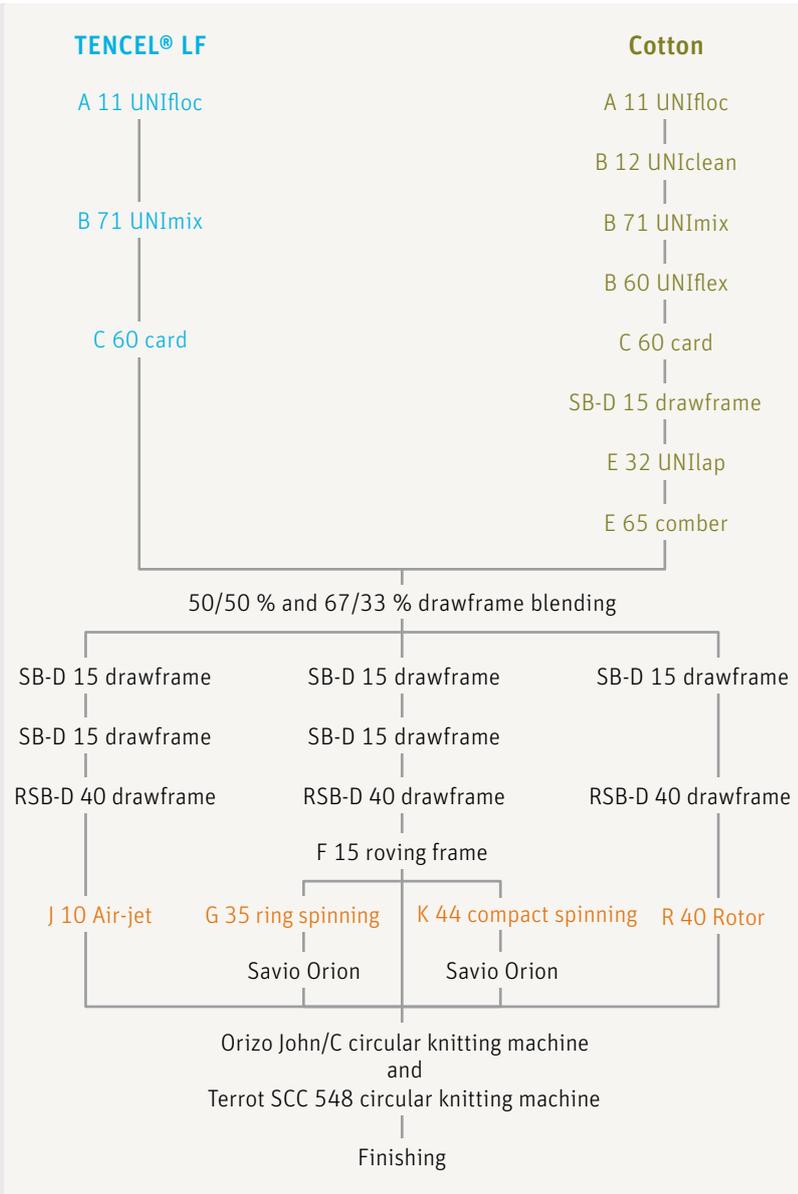


Fig. 5 Spinning schedule

SPINNING SCHEDULE

TENCEL® and the cotton were processed using the appropriate sequence of machines in each case. The TENCEL® fibers were prepared using only one opening unit. Cotton preparation consisted of coarse cleaning, fine cleaning and the combing process.

Up to three drafting passages were used to achieve adequately thorough blending and homogenization of the fibers. The yarns were processed on two different knitting systems (Fig. 5).

RESULTS IN THE INTERMEDIATE PRODUCT

With a mean value of 1.7 dtex, the fiber count of the cotton fiber used is 30 % coarser than that of the TENCEL® fiber. Ideally, a somewhat coarser and shorter cotton fiber can be chosen for raw material blends on economic grounds. A corresponding reduction in noil can be achieved, of course, when combed cotton is used.

The percentage of noil was specified at 16 % on the basis of preliminary tests for the ring spinning process. The same raw material was used for rotor and air-jet spinning in order to ensure comparability with the ring spinning process. In the combing process the same noil content was used as for ring-spun yarn.

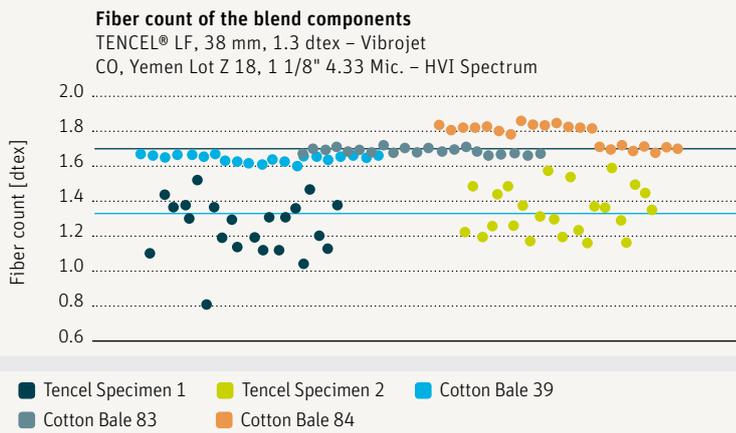


Fig. 6

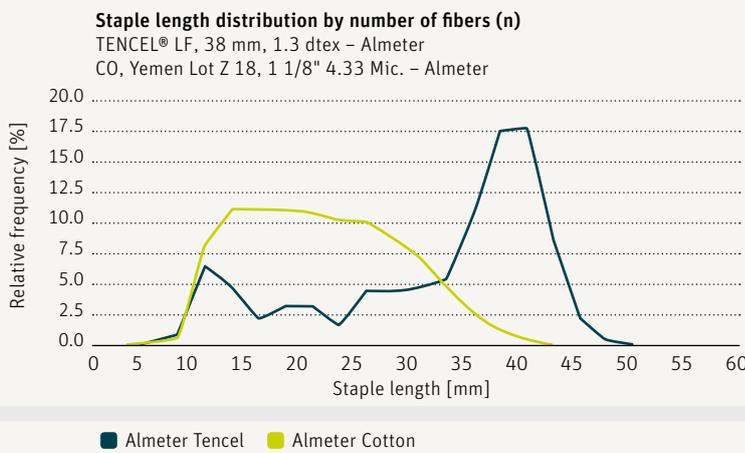


Fig. 7

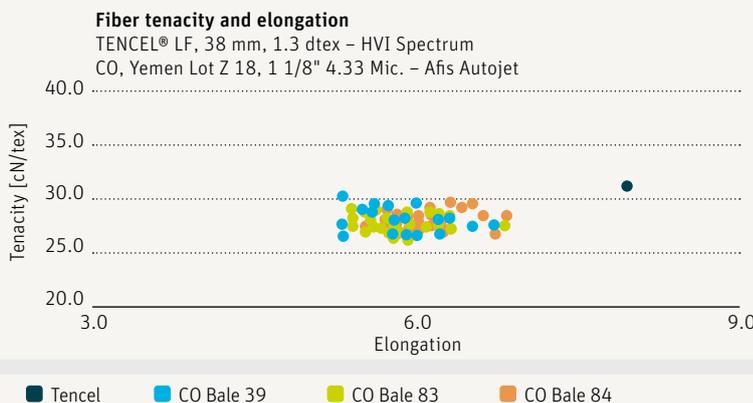


Fig. 8

The physical raw material and yarn properties are enhanced as a result of both an ideal noil percentage on the comber and the composition of the cotton and TENCEL® LF blend (Fig. 6).

The staple length distribution of both raw materials shows that the mean staple length is increased by the addition of TENCEL® (Fig. 7). This will not only be reflected positively in the physical yarn parameters, but also primarily in the running behavior of the ring and air-jet spinning process.

Rotor spinning is much more accommodating in this respect. It should be noted that in the rotor spinning process the required quality standards were generally achieved with carded cotton raw material. Carded cotton and cotton with a considerably reduced percentage of noil was processed in air-jet spinning.

The addition of TENCEL® to cotton will also have a positive impact on yarn tenacity and elongation, and thus on spinning stability (Fig. 8).

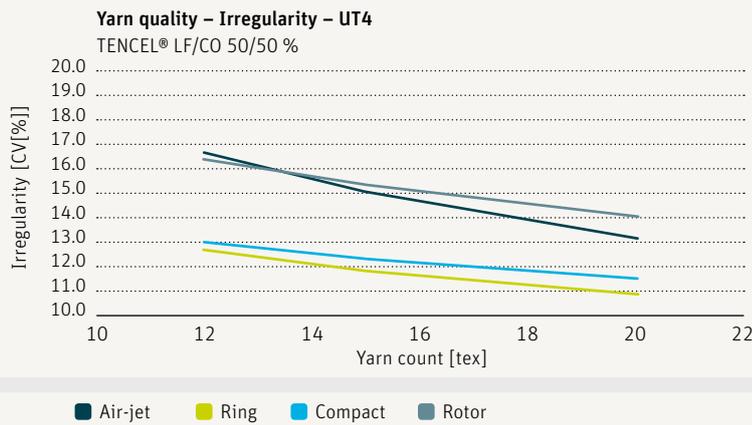


Fig. 9

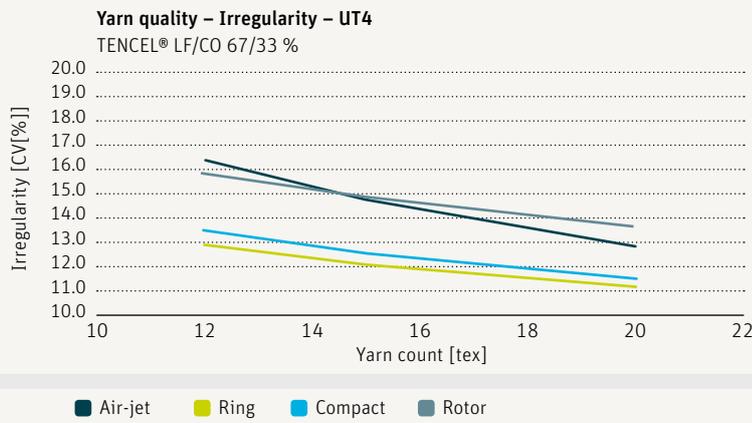


Fig. 10

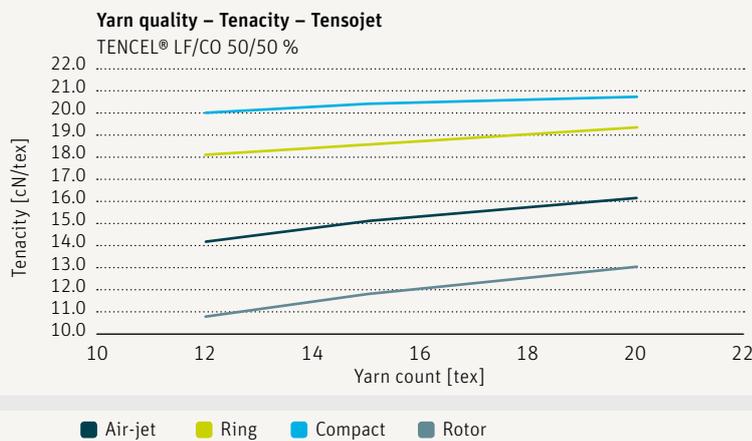


Fig. 11

Yarn results

YARN IRREGULARITY

Due to the specific yarn structures in air-jet and rotor spinning, irregularity values are some 30 % higher than for ring spinning. With increasingly fine yarn counts, yarn irregularity values deteriorate to the same degree in all spinning processes, i.e. yarn irregularity increases with a declining number of fibers in the yarn cross section. (Fig. 9).

The measuring methods available for ascertaining yarn quality, especially irregularity, are essential for quality assurance and optimizing machine settings. However, in the case of new yarn structures it must be ensured that, for example, high yarn irregularity does not at the same time result in optically uneven fabric appearance. Especially in the case of yarn irregularity measurements, irregularities related to the yarn structure are also reflected in the readings. Due to the specific yarn structure, the effect of this on the textile fabric is by no means disturbing, since the visual appearance of the textile is evened out in this way.

Numerous studies of rotor-spun yarn have already shown that the textile fabric displays high density of the surface and regularity due to the larger diameter of the yarn compared to a ring-spun yarn. The diameter of a rotor-spun yarn is also determined, of course, by technology components, such as the shape of the rotor groove, rotor diameter and rotor speed. These technology elements and the relevant machine settings determine whether the general advantages of a rotor-spun yarn structure are clearly apparent in the textile end product.

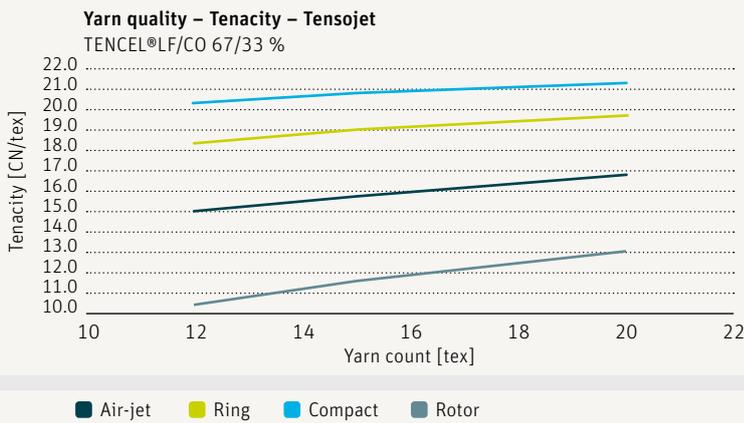


Fig. 12

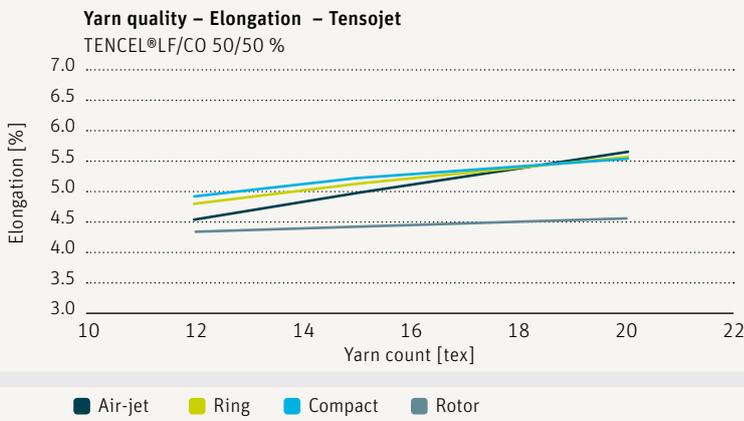


Fig. 13

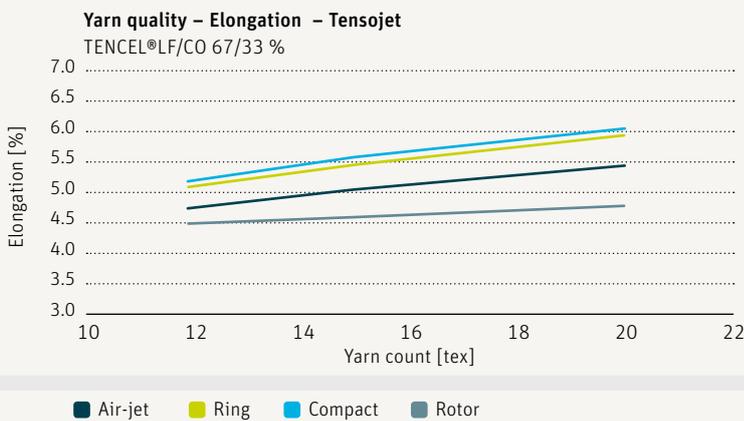


Fig. 14

The numerous tests conducted with air-jet-spun yarns in comparison to rotor-spun yarns show the same relationships between yarn irregularity measurements and optical uniformity in the fabric (Fig. 10).

YARN TENACITY AND ELONGATION

The structure of the air-jet-spun yarn consists of core fibers without significant twist and covering fibers with a genuine twist which ultimately produces the corresponding yarn tenacity. The specific yarn structure results in a yarn tenacity between that of a ring-spun yarn and of a rotor-spun yarn. The very high yarn tenacity of a compact yarn cannot be achieved by any other spinning system due to its virtually total integration of fibers into the yarn strand and the simultaneous, complete twisting of the fibers (Fig. 11, 12).

Due to their yarn structure, air-jet-spun yarns display good yarn elongation values equaling those of ring-spun yarns, depending on yarn count and raw material. The elongation of air-jet-spun yarns are also reflected in a good processing behavior of the yarns (Fig. 13, 14).

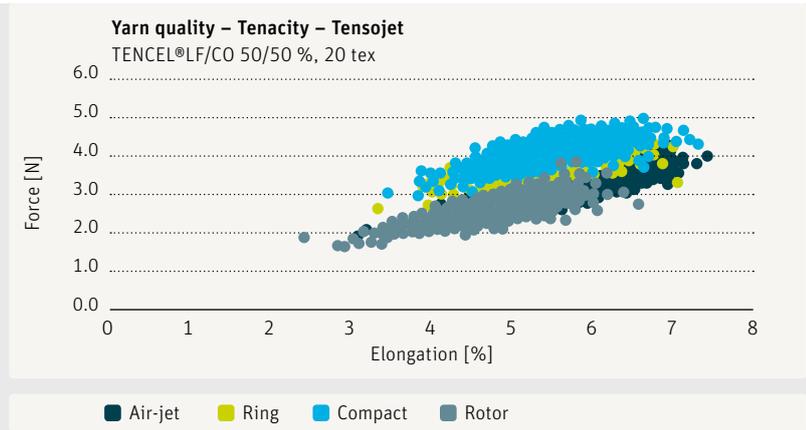


Fig. 15

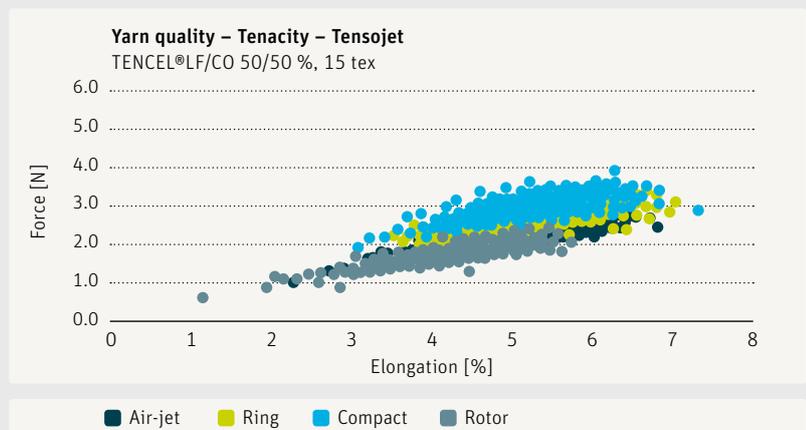


Fig. 16

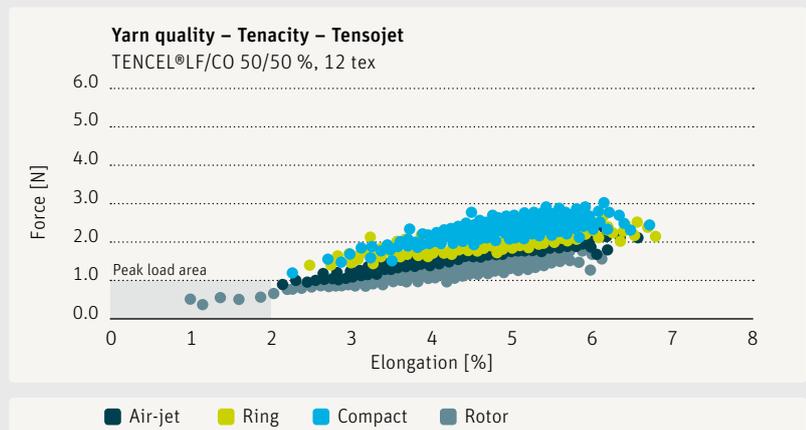


Fig. 17

In addition to the mean yarn tenacity, measurement using the Tensojet system provides important information regarding any weak points in the yarn. Weak points in the yarn are ultimately also decisive for good downstream processing of the yarns, especially in warp preparation and weaving itself. The coarser the yarns, the further the weak points in the yarn are from a yarn strain peak. The measured values of the air-jet-spun yarns indicate that the distribution of tenacity and elongation readings compared to existing spinning processes is in the normal range (Fig. 15).

The finer the yarns, the higher the scatter in yarn tenacity and elongation. Brief yarn strain peaks can result in yarn breakages. This means that the finer the yarn, the more important is a small degree of scatter in yarn tenacity and elongation (Fig. 16).

With a yarn count of 12 tex (Ne 50), minor erratic values in tenacity and elongation are apparent in the air-jet-spun yarn. It can be deduced from this that downstream processing of the yarn in this yarn count range is possible without any difficulty. Rotor spinning reaches its spinning limits for the raw material in question with this yarn count (Fig. 17).

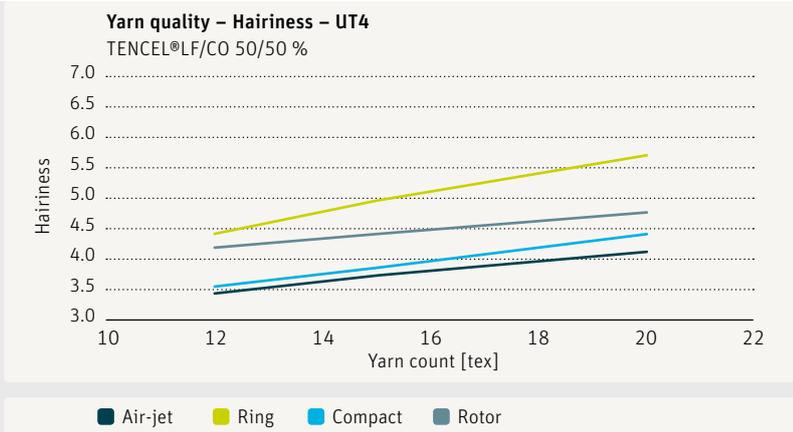


Fig. 18



Fig. 19



Fig. 20

YARN HAIRINESS, ABRASION AND WEAR RESISTANCE

Compared to existing spinning processes, air-jet-spun yarn displays the lowest hairiness. The spinning process and the yarn structure obtained as a result create new possibilities in downstream processing of the yarn which are complementary compare to yarns of established spinning processes.

The advantages of low hairiness range from cost savings in the knitting process to unique advantages in the textile product in terms of:

- abrasion
- wear resistance
- pilling
- washfastness (Fig. 18).

Yarn abrasion is directly related to yarn hairiness and the integration of the fibers in the yarn strand. One advantage of air-jet-spun yarn becomes clearly apparent here. Lower abrasion will result in significantly less soiling and less fiber fly during downstream processing of the yarns. Cleaning intervals on the machines could therefore be extended (Fig. 19, 20).

Reutlinger Webtester

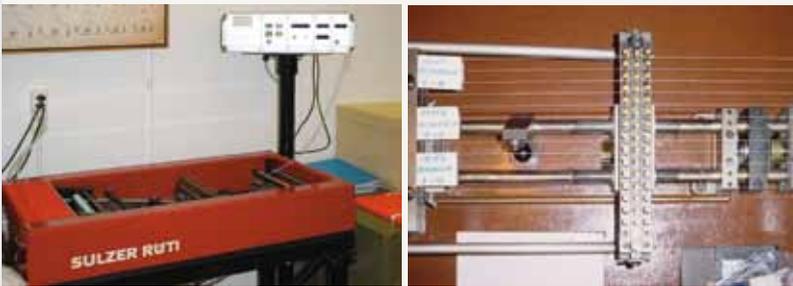


Fig. 21

The abrasion resistance of the yarns is a further important criterion in subsequent process stages of downstream processing of the yarns and their serviceability properties in the textile fabric. For this purpose the resistance of the yarns at a given number of wear cycles on the yarn strand was measured using the “Reutlingen Webtester”. This test allows simulation of the abrasion resistance of yarns. This is of special interest when yarns are used as warp. These readings are, however, also an excellent criterion of precise fiber integration in the yarn. It can also be assumed in this case that a abrasion resistant yarn brings advantages not only in the weaving process, but also at all downstream processing stages right up to the properties of the textile fabric (Fig. 21).

Yarn quality – Abrasion resistance – Reutlinger Webtester

TENCEL®LF/CO 50/50 %, 20 tex

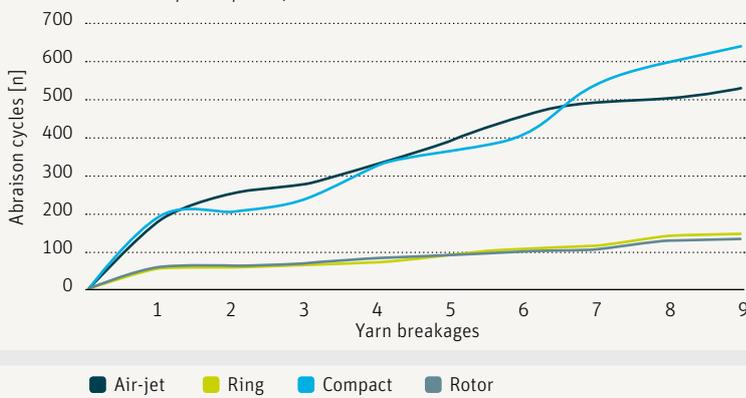


Fig. 22

The abrasion resistance of air-jet-spun yarn in a fiber blend of 50/50 TENCEL® / cotton is comparable with that of a compact yarn (Fig. 22).

Yarn quality – Yarn structure – Reutlinger Webtester

TENCEL®LF/CO 50/50 %, 20 tex

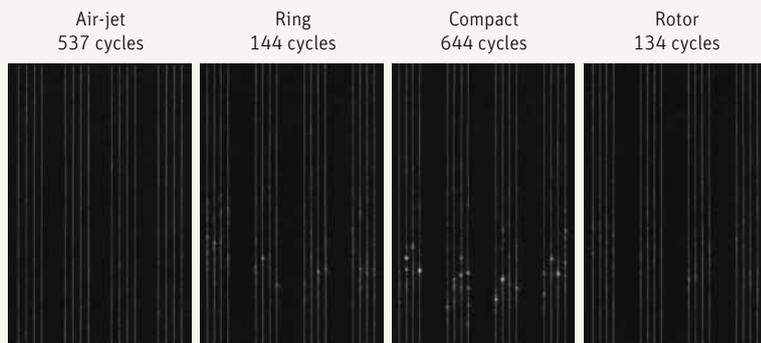


Fig. 23

After establishing the maximum number of abrasion cycles until shortly before a yarn breakage, visual appearance with regard to fiber sloughing must also be observed. air-jet-spun yarns displayed the best results. Up to a maximum of 537 abrasion cycles virtually no fiber sloughing had occurred. Rotor-spun yarns also displayed no fiber sloughing up to the conclusion of testing (Fig. 23).

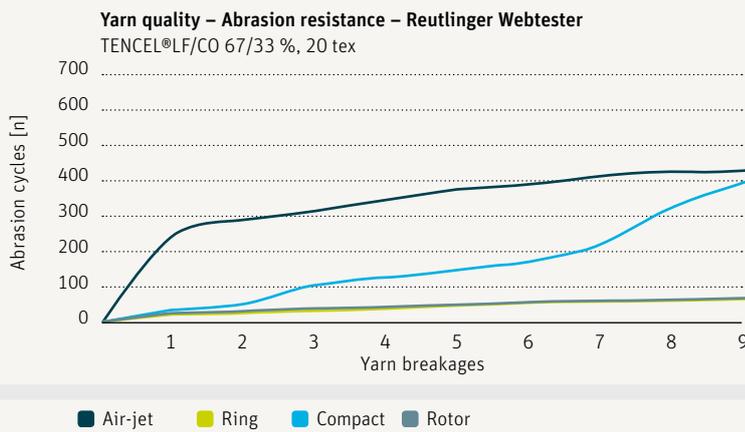


Fig. 24

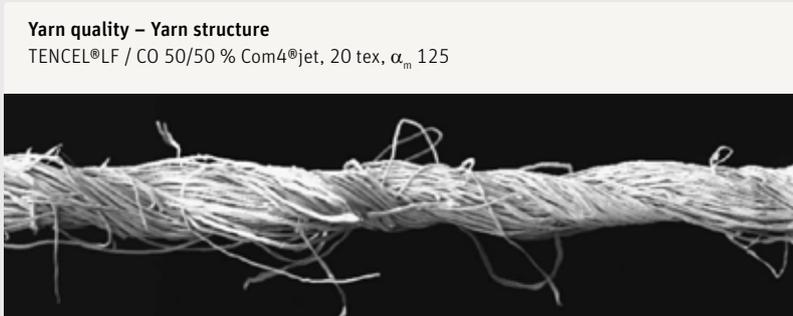


Fig. 25

Abrasion cycles in all final spinning processes decline with increased TENCEL® content in the blend. Due to the yarn structure of an air-jet-spun yarn, the influence of the raw material blend on abrasion resistance is secondary. Irrespective of raw material composition, air-jet-spun yarns achieved the best abrasion resistance values in all tests conducted to date (Fig. 24).

YARN STRUCTURE

If the yarn structure is examined more closely, most physical properties of the yarn and the end product are easily explained. Air-jet-spun yarns are characterized by their specific structure featuring core and covering fibers. The fiber ends are mostly integrated in the yarn strand. It is virtually impossible for fiber loops of this kind to form fiber pills, despite mechanical stress.

The microscopic image shows a wavy surface structure. This structure is formed by the packages of covering fibers which compress the core fibers. As far as is known to date, this is probably one of the main reasons for the outstandingly uniform appearance of the surface structure and the excellent density of the surface in the end product, despite the higher yarn irregularity (Fig. 25).

The different final spinning processes display the following variations in yarn structure, taking the 50/50 TENCEL® LF / cotton blend as an example:

- The air-jet-spun yarn with its parallel core fibers and its covering fibers resembling ring-spun yarn, and its low hairiness.
- The ring-spun yarn with its completely twisted fibers and conventional hairiness.
- The compact yarn with its completely twisted fibers, lean yarn strand and reduced hairiness.
- The rotor-spun yarn with its greater yarn bulk and belly bands which hold the fiber strand together, even with shorter fibers, and prevent fiber sloughing.

The variations in yarn structure between the different final spinning processes are very clearly apparent. Each spinning process displays specific advantages due to the different yarn structures (Fig. 26).

Yarn quality – Yarn structure

TENCEL® LF / CO 50/50 %, 20 tex

Com4®jet
α_m 125



Com4®ring
α_m 110



Com4®compact
α_m 110



Com4®rotor
α_m 125



Fig. 26

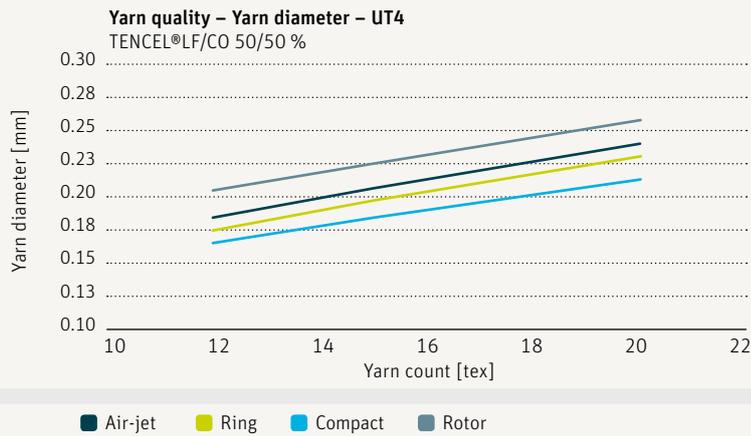


Fig. 27

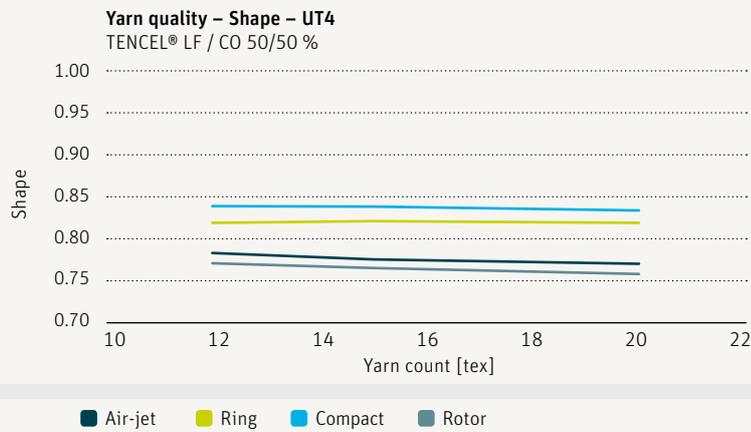


Fig. 28

All existing spinning processes create yarns of different structures, yarn diameters and shapes. The optical uniformity of an end product is affected by the structure and diameter of a yarn. A larger yarn diameter with the same yarn count demonstrably exerts a positive influence on the optical uniformity of the end product. In the case of rotor-spun yarn, more bulky yarns and thus larger yarn diameters are achieved by the appropriate choice of technology components and settings, in particular rotor speed. Good density of the fabric surface is therefore achieved in the end product with rotor-spun yarns by means of larger yarn diameters, whereas with air-jet-spun yarns this is achieved primarily via the typical yarn structure. High density of the surface in the knitted fabric usually plays a significant role in the positive evaluation of a knitted fabric (Fig. 27).

The best yarn shape (roundness) is achieved by means of ring spinning technology, especially with compact yarns. In addition to hairiness, this yarn shape also affects light reflectance and – in conjunction with this – brilliance in textile fabrics, i.e. brilliance is highest with compact yarns (Fig. 28).

Properties in downstream processing (knitting)

PRODUCING AND FINISHING KNITTED FABRICS

The characteristics, i.e. properties of yarns influence the properties of the textiles. The relevant yarn values measured are usually reflected in the textile fabric. Despite the many possible ways of ascertaining yarn properties, the actual effects of yarns on textile fabrics must be verified and confirmed. Furthermore, not all yarn values relevant for downstream processing of the yarn can be measured. Nor is the sum of the yarn properties or their interaction always clearly predictable.

Experience teaches us that conclusions regarding the appearance of a textile fabric can be drawn only to a limited extent from the results of measurements such as yarn irregularity. It must also not be forgotten that the properties of woven and knitted fabrics depend not only on yarn properties, but that the structure of the end product and the processes used exert a significant influence.

Past experience has shown us that the standards imposed on the properties of textile fabrics have risen continuously and are still rising. This is true both for qualitative demands on the textile product and also for requirements in terms of the functional features and wearability of the textile in question.

Both large retailers and consumers have continuously raised their demands on the quality of textiles over the course of time. The following example shows the present requirements of a large-scale purchaser (Marks & Spencer) in respect of knitted fabrics:

Parameter	Test method DIN EN ISO	Requirement
Washing (60°C)	DIN EN 26330	Length - 7 % Width - 8 %
Pilling (Martindale)	EN ISO 12945-2	3 - 4 (2 000 T)
Burst pressure / strength	ISO 2960	170 kPa
Spirality		<20 mm
Visual appearance after washing	According to Lenzing	

WASHING

Pre-fixing

45 seconds at 195°C

Pre-washing

1 g/l Kieralon JET
 1 g/l sodium carbonate
 1 g/l Albaflow FFA
 1 g/l Persoftal L

20 minutes at 80°C
 Rinsing hot and cold

BLEACHING

3.0 g/l sodium carbonate
 2.0 g/l Kieralon MFB
 1.5 g/l Prestogen PL
 0.4 g/l magnesium chloride
 0.8 g/l Kappafos D11
 1.0 g/l Persoftal L
 3.0 ml/l hydrogen peroxide 50 %

Heating at 1°/min. up to 90°C - 45 minutes
 Cooling at 2°/min. to 70°C
 Rinsing hot and cold

Fig. 29 Finishing knitted fabrics

DYEING FORMULA: REACTIVE DYEING (STEAMING OFF)*

0.250 % Remazol Red 3B
 0.226 % Remazol Brilliant Blue BB 133 %
 50 g/l sodium sulphate
 1.5 g/l sodium carbonate ①
 3.5 g/l sodium carbonate ②
 1.0 g/l Albaflow FFA
 1.0 g/l Persoftal L

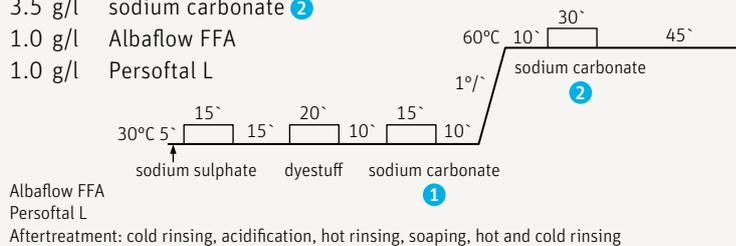


Fig. 30 Finishing knitted fabrics

HIGH-CLASS FINISHING WITH SYNTHETIC RESIN

50 g/l Knittex FEL
 17 g/l Knittex Kat. MO
 30 g/l Ultratex FMW
 1 g/l Leonil SR

Pick-up: approx. 90 %
 Drying out: 130°C
 Curing: 45 sec. at 175°C

Fig. 31 Finishing knitted fabrics

For final evaluation of a new or alternative spinning process it is therefore essential to conduct a comprehensive qualitative assessment of the textile fabrics which, for example, are manufactured from the yarns produced by a new spinning process.

Due to their product characteristics, knitted fabrics are an excellent medium for examining the influences exerted by yarns and their impact on properties of the end products in question. The different types of yarns produced from TENCEL® / cotton blends were therefore processed into single jersey fabrics. In single jersey-based knitted fabrics even very small yarn irregularities disturb the appearance of the knitted fabric. Faults in the fabric are therefore very easy to detect.

Yarns in counts of 20 dtex (Ne 30) were used in downstream processing. The yarns were processed on two different knitting machines. The circular knitting machines are the current state of the art in knitting machine design.

A part of the yarns was processed on a Terrot SCC 548 knitting machine with E 28 gauge. The fabric weight was specified at 150 g/m². The yarns produced from both TENCEL® / cotton blends were also plated and knitted with a 22 dtex elastane fiber. In relation to the yarn count and depending on the knitting machine setting, the elastane content amounted to approx. 2 - 3 %. Other knitted fabrics were processed on an Orizio John/C circular knitting machine with E 24 gauge into a fabric weight of 110 g/m².

The knitted fabrics were then finished, i.e. washed, bleached, dyed and given a surface finishing treatment (Fig. 29 - 31).

As we have already stated, in order to compare different spinning technologies the textile fabrics should also be evaluated after finishing and with respect to certain critical serviceability values in addition to an evaluation of the yarns. In this specific case the following criteria, which are customary and typical in practice, were taken into consideration for evaluating the knitted fabrics:

- dimensional stability after washing cycles
- stitch skew (twist)
- burst pressure
- pilling on the gray fabric, the finished fabric, and after one washing cycle
- appearance after washing

DIMENSIONAL STABILITY AFTER WASHING

In order to evaluate dimensional stability all knitted fabrics were washed at a temperature of 60°C using a household washing machine as stipulated in DIN EN ISO 26330 and then dried in a tumble dryer. Dimensional stability was measured after 1, 5, 10, 15 and 25 washing cycles.

In all knitted fabrics tested, irrespective of the fiber blend used or the type of knitted fabric (e.g. plated), the rotor-spun yarn and the air-jet-spun yarn displayed the best dimensional stability in the knitted fabric, in both the length and the width. This is true for dimensional stability both after the first and after the 25th washing cycle (Fig. 32, 33).

STITCH SKEW

The skew of stitch courses depends in principle on the twist factor of the yarns and the number of systems used in knitting. The higher the twist factor of the yarns and the higher the number of systems, the more pronounced the stitch skew in the knitted fabric.

The tendency of the yarns to produce skewed stitches can be reduced by a steaming process. On knitting machines with a high number of systems the tendency to produce skewed stitches cannot be eliminated completely, even by a steaming process.

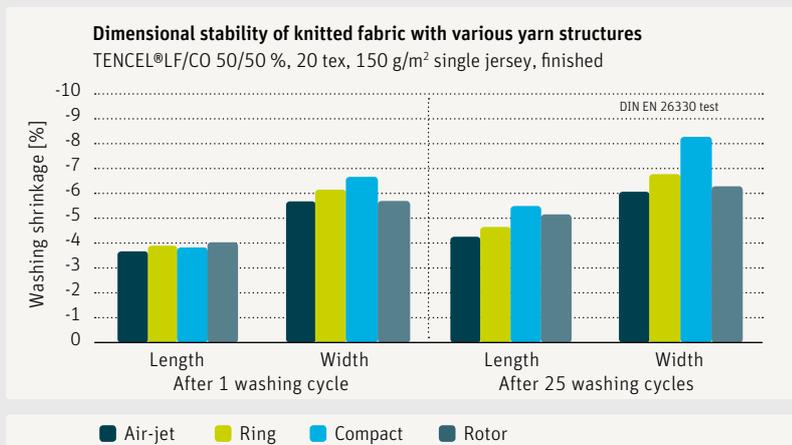


Fig. 32

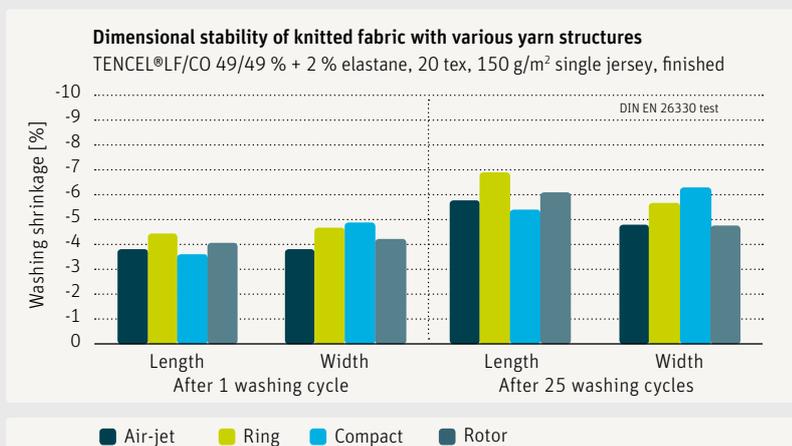


Fig. 33

Another method of reducing stitch skew is to process yarns with different directions of twist (S/Z) together. However, this involves considerable logistical effort in procuring and storing yarns.

BURST PRESSURE

Burst pressure is measured as stipulated in DIN EN ISO 13938-2. In practice, measurements are not always made as stipulated in this standard. This leads to widely differing absolute measuring results and thus to confusion when evaluat-

ing the measuring results. As is to be expected, burst pressure is influenced by yarn tenacity and thus by the specific spinning process used. Higher yarn tenacity thus also results in higher burst pressure. Burst pressure is also influenced by the raw material.

Knitted fabrics with a higher TENCEL® content of 67 % display higher yarn tenacity and correspondingly higher burst pressure in the fabric compared to knitted fabrics made from a 50/50 TENCEL® / cotton blend. The addition of a higher proportion of TENCEL® results in higher burst pressure due to the higher fiber tenacity of TENCEL® compared to cotton.

Summarizing, the following can be stated:

- The compact yarns display the highest yarn tenacity, i.e. burst strength.
- Knitted fabrics made from rotor-spun yarn display the lowest burst strength. The reason for this is to be found in the structure of rotor-spun yarn, which features low utilization of fiber tenacity.
- The tenacity values of air-jet-spun yarns lie between those of ring-spun and rotor-spun yarns. The burst pressure of knitted fabrics made from air-jet-spun yarns is therefore higher than that of knitted fabrics made from rotor-spun yarns, but lower than that of knitted fabrics made from conventional ring-spun or compact yarns.

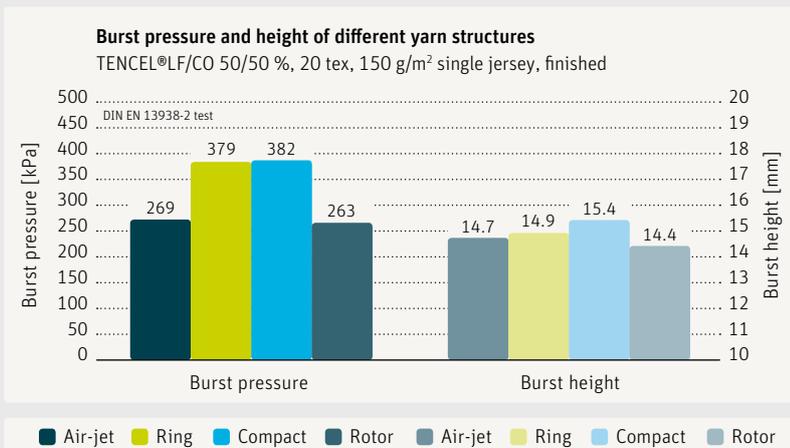


Fig. 34

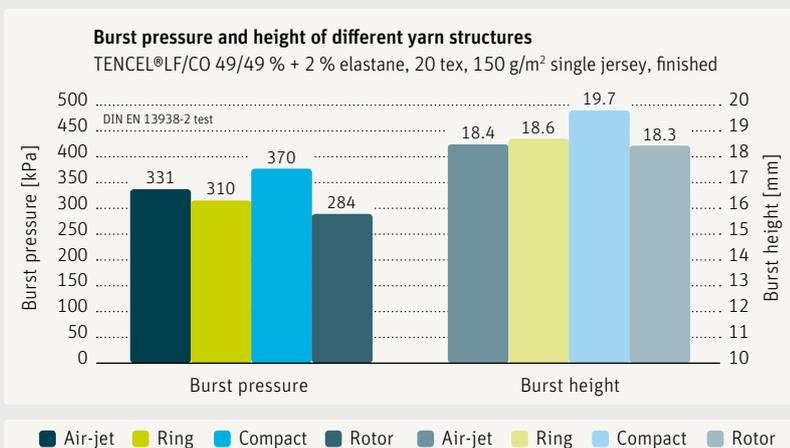


Fig. 35

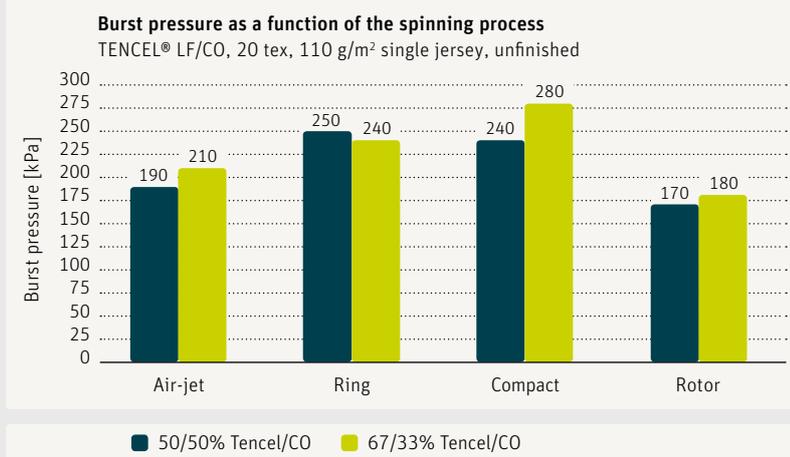


Fig. 36

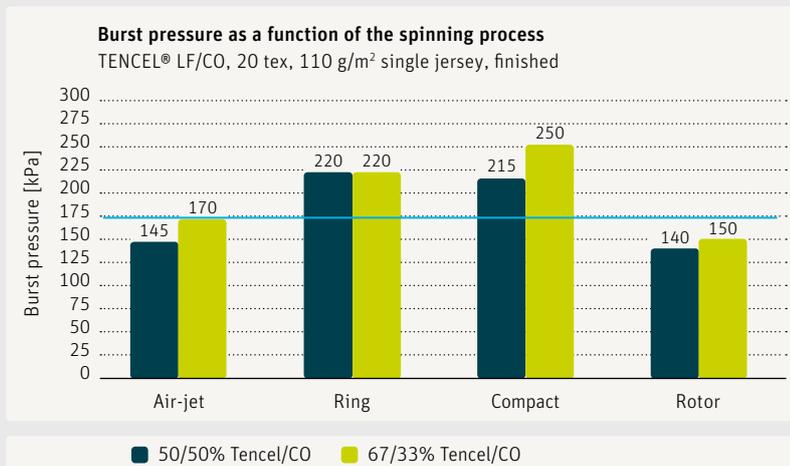


Fig. 37

- It is clearly apparent that in knitting the addition of elastane has a positive impact on maximum burst pressure and also burst height. Conversely, however, this means that the influence of yarn structure on burst pressure is reduced by plating (Fig. 34, 35).

In tests with a fabric weight per unit area of 110 g/m², the burst pressure also indicated very clearly the differences arising between the unfinished and the finished material. Unfortunately, textile finishing usually results in a significant loss in tenacity of the yarns and the textile end product due to chemical stresses. In these products burst pressure declined by approx. 30 kPa in ring-spun and rotor-spun yarns, and by as much as 40 kPa in air-jet-spun yarns as a result of the finishing process (Fig. 36, 37).

This is an indication that the manufacturing process in downstream processing and finishing must also be adapted in the product development of textiles using new yarn manufacturing processes.

PILLING

Pilling behavior in the textile fabric, especially in knitted fabrics, is one of the most important quality criteria. End products that already display pilling after a short time drastically devalue quality and are therefore unwelcome. Pilling is therefore a constant topic and can be influenced significantly by low yarn hairiness and the yarn structure.

Pilling occurs when fibers protruding from the knitted fabric develop into nops of different sizes due to mechanical stress during wearing. As soon as they become clearly visible due to their size and frequency, they have a negative impact on the appearance of the knitted fabric.

Measuring pilling behavior is therefore very important for the qualitative evaluation of knitted fabrics. The Martindale and ICI Box testing methods (DIN EN ISO 12945-2 and DIN EN SO 12945-1, respectively) are customary in mill operations. In order to avoid diluting the impact of the different yarn structures, pilling tests were performed on the knitted fabrics without elastane (Fig. 38).

In the ICI pilling test using the pilling box method, the pilling behavior of the knitted fabric was ascertained in the finished state (incl. synthetic resin) before and after household washing at 60°C with subsequent tumble drying.

All knitted fabrics displayed very good pilling values before washing. The pilling values are certainly also affected by the finished methods chosen. However, the evaluation nevertheless shows that the pilling values of non-plated knitted fabrics in the case of air-jet-spun and rotor-spun yarns were 0.5 - 1 pilling grade better throughout than knitted fabrics made from classical ring-spun and compact yarns (Fig. 39).

Martindale pilling tests conducted at the same time, in which no synthetic resin was used in finishing the knitted fabrics, showed the same picture. The knitted fabric produced from air-jet-spun yarn again displayed the best pilling values, followed by the knitted fabric made from rotor-spun yarn. Knitted fabrics made from "classical" ring-spun yarn and compact yarn also had pilling grades 1 - 1.5 lower in this test (Fig. 40).



Fig. 38

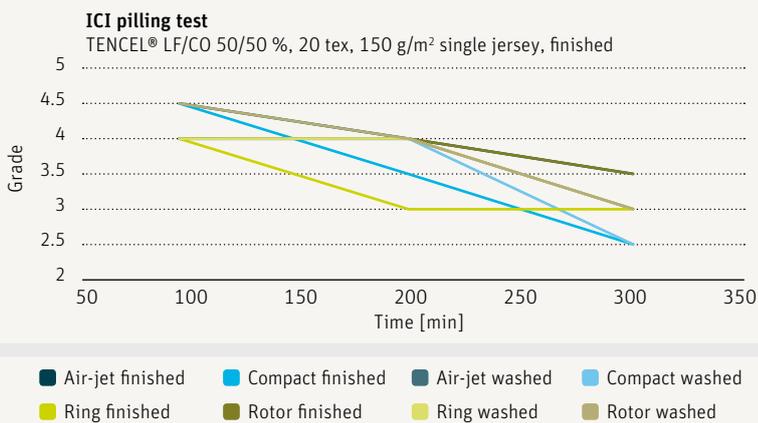


Fig. 39

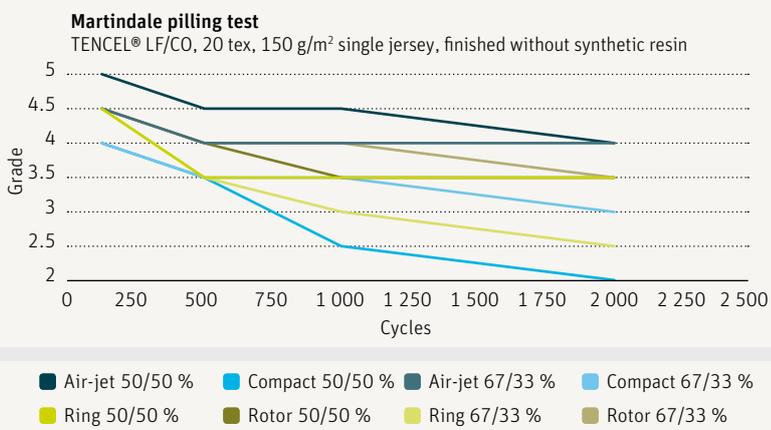


Fig. 40

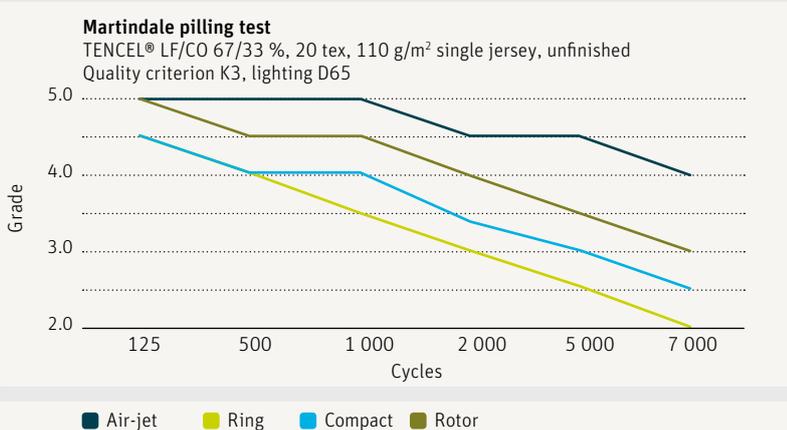


Fig. 41

Pilling evaluation of unfinished and finished material with a fabric weight of 110 g/m² also showed the best values in knitted fabric made from air-jet-spun yarn (Fig. 41).

No differences could be detected between the other three spinning systems when analyzing the finished material. As we have already said, the pilling behavior of knitted fabrics can be improved significantly by means of correspondingly complicated finishing processes.

APPEARANCE AFTER WASHING

The washing process, the mechanics of the washing processes and the detergents used in each case have a clear influence on changes in the surface of a knitted fabric and its appearance. The appraisal by Lenzing of the surface of textiles before and after washing seeks to make a visual assessment of changes in the surface of the specimens and to record and describe these in a grading system.

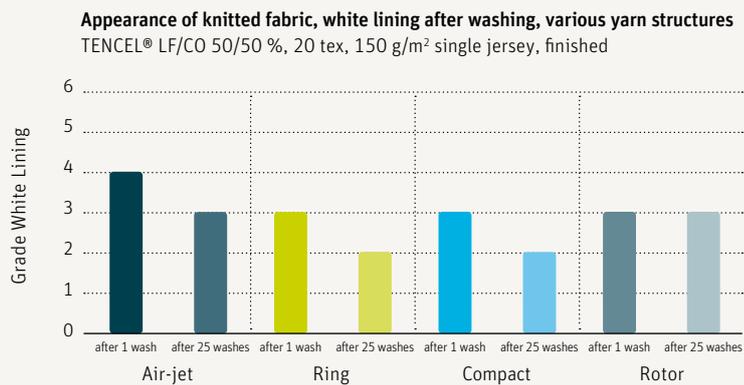


Fig. 42

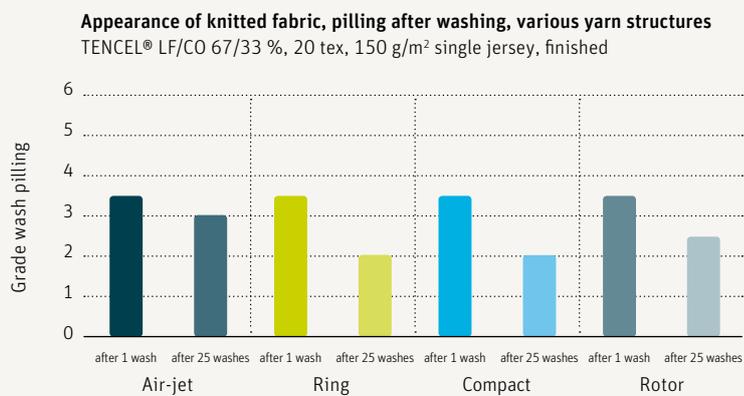


Fig. 43

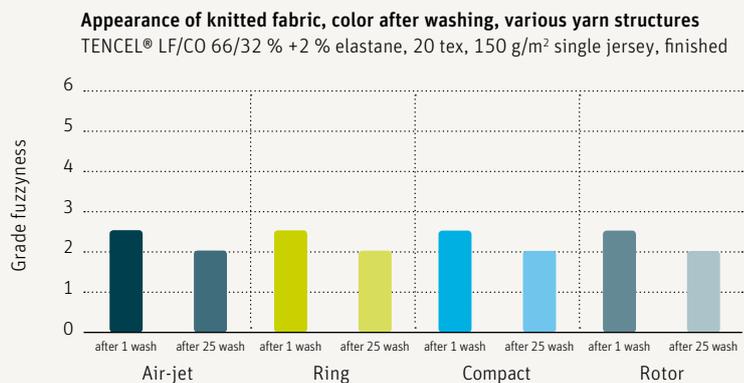


Fig. 44

As with pilling evaluation, the changes were graded on a scale of 1 to 5. In this evaluation grade 1 signifies a large change, while grade 5 indicates a minimal change in the textile surface.

- The evaluation criteria are defined as follows:
- Change in the surface due to napping and the formation of creases from washing.
 - Pilling after washing.
 - Change in color, for example due to a change in hairiness on the surface.

The tests already showed a change in appearance after the first washing cycle in all knitted fabrics examined. After 25 washing cycles all types of yarn and both raw material versions display a clear deterioration in appearance. However, knitted fabrics produced from air-jet-spun yarns displayed the smallest changes after the washing cycles, followed by knitted fabrics made from rotor-spun yarns. This effect was most pronounced with the 67/33 fiber blend. All knitted fabrics with elastane also have a clearly positive influence on appearance after washing, irrespective of yarn type (Fig. 42 - 44).

Changes in fabric appearance between the unwashed state and after 25 washing cycles are also clearly recognizable in microscopic images of the 67/33 blend without elastane. It can be stated that items made from ring-spun or compact yarns displayed a clearer change in the appearance of the textile fabric in all test criteria than knitted fabrics produced from air-jet-spun and rotor-spun yarns (Fig. 45 - 52).

Appearance of knitted fabric

Com4®jet yarn
TENCEL® LF/CO 67/33 %, 20 tex, 150 g/m² single jersey, finished

unwashed

after 25 washing cycles

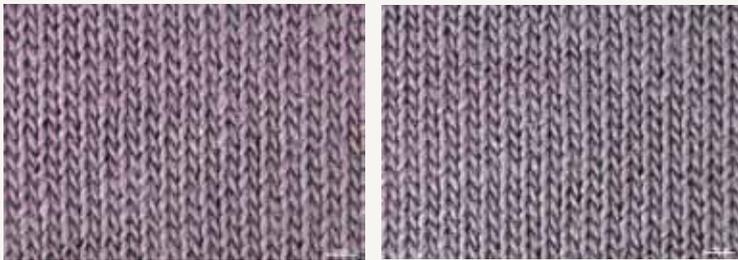
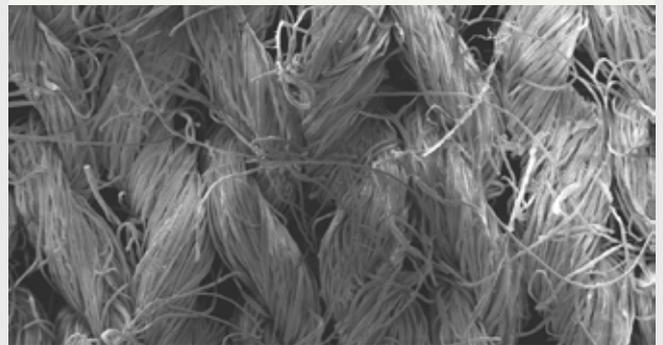


Fig. 45

Appearance of knitted fabric

Com4®jet yarn
TENCEL® LF/CO 67/33 %, 20 tex, 150 g/m² single jersey, finished



08/0280/2561 dyed, unwashed 50x

Fig. 46

Appearance of knitted fabric

Com4®ring yarn
TENCEL® LF/CO 67/33 %, 20 tex, 150 g/m² single jersey, finished

unwashed

after 25 washing cycles

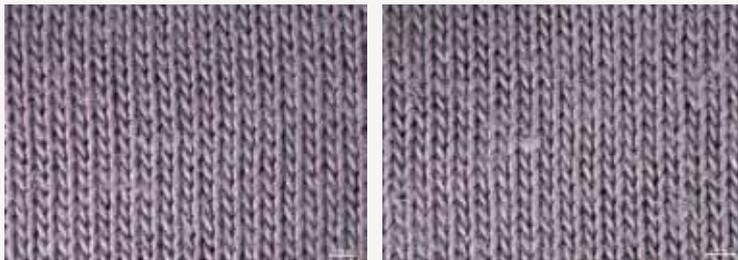
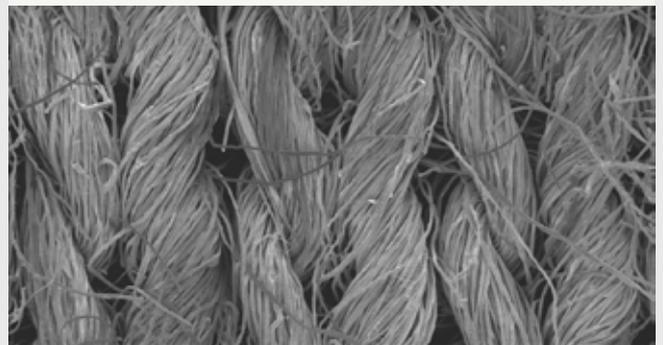


Fig. 47

Appearance of knitted fabric

Com4®ring yarn
TENCEL® LF/CO 67/33 %, 20 tex, 150 g/m² single jersey, finished



08/0280/2559 dyed, unwashed 50x

Fig. 48

Appearance of knitted fabric

Com4®compact yarn
TENCEL® LF/CO 67/33 %, 20 tex, 150 g/m² single jersey, finished

unwashed

after 25 washing cycles

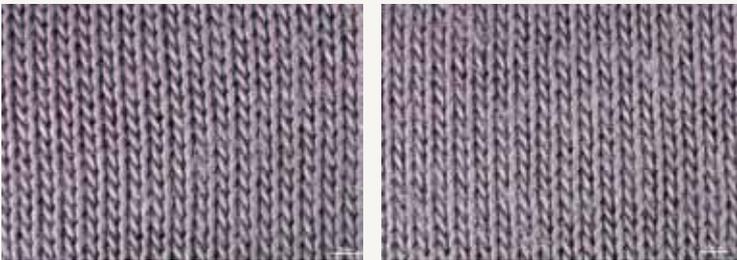
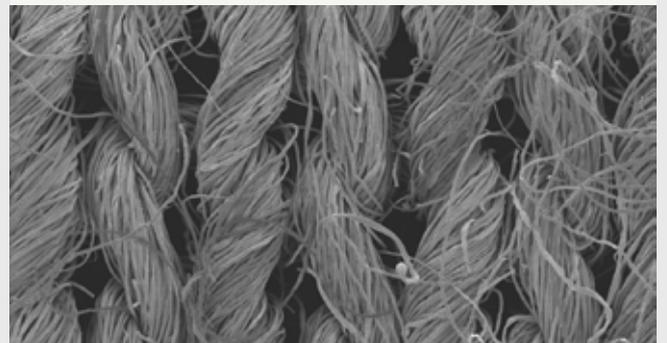


Fig. 49

Appearance of knitted fabric

Com4®compact yarn
TENCEL® LF/CO 67/33 %, 20 tex, 150 g/m² single jersey, finished



08/0280/2555 dyed, unwashed 50x

Fig. 50

Appearance of knitted fabric

Com4®rotor yarn
TENCEL® LF/CO 67/33 %, 20 tex, 150 g/m² single jersey, finished

unwashed

after 25 washing cycles

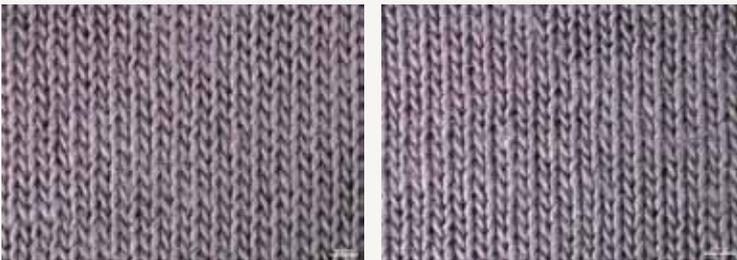
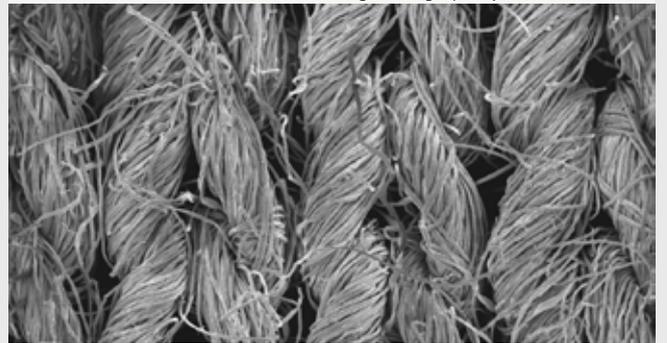


Fig. 51

Appearance of knitted fabric

Com4®rotor yarn
TENCEL® LF/CO 67/33 %, 20 tex, 150 g/m² single jersey, finished



08/0280/2557 dyed, unwashed 50x

Fig. 52

Economics and sphere of application

The appropriate sphere of application of air-jet spinning depends on the following influencing factors:

- yarn tenacity, dependent on yarn structure
- raw material, dependent on fiber length and purity
- quality of fiber preparation, dependent on optimum coordination and condition of the individual process stages
- economics, dependent on yarn manufacturing costs

An estimate of the potential sphere of application of air-jet-spun yarns already made in the year 2 000 has remained valid to this day. This diagram shows that this new spinning process can cover a feasible yarn count range of 10-30 tex (Ne 20-60) in technological and economic terms. However, this technological study is not in a position to make a statement on the future market share of this new spinning process (Fig. 53). Yarn manufacturing costs are lower than for the ring spinning process due to the higher delivery speed of the air-jet spinning system. Depending on yarn count, manufacturing costs lower than for the rotor spinning process are also possible. Economic considerations do not, of course, take into account any development effort that has to be expended on downstream processing of the yarn, for example, in order to exploit the unique advantages of air-jet spinning to the full.

Economic considerations are based on the following outline conditions:

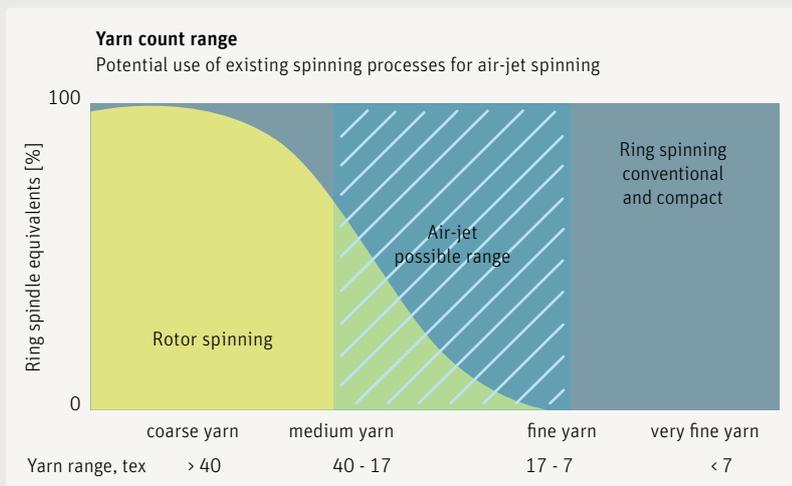


Fig. 53

Spinning system	Air-jet spinning J 10	Ring and compact spinning G 33 / K 44	Rotor spinning R 40
Spinning positions per machine	100	1 632	500
Delivery speed (m/min)			
20 tex (Ne 30)	380	23	129
15 tex (Ne 40)	380	18.7	107
12 tex (Ne 50)	380	16.8	79
Raw material	50/50 TENCEL® LF / cotton blend		
Spinning process	cotton 10% noil removal	cotton 17 % noil removal	cotton carded
System size	medium system size of 690 kg/h with optimum machine utilization		
Location	Indonesia		

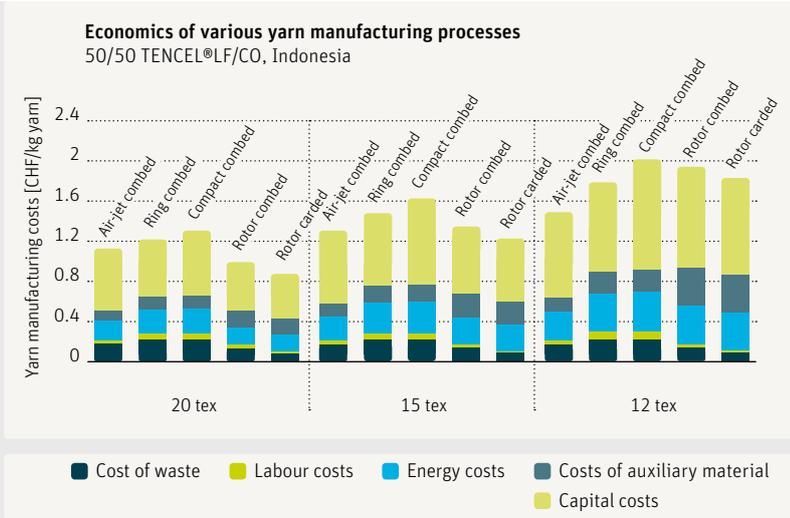


Fig. 54

The calculation shows that manufacturing costs, in addition to upstream processing, largely depend on yarn count and the resulting delivery speed (output). The maximum delivery speed in its turn depends on raw material, yarn structure, i.e. the spinning process, and the yarn tenacity achieved.

With a yarn count of 20 tex (Ne 30) the rotor spinning process displays the lowest manufacturing costs. Even if a combed cotton were to be used in the rotor spinning process, yarn manufacturing costs in this case would still be some 20 % lower than with the air-jet spinning process.

Only with yarn counts finer than 15 tex (Ne 40) are yarn manufacturing costs significantly lower with the air-jet spinning process than with the other spinning systems in this example. Market share is also affected in the long term by yarn manufacturing costs as well as the technological advantages. The challenges to achieve optimum spinnability of fine yarns using air-jet technology will thus increase in the long term due to its economic importance.

It can also be deduced from the economic considerations in this example that primarily the technological advantages of air-jet technology should be exploited and the focus directed toward developing specific end products (Fig. 54).

Summary

This study was conducted in the context of a cooperative venture between Lenzing and Rieter. It seeks to establish the properties of yarns produced using the air-jet spinning system and compares them with those of yarns produced using existing, established spinning systems (ring, compact and rotor spinning systems). In addition to yarn properties, characteristic differences in downstream processing of the yarns and in the textile fabrics (knitted fabrics) were also measured. Two different TENCEL® LF / cotton blends were used as raw material.

The different final spinning processes display the following differences in yarn structure, using the 50/50 TENCEL® LF / cotton blend as an example:

- The air-jet-spun yarn with its parallel core fibers and covering fibers resembling ring-spun yarn, and low hairiness.
- The ring-spun yarn with its completely twisted fibers and conventional hairiness.
- The compact yarn with its completely twisted fibers, lean yarn strand and reduced hairiness.
- The rotor-spun yarn with its greater bulk and belly bands which hold the fiber strand together, even with short fibers, and prevent fiber sloughing.

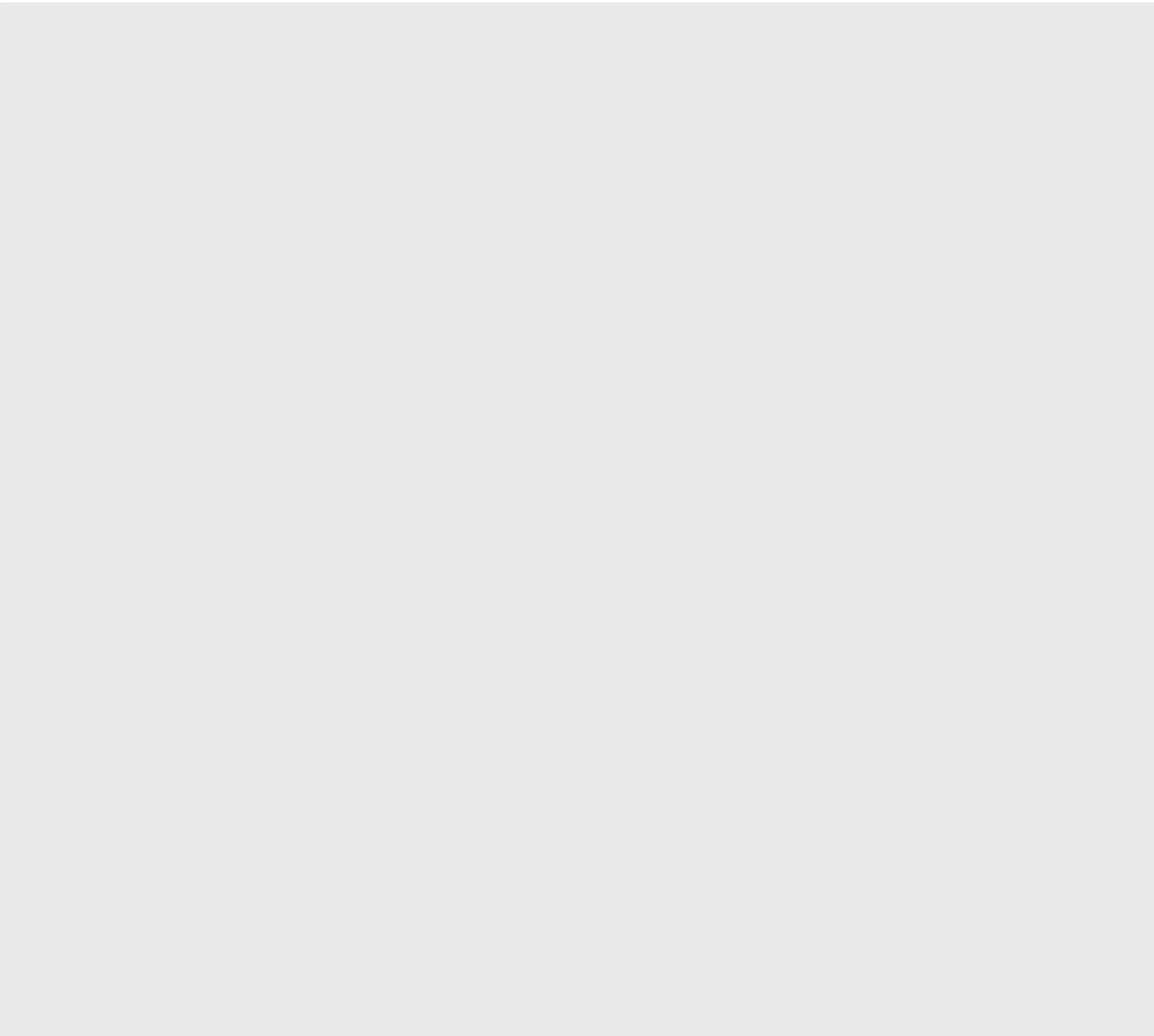
Compared to existing spinning processes, air-jet-spun yarn has the lowest hairiness. The spinning process and the resulting yarn structure create new possibilities in downstream processing of the yarn which complement the range of established spinning processes. The advantages of the specific yarn structure extend from any cost savings in downstream processing of the yarn to unique advantages in the textile product in terms of:

- fabric appearance
- abrasion resistance
- pilling
- washfastness.

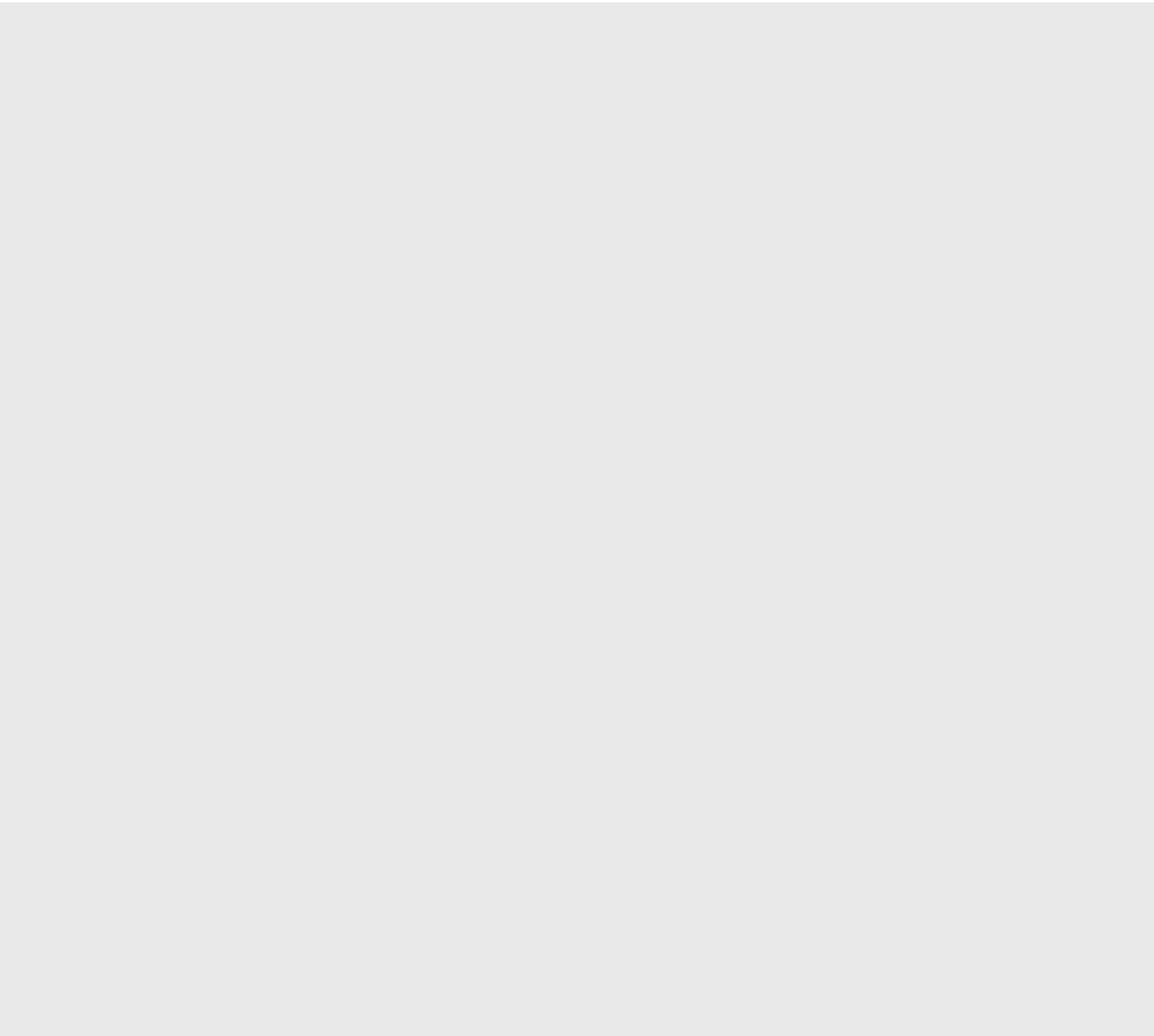
By virtue of their product characteristics, knitted fabrics are an excellent medium for examining the influence of yarns and their impact on the properties of the end product in question. For this reason the various types of yarn were processed into single jerseys. The properties of the different yarns are reflected in the examinations of the textile fabrics. Tests and measurements conducted on the knitted fabrics confirm and complement this on the basis of the different yarn structures. It was apparent that the properties of the end product can also be influenced by the type of downstream processing on the knitting machine, for example by plating with elastane, and by technically appropriate finishing processes.

As the study shows, the air-jet system can be used to manufacture not only yarns made from 100 % cellulose fibers, but also blends with a medium cotton quality (Yemen from 1 1/8"). Yarns and knitted fabrics meeting consumers' high quality standards were produced from blends with a 50 % cotton content.

The test results show that air-jet spinning will secure a significant market share in the medium and fine yarn count range in future.



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