Comparative Analysis of Cotton Yarn Properties Spun on Pneumatic Compact Spinning Systems

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Abstract
The article presents a comparative analysis of the properties of cotton yarn spun on three pneumatic compact spinning systems Rieter® K-44, Suessen® Elite and Toyota® RX-240. Combed compact cotton yarn with a linear density of 10 tex was spun on these compact spinning systems using medium staple cotton. The roving processed had the same technological and kinematical parameters. The quality parameters such as mass irregularity, the imperfection index (IPI), hairiness and tensile behavior of the compact spun yarns were tested and analysed. The results revealed that K-44 compact spun yarn had less mass variation, a low IPI value, less hairiness and high tensile properties compared to the other compact spinning systems employed in the present work.

Key words: *compact yarn, combed yarn, quality parameters, Rieter® K-44, Suessen® Elite, Toyota® RX-240.*

Introduction

The conversion of textile fibres into yarns is called spinning. Textile yarns can be classified on the basis of spinning techniques such as ring, compact, rotor, air jet and friction spun yarn [1]. The main purpose of a spinning technology is to achieve higher production with adequate yarn quality. Although ring is one of the leading spinning techniques, it is far behind in terms of yarn production. The low production is related to many limitations such as traveller speed, balloon tension, spindle speed and the spinning triangle. These limitations encouraged researchers to develop new spinning systems e.g. rotor, air jet and friction spinning. No doubt these spinning systems have a remarkable production edge over the ring spinning system but the characteristics of ring spun yarn are still matchless. That is why these spinning techniques could not replace ring spinning. Alternatively researchers have focused on enhancing the production of ring spinning by overcoming these limitations [2 - 4].

Dr. Fehrer focused on eliminating the spinning triangle. The spinning triangle is the region between the nip of delivery rollers and the twisted end of the yarn. It is the weakest point because there is no twist in this region. When drafted fibres leave the nip of the delivery roller, the outer edge fibres do not contribute to the yarn structure due to this triangle. It requires more twist in the yarn to achieve the strength desired. Dr. Fehrer eliminated the spinning triangle by condensing the fibre assembly in the spinning triangle zone. Consequently it increases the participation of outer edge fibres in the yarn body, which achieves the same yarn strength for a 20% less twist. The low twist level ultimately increased the yarn production [3 - 8].

Compact spinning eliminates the spinning triangle by condensing the fibres pneumatically or mechanically [9]. In pneumatic compacting, fibres in the spinning triangle zone are condensed by pneumatic compression. It controls the outer edge fibres of the spinning triangle, which then develops a compact yarn structure. This compact structure has less protruding fibres on the outer surface of the yarn. Consequently the hairiness of the yarn is reduced, which in turn increases the uniformity and strength of the yarn [2, 3, 6, 10 - 13]. This compact structure has significant advantages in spinning and subsequent processes. The breakage rate of the ring machine is reduced by up to 50%. It also reduces the breakage rate of warping and weaving machines. It increases warping and weaving production by increasing the efficiency of the machines. The size consumption of the sizing machine is reduced by up to 25 - 50%. The low degree of hairiness eliminates the singeing process and the consumption of dye is reduced in the dying process. Fabric woven from compact yarn has improved tensile strength, pilling and abrasion resistance [6, 7, 14].

It has been established to a large extent that the improved compact yarn properties are related to the change in structure such as higher migration and packing density as compared to the ring yarn structure [15 - 18]. Many researchers have either focused on the comparison of conventional ring spun yarn properties with compact spun yarn properties or compared yarn properties of different pneumatic compact spinning systems e.g. Rieter, Suessen, Zinser [2 - 4, 6, 10, 14, 17].

The aim of this study was to compare 100% cotton yarn properties with a linear density of 10 tex spun on Rieter® K-44, Suessen® Elite and Toyota® RX-240 compact spinning systems, with the processed roving having the same technological and kinematical parameters.

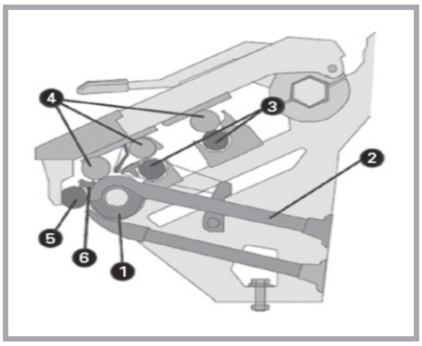

Figure 1. Rieter compact spinning principle [1, 4]; 1) perforated drum, 2) suction system, 3) bottom roller, 4) top roller, 5) nip roller, 6) air guide element.

Khurshid MF, Nadeem K, Asad M, Chaudhry MA, Amanullah M. Comparative Analysis of Cotton Yarn Properties Spun on Pneumatic Compact Spinning Systems.
FIBRES & TEXTILES in Eastern Europe 2013; 21, 5(101): 30-34.

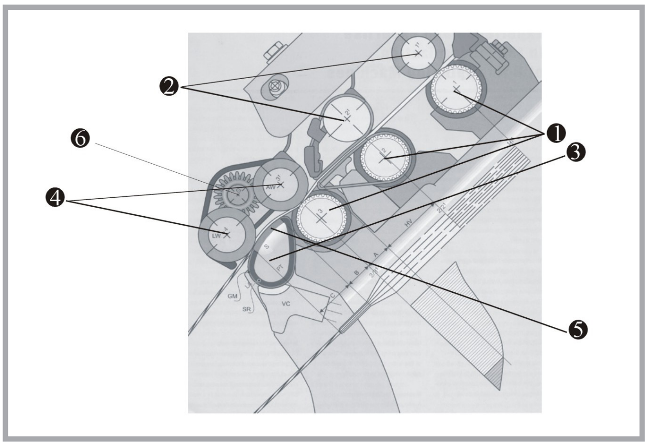

Figure 2. Suessen compact spinning principle [1, 3, 18]; 1) bottom rollers, 2) top rollers, 3) suction slot, 4) front top rollers, 5) air permeable lattice apron, 6) carrier wheel.

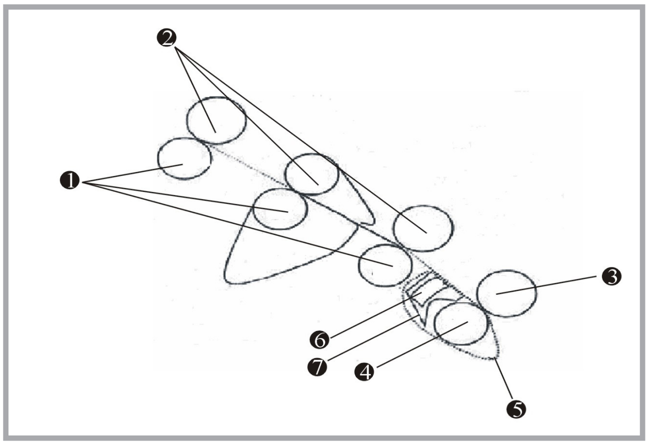

Figure 3. Suessen compact spinning principle [19]; 1) bottom rollers, 2) top rollers, 3) top front rollers, 4) mesh apron roller, 5) mesh apron, 6) suction slot, 7) suction bar.

To the best of the author's knowledge, Toyota is compared for the first time in this study.

Comparison of the three compacting principles

The Rieter compact spinning system (see ***Figure 1***) consists of a perforated drum, air guide element and suction system. The perforated drum is an alteration of the 3/3 double apron standard drafting system by adding an extra nip roller. The purpose of this additional nip roller is to prevent the propagation of twist to the condensing zone and to reduce the size of the spinning triangle. The perforated drum condenses all the fibres after main drafting through air currents. This condensing controls the fibres in the spinning triangle region, which enhances maximum participation of fibres in the yarn structure [1, 4].

The Sussen Elite compact spinning system (see ***Figure 2***) introduces an additional drafting zone in the 3/3 double apron standard drafting system. This additional drafting zone consists of an air permeable lattice apron and suction slot. This air permeable lattice apron slides over the suction slot. The fibres that leave the nip of the front are then condensed by the negative pressure of the suction slot. It has an incline against the flow of fibres. Both the front top roller and delivery top roller are mounted in a housing and are connected with the help of a carrier wheel. This can set a tension draft (1.065) between these two rollers [1, 3, 18]. The Toyota compact spinning system (see ***Figure 3***) has an alteration in the 3/3 double apron standard drafting system. This system has a condensing unit which consists of a mesh apron and suction slot. This condensing unit is driven by the front bottom roller with a positive drive mechanism, specially designed by Toyota. The fibre stream that entered in the condensing zone is compacted by the mesh apron,, which is under negative pressure [19].

Experimental design

Material

The raw material used to spin 10 tex combed weaving yarn is a blend of Ghiza, Indian and Tajic cotton. The cotton bales were opened and mixed manually. The mixed cotton was conditioned for 24 hours under 40% relative humidity (RH). Cotton samples were tested under standard atmospheric conditions 20 ± 2 °C and 65% RH) on a High Volume Instrument (HVI). The average cotton results of this blend are given in ***Table 1***.

Method

A medium capacity spinning mill named "FCM Ltd Pakistan" was selected for the present study. This mill is designed for the spinning of fine count. This mill consists of state of the art machinery, which was imported from the world's leading manufacturer (Rieter, Suessen, Toyota and Schalafhorst). The back process machinery of the mill is from Rieter, except the roving, which is from Toyota. The ring and compact machinery are from the Rieter, Toyota and Suessen companies. Roving of 590 tex with 49.2 t.p.m is processed on a standard spinning machinery setup with the same technological and kinematical parameters (roving was processed on the same roving frames with similar spinning plans). ***Figure 4*** (see page 32) shows the flow chart of the machinery setup.

Combed compact weaving yarn with a linear density of 10tex was spun on Rieter K-44, Toyota RX-240 and Suessen Elite compact spinning systems with the technological and kinematical parameters as given in ***Table 2***. Quality parameters such as mass irregularity, the imperfection index (IPI) and hairiness were measured with an Uster Tester-4. The tensile properties such as tenacity in cN/tex, elongation in % and B-work (work of rupture) were tested on an Uster Tenso Jet-4 under standard atmospheric conditions (20 ± 2 **°C** and 65% RH).

Results and discussion

The results of measurements of the irregularity, imperfection index, hairiness and tensile behaviour of cotton yarn (with linear density of 10 tex) spun on a Rieter K-44, Suessen Elite and Toyota RX-240 are given in ***Table 3*** (see page 32).

Table 1. *Properties of cotton fibres.*

Cotton parameter	Mean
Spinning consistency index (SCI)	150
Fineness, mtex	157
Maturity index (Mat)	0.88
Length, mm	30.7
Uniformity index (Unf)	83.77
Short Fibre index (SFI)	8.15
Strength (Str), cN/tex	31.50
Elongation (Elg), %	7.58
Moisture (Moist) %	6.36
Reflectance (Rd)	75.3
Yellowness (+b)	8.6

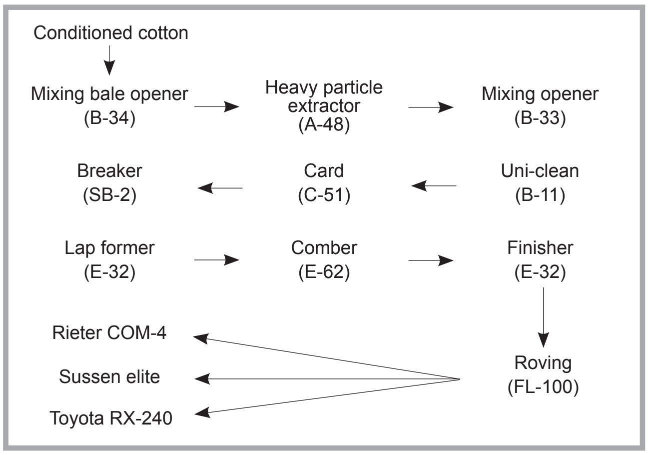

***Figure 4.** Flow chart of spinning process.*

Comparison of yarn irregularity (unevenness)

Yarn unevenness can be defined as the variation in weight per unit length of the yarn or as the variation in thickness thereof. The Uster tester measures the thickness variation of a yarn by measuring capacitance. The irregularity (unevenness) of mass indicates the amount of overall mass variation in % from the mean mass of the sample tested [20, 21].

Both the irregularity and coefficient of variation of irregularity (CVm) of the compact yarn (with linear density of 10 tex) spun on a K-44 machine are 3.8% and 3% higher than that spun with RX-240 and Suessen Elite compacting machines, respectively (see ***Figure 5***). However, the coefficient of variation of irregularity (CV10m %) of Suessen compact yarn is better compared to K-44 and RX-240 compact spun yarn (see ***Figure 6***). There is a slight improvement in yarn irregularity (0.4%). The significance of this small improvement in fabric appearance is well known to spinners.

***Table 2.** Technological and kinematical parameters of compacting systems.*

Parameters	Compact spinning machine		
	Rieter COM-4	Toyota RX	Sussen Elite
Yarn linear density, tex	10		
Roving linear density, tex	590		
Spindle speed, r.p.m	21800		
Yarn twist per meter	1056	1125	1136
Top roller (Rubber Cots)	Accotex		
Drafting gauge, mm	54 - 70	44 - 58	
Back draft	1.15	1.18	
Spacer	Rieter, Grey (2.75)	SKF, Yellow (2.50)	
Cradle load	0.30 MPa	14 kg	
Lattice Apron type	Suction Drum	Original	
Lattice Apron density, holes/cm^2	Suction Drum	3,000	
Ring diameter, mm	36		
Traveller type	C1SELUdr, 14/0		R+F EL1 hd wwd 17/0

***Table 3.** Comparison of the properties of yarns made of 100% cotton fibres.*

Yarn quality parameter	Unit	Rieter	Toyota	Suessen
Irregularity	Uster U%	10.63	11.03	10.96
CV of irregularity	Uster CVm%	13.46	13.97	13.85
CV of irregularity	Uster CV 10 m%	2.40	2.39	2.30
Thin places -50%	Thin -50%/km	8	11	18
Thick places +50%	Thick +50%/km	56	73.5	54.5
Neps +200%	Neps +200%/km	152	167.5	146.5
Imperfection index (IPI)	Uster	216	252	219
Hairiness	Uster H	3.05	3.27	3.25
B- Force	cN	221.3	206.7	208.5
Tenacity	cN/tex	22.84	21.34	21.36
Elongation	%	3.21	3.26	3.19
B-Work	cN·cm	218	209	205

Comparison of imperfection index (IPI)

The imperfection index (IPI) is the sum of yarn thin places (-50), thick places (+50) and neps (+200) per kilometer. There is no change in the values of thin places and neps of compact yarn spun on K-44 and Suessen compact spinning systems. K-44 compact spun yarn has 31% fewer thick places as compared to that spun on RX-240. Consequently, the yarn spun by K-44 compact spinning has 16.5% less IPI as compared to that spun by RX-240 compact spinning. However, the IPI value obtained from K-44 and Suessen were observed to be the same (***Figure 7***).

Comparison of yarn hairiness

On the Uster tester, hairiness is the ratio of the total length of protruding fibres (in centimeters) per centimeter of yarn [20, 21]. The yarn spun by K-44 compact spinning has 6.5% less hairiness compared to that spun by RX-240 and suessen elite compact spinning, which indicates that K-44 compact spinning produces a better integrated structure of yarn than the RX-240 and Suessen Elite compact spinning systems (see ***Figure 8***).

Comparison of tensile properties of yarn

The breaking force represents the tensile strength. It is a measure of the steady force necessary to break the specimen and is given experimentally by the maximum load developed in a tensile test [19, 22]. The breaking force of K-44 compact spun yarn has a 6.5% higher value than that for RX-240 and Suessen compact spun yarn.

The tenacity is defined as the ratio of force per unit linear density. It is also measured in terms of rupture per kilometer (Rkm). It is defined as the theoretical length of a specimen of yarn whose own weight would exert a force to break the specimen of yarn [19, 22, 23]. The tenacity of K-44 compact spun yarn also has a 6.5% higher value than that for RX-240 compact yarn and Suessen compact spun yarn, meaning that fibres are better condensed in the K-44 compacting system. A higher strength is a reflection of better fibre migration in compact spun yarn [15, 18].

The B-work (work to break) represents the work of rupture. It is also the measure of the modulus of toughness (energy needed to break the specimen in a tensile test). The B-work is calculated by meas-

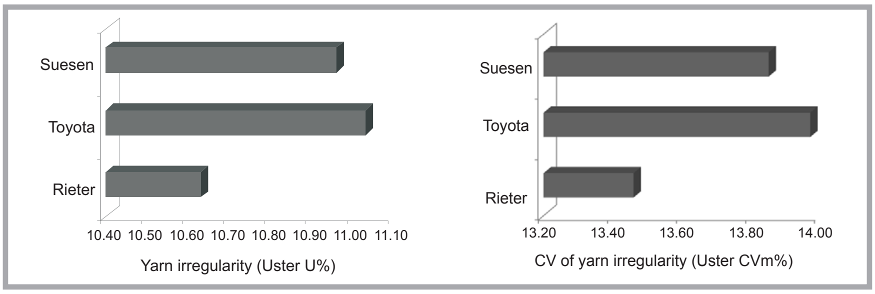

Figure 5. *Comparisons of yarn irregularity and CV of irregularity.*

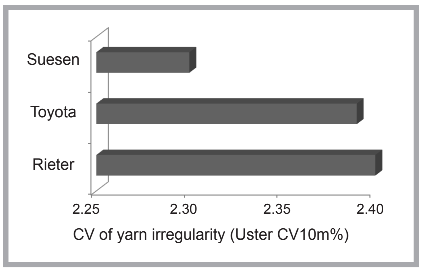

Figure 6. *Comparisons of CV of irregularity (CV10m %).*

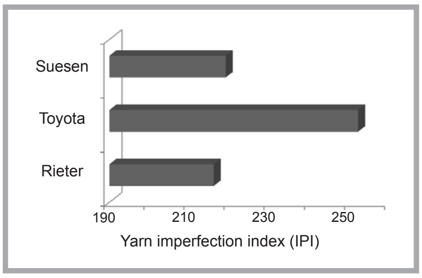

Figure 7. *Comparisons of yarn imperfection index.*

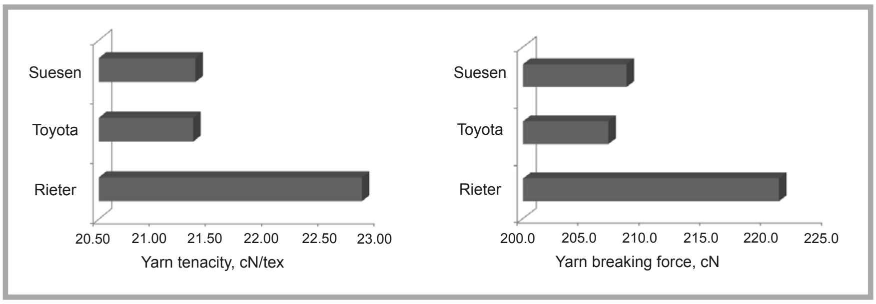

Figure 9. *Comparisons of yarn tenacity and B-force.*

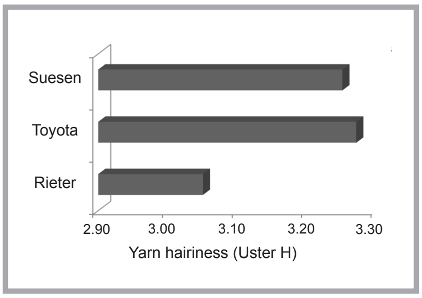

Figure 8. *Comparison of yarn hairiness.*

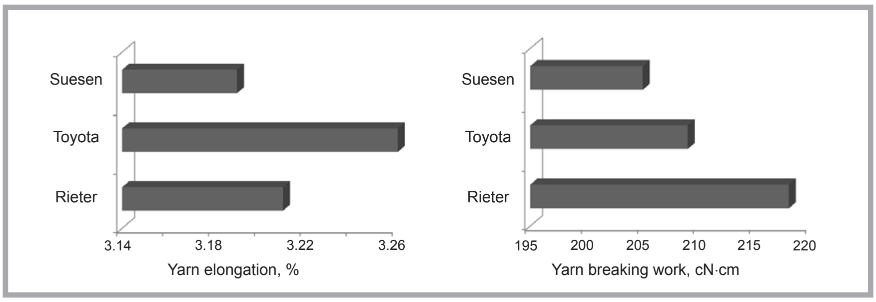

Figure 10. *Comparisons of yarn elongation and B-work.*

uring the area under the force-elongation curve at the time of break of the specimen [20, 22, 23]. The results showed that K-44 compact spun yarn has a 6 and 4.3% greater B-work value compared to that for Suessen and RX-240 compact spun yarn, respectively (see ***Figure 9***).

The elongation percentage is defined as the ratio of elongation of the specimen to the initial length thereof expressed as a percentage. It is also known as the extension percentage [19, 22]. RX-240 compact spun yarn has a slightly higher elongation percentage value compared to that for K-44 and Suessen compact spun yarn. However, there is no change in elongation % of Rieter and Suessen compact spun yarn (see ***Figure 10***).

Conclusion

The properties of combed cotton yarn with a linear density of 10 tex spun on K-44, Suessen® Elite and RX-240 compact spinning systems were investigated. It is concluded that:

- K-44 compact spun yarn was the most effective in terms of irregularity, the CV of irregularity (CV m), IPI, hairiness, tenacity,breaking force and work of rupture as compared to the other two compact spinning systems chosen
- RX-240 compact spun yarn was the most effective in terms of the elongation percentage as compared to K-44 and Suessen compact yarn.
- Suessen compact spun yarn was also the most effective in terms of the CV of irregularity (CV 10 m) compared to K-44 and RX-240 compact yarn

It is also concluded from the properties of compact yarn that the perforated drum compacting system is better for the spinning of 10 tex yarn compared to the apron or lattice type condensing systems.

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Received 09.07.2012 Reviewed 11.03.2013