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Comparative assessment of Eli-Twist and TFO yarns

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An attempt has been made to compare the properties of Eli-Twist yarn with those of conventional TFO yarn. Yarns of three compositions (100% Polyester, 50/50 Polyester/Cotton and 100% Cotton) were produced on Eli-Twist and ring spinning systems. Three different counts (39.4tex, 29.5tex and 23.6tex) from each composition have been produced, maintaining 40 twist factor for all the yarns. Hairiness, tensile strength, breaking extension, diameter, abrasion resistance and coefficient of friction have been measured and then compared with those of conventional ring-spun TFO yarn. The mass irregularity and imperfections are found more or less similar in both the yarns, while Eli-Twist yarn exhibits higher breaking strength and breaking extension. Both coefficient of friction and abrasion resistance of Eli-Twist yarn are found to be low as compared to ring- spun TFO yarn.

Keywords: Cotton, Eli-Twist yarn, Polyester, Relative resistance index, Ring-spun yarn, TFO yarn, Yarn hairiness

1 Introduction

The quest for new spinning system aiming economic production of quality yarn has given birth of various successful spinning technologies for producing staple fibre yarn. The aim was to develop an alternative spinning system which may replace ring spinning with a superior quality of yarn[1]. Many developed technologies, however, failed to offer any real challenge to the ring spinning system. Most of the new technologies showed inherent problem of catering only a narrow count range and most importantly, the quality of yarn was never found superior to that of the ring-spun yarn. Though Siro and compact spinning systems can produce superior quality yarn but both the technologies are considered as a derivative of ring spinning system. In recent years, Eli-Twist spinning system offered by Suessen has drawn some attention in the industry[2-4]. However, this spinning technology can also be considered as derivative of the age old ring spinning technology.

In most of the application areas, a yarn not only needs to be uniform but also be strong enough to withstand various kinds of forces to be applied during processing and in use[5]. Doubling at the preparatory stage can improve mass uniformity, while doubling at the post spinning stage leads to improvement in both mass and strength variability. The mechanical and physical properties of yarn are primarily influenced by the parameters pertaining to raw material, process and machine. Improvement in mass irregularity and mechanical properties during post spinning stage is possible through doubling and/or suitable finishing process[6, 7]. Eli-Twist spinning system offers a unique opportunity to exploit advantages of both Siro and compact spinning systems through fibre doubling during spinning, while compaction of the structure is assisted by air suction. There is a conflicting view on doubling at fibre stage and at yarn stage. Fibre doubling, due to the possibility of randomization, is believed to provide more improvement than doubling at yarn stage. The later process, however, leads to a reduction in hairiness alongwith the improvement in mechanical properties[8]. In the Eli-Twist spinning system, applied air suction helps in reducing hairiness and better integration of fibre, resulting in improvement in mechanical properties as well.

The process of fibre integration in four spinning systems, as illustrated in Fig. 1, represents the technological difference employed by various machine manufacturers in the yarn formation zone.

The present study attempts to analyse the properties of Eli-Twist yarn and then compare it with TFO yarn.

2 Materials and Methods

2.1 Materials

Polyester and cotton fibres were used to produce homogeneous and blended yarns. Polyester fibres of

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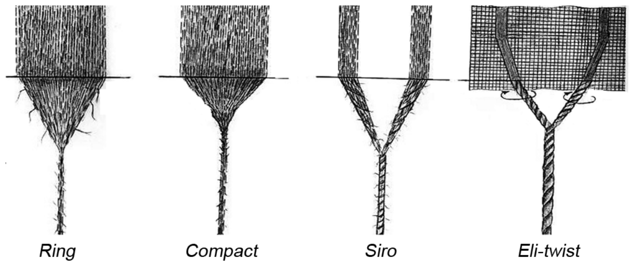

Fig. 1 — Spinning triangle for different spinning systems

1.2 denier fineness and 38mm fibre length; and cotton fibres (H-4) of 1.5 denier (4.2 micronaire) and 30mm fibre length were used.

The Eli-Twist yarns were produced on Elite compact set ring frame (LR60/AX) from Suessen. Single yarns were spun on a Lakshmi spinning line and doubled on a Saurer compact twist TFO machine. All yarns were spun using 40 twist factor. To produce Eli-Twist yarn, the distance between the two roving strands in drafting system was kept at 8 mm and a negative pressure of 30 mbar was maintained. Three different compositions [100% polyester (P), 50/50 P/C and 100% cotton (C)] were taken to produce 3 different counts (39.4tex, 29.5tex and 23.6 tex) from each composition. The design plan of experiment is given in Table 1. A total of 18 yarns were produced for the study.

Table 1 — Design plan of experiment

Factor	Level		
	-1	0	1
Linear density, tex	23.6 (2/50 Ne)	29.5 (2/40 Ne)	39.4 (2/30 Ne)
Blend	Cotton	50/50 P/C	Polyester

2.2 Testing Methods

The yarns were conditioned for 24h under standard tropical atmosphere of 65±2% RH and 27±2^{o}C temperature. The number of test for each parameter was taken to ensure the result to remain within 95% confidence limit.

2.2.1 Unevenness and Imperfection

The unevenness was measured on Uster Evenness Tester-5, which simultaneously measures the hairiness and imperfections (thin places, thick places and neps).

2.2.2 Tensile Testing of Yarn

Zwick universal tensile tester was used to measure the tensile properties. The yarns were tested at 120 mm/min extension rate using a gauze length of 250 mm (ASTM D 2256). At least 30 readings were taken for each sample to get the result at 95% confidence limit.

2.2.3 Yarn Abrasion Resistance

The abrasion resistance of the yarns was tested on yarn abrasion tester following ASTM D-4157. The abrasion resistance has been expressed in terms of number of strokes required to rupture the yarns completely. The sheet consisting of 20 yarns was kept pressed at constant tension against the cylinder wrapped with an abrader. The yarns were abraded by the cylinder surface while it oscillates at constant speed and stops when all the yarns break. For each sample at least 30 readings were taken to get the results at 95% confidence level. Barella (1990) introduced an index 'Relative Resistance Index' (RRI) by converting the average number of strokes including both the linear density of the yarn and the applied pretension. The RRI, used to compare the resistance of yarns varying in linear density, was calculated using the following equation:

$$\text{RRI}=\frac{\text{No of strokes}\times\text{Pre-tension (g)}}{\sqrt{\text{Linear density (tex)}}}$$

2.2.4 Yarn Diameter

The diameter of yarn was measured by optical method using Leica image analyzer. At least 100 readings were taken for each sample.

2.2.5 Coefficient of Friction

Uster Zweigle Friction Tester 5 was used to measure the fibre to metal friction. The instrument used classical friction measurement principle and was based on the force required to move a yarn horizontally through a disc tensioner. A constant force was applied to the upper disc while the yarn was passed through the disc plates, which, in turn, produced a defined force on the yarn in vertical direction (F_1); F_2 being the force required to pull the yarn. The friction coefficient (μ) can be calculated using the formula $F_2=\mu F_1$.

3 Results and Discussion

3.1 Unevenness and Imperfections

No significant difference in the unevenness and imperfections of both the yarns is observed (Table 2). While producing the Eli-Twist yarn, the feeding of two roves in the twisting zone results in fibre doubling which improves its mass regularity. In case of TFO yarn, doubling of two yarns also results in improvement in unevenness compared to a single yarn. The total imperfections of Eli-Twist yarn,

Table 2 — Unevenness and imperfections of yarns

Linear density, tex	Yarn composition	Unevenness		Total IPI	
		Eli-Twist	TFO	Eli-Twist	TFO
39.36	Polyester	6.35	6.09	22	8
39.36	50/50 P/C	7.19	7.05	28	23
39.36	Cotton	7.45	7.27	16	10
29.63	Polyester	6.9	7.44	14	12
29.63	50/50 P/C	7.81	7.64	26	21
29.63	Cotton	7.93	7.87	19	27
23.62	Polyester	7.02	8.26	15	6
23.62	50/50 P/C	8.89	9.23	46	39
23.62	Cotton	8.98	9.58	55	48

however, are marginally higher than that of TFO yarn. The increased level of imperfection in Eli-Twist yarn may be due to the difference in the stage of doubling and presence of additionally integrated fibre on the surface of yarn. In TFO yarn, on the other hand, doubling helps in hiding the imperfections of individual strands.

3.2 Hairiness

The hairiness of a yarn is due to fibre protrusion from the yarn surface. Hairs in a yarn can add to the problem in subsequent processing, though it provides a soft handle to the product. Trapping of protruded fibres from the surface of the yarn can be an effective measure to reduce hairiness. The suction provided in the twisting zone of Eli-Twist spinning system helps in integrating such fibres during yarn formation, while doubling of single yarns at the post spinning stage helps in trapping the protruded fibres at the interface of two single yarns.

Figure 2 represents the effect of different parameters on the hairiness of yarns. It is observed from the figure that the spinning system has significant influence on the level of hairiness. The hairiness of TFO yarn is found to be higher than that of Eli-Twist yarn. The ANOVA analysis shows that the effect of spinning system on yarn hairiness is significant. The reasons for higher hairiness in TFO yarn can be ascribed to the abrasive stresses on the yarn surfaces as mentioned below:

(i) In conventional ring spinning, strand width at the front roller nip is much wider than the final yarn diameter and as a result twist does not flow right up to nip of front roller, restricting the edge fibres from integrating well into the yarn structure.

(ii) Further, the yarn undergoes two additional processes i.e. cop to cone and cone to cheese conversion. The cheeses are the input package for

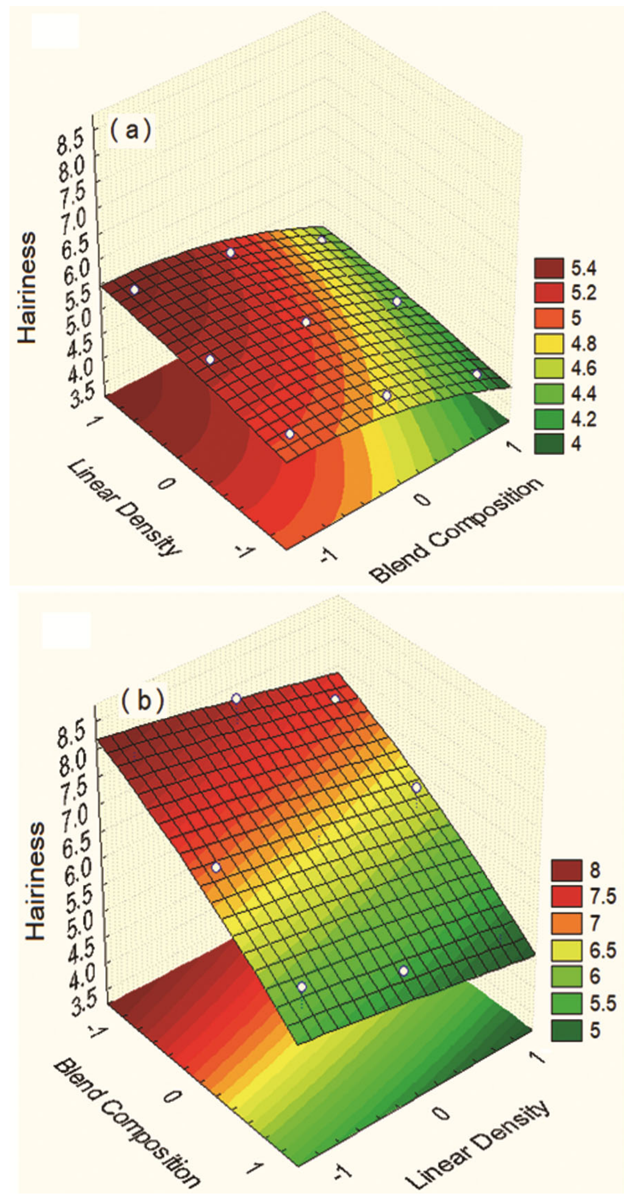

Fig. 2 — Influence of blend composition and linear density on hairiness of (a) Eli-Twist and (b) TFO yarns

TFO. In both the processes, the yarn is subjected to abrasion while passing over any machine part.

(iii) The ring yarn, meant for doubling in TFO, abrades with ring and traveller during its formation. The rotating yarn balloon also abrades with the lappet guide.

In Eli-Twist spinning system, the suction through the slot compels the fibres in the strand to be delivered in a straightened condition. Air drawn through the inclined slot causes rotation of fibres around the axis of the yarn and helps better integration of fibres into the main strand. The strand width is reduced and twist can flow closer to front roller nip, leading to a shorter spinning triangle. This facilitates the edge fibres for better integration into yarn body.

It is also observed from Fig. 2 that the hairiness of yarn increases with the change in yarn composition from 100% polyester to 100% cotton. The polyester fibre used in the study is longer (38 mm) than the cotton fibre (30 mm). Presence of shorter cotton fibre is also a source of hairiness in cotton and blended yarns. Presence of cotton fibre leads to an increase in hairiness in both yarns.

It is also observed that hairiness increases as the yarn becomes coarser, irrespective of composition. The ANOVA result indicates a significant contribution of linear density on hairiness. With an increase in yarn linear density (tex), surface area of yarn increases and thus the possibility of protruding fibre ends also increases. The difference in other fibre characteristics also influences its preferential location.

3.3 Diameter

The surface characteristics and appearance of a yarn influence the appearance of the product made out of it. For some specific application of a yarn, the uniformity of its diameter is also desired for improved process efficiency and product performance. The diameter of the yams is measured using an image analyser. The diameter is also calculated theoretically using the Pierce formula (1937); as shown below:

$$\text{Yarn diameter (mm)} = \frac{0.907}{\sqrt{\text{Count (Ne)}}}$$

The diameter of the cotton yarns spun on the two systems is given in Table 3.

The diameter is found to be influenced by the mode of yarn production and the fineness of yarn. It is also observed that the deviation in calculated value is more in case of TFO yarn than in case of Eli-Twist yarn. TFO yarns are Z over S twisted yarns. The reverse twisting causes the single yarns to loose twist, causing diameter of individual yarn to increase. As a result, the plied yarn diameter is greater than that of calculated ones. In Eli-Twist yarns, the components and the final yarn have twist in the same direction. Thus, there is no scope for the single component to loose twist. On the contrary, twist direction being same, they get compacted. The suction also compacts the drafted fibre ribbon before getting twisted. Therefore, we can expect its diameter to be smaller than the diameter calculated on the basis of Pierce's theory, where the yarn specific volume is assumed to be 1.1 cm^3/g. This is observed for finest yarn (23.5 tex). The other two Eli-Twist yarns do not show such trend. As, all the yarns are spun under identical suction pressure, the drafted ribbon in the case of coarser yarns could get compacted well due to large number of fibres. Thus, the final yarn shows greater diameter than calculated one.

The images of the two types of yarns are given in Fig. 3. The surface of Eli-Twist yarn appears to be smoother having very less number of protruded fibres. It is also evident from the images that Eli-Twist yarn has lower diameter than TFO yarns; presumably due to additional compactness of the structure. The

Table 3 — Measured and predicted diameters of yarns produced on different spinning systems

Yarn	Yarn linear density, tex	Yarn diameter, mm		Deviation, %
		Measured	Calculated	
Eli-Twist	39.36	0.26	0.234	9.92
Eli-Twist	29.63	0.23	0.203	11.82
Eli-Twist	23.53	0.17	0.181	-3.65
TFO	39.36	0.32	0.234	26.81
TFO	29.63	0.26	0.203	21.99
TFO	23.53	0.22	0.181	17.54

(-)Sign indicates the calculated value to be higher than the experimentally measured value.

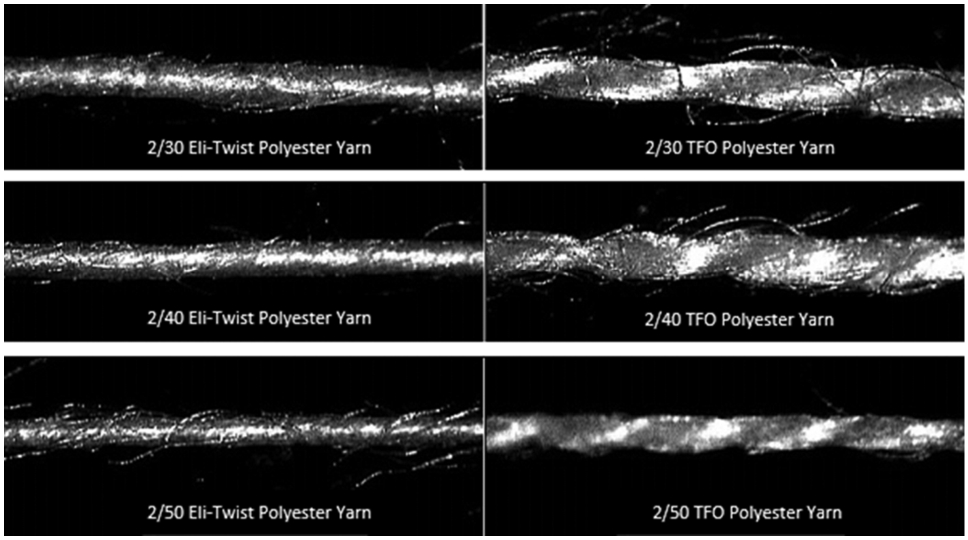

Fig. 3 — Microscopic images of yarns

suction applied in the twisting zone helps in integrating the protruded fibres providing a smooth surface and influencing the compactness.

The variation in diameter of the yarns is represented in Fig. 4. It is observed that the Eli-Twist yarn has lesser diameter than equivalent TFO yarn, irrespective of its composition and linear density. The ANOVA analysis shows that the effect of spinning system on yarn diameter is significant. The applied suction in Eli-Twist spinning system provides additional compactness, leading to reduction in diameter.

It is observed from the Fig. 4 that the yarn diameter steadily increases with change in yarn composition from 100 % polyester to 100 % cotton for both types of yarn. Lower bending rigidity and circular cross-section of polyester also assists packing. On the other hand, non-circular cross-section of cotton does not allow close association and hence the diameter of 100% cotton yarn is more than that of 100% polyester yarn. The diameter of both the yarns has also been found to increase with increase in linear density. As the linear density increases, the number of fibres in the cross-section increases, leading to an increase in diameter.

3.4 Mechanical Properties of Yarn

Figure 5 shows the load extension behaviour of the two yarns. The Eli-Twist yarn shows marginally higher initial modulus than that of TFO yarn. The yield point in Eli-Twist yarn is also distinctly visible. The average breaking load and breaking extension are also found to be higher.

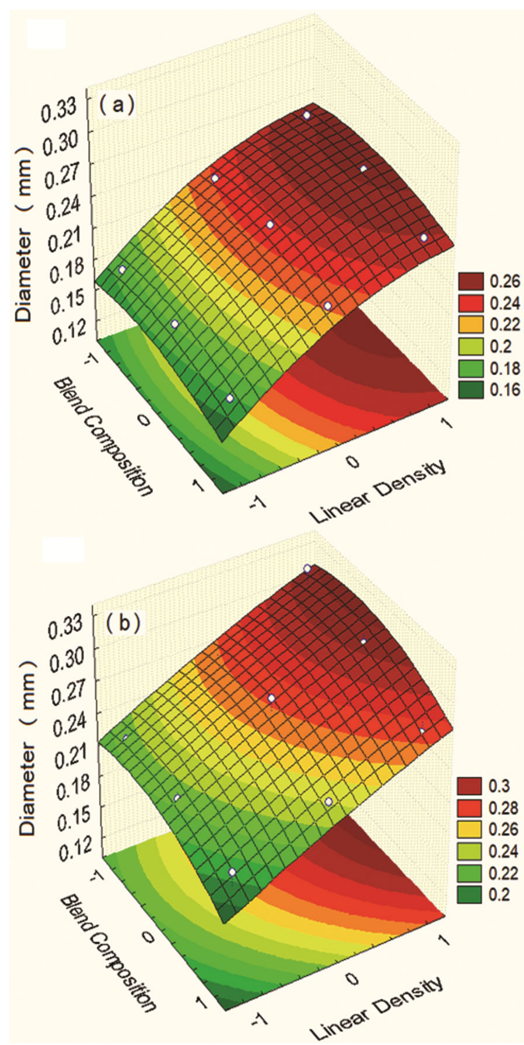

Fig. 4 — Influence of blend composition and linear density on diameter of (a) Eli-Twist and (b) TFO yarn

3.4.1 Influence of Blend Composition and Linear Density on Mechanical Properties

The mechanical properties of a staple fibre yarn is influenced by the fibre properties and yarn structural parameters. The tenacity and breaking extension of the yarn are represented in Figs 6 and 7 respectively.

It is observed from the figures that the tenacity as well as breaking extension of Eli-Twist yarn are more as compared to those of TFO yarn, when other parameters, viz linear density and blend composition are kept constant.

In Eli-Twist spinning system, the condensing zone helps in integrating the protruding fibres within the yarn structure. The integration of short fibres makes more number of fibres available to participate in load sharing during loading, thereby contributing towards strength realisation. In a TFO yarn, the possibility of twist reduction in individual yarn during doubling reduces its compactness. Short fibres fail to develop sufficient tension along their length during extension of the yarn and are liable to slip during rupture.

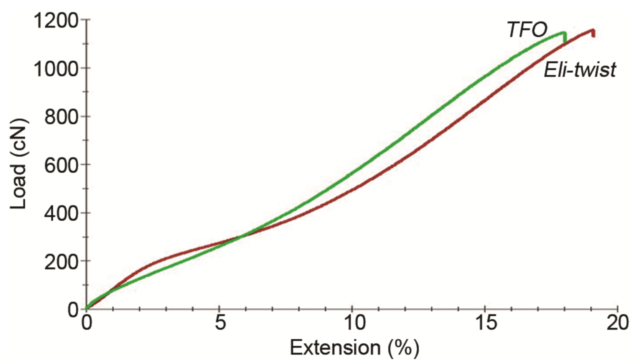

Fig. 5 — Load extension behaviour of 100% polyester yarn of 39.4 tex

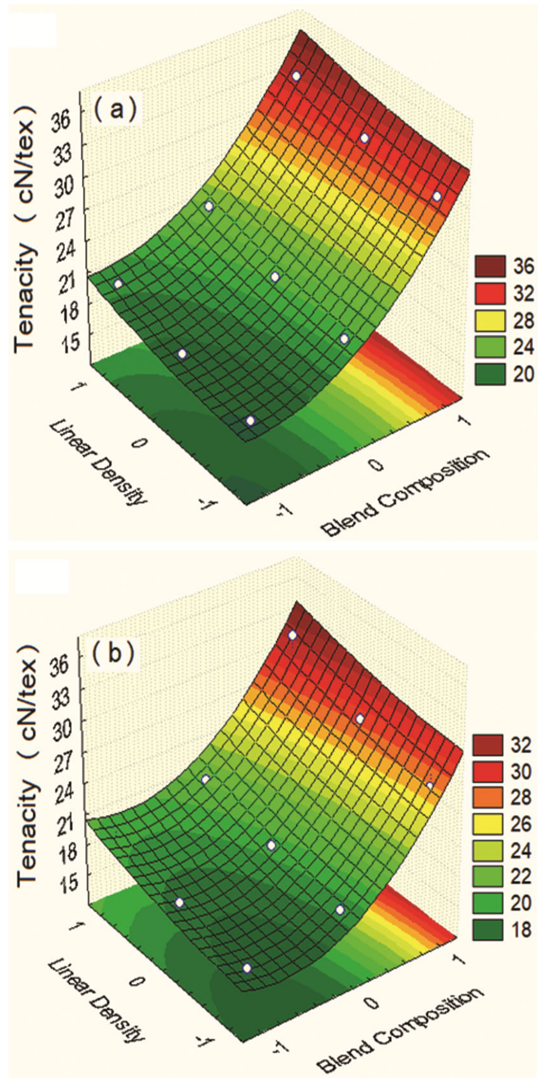

Fig. 6 — Influence of blend composition and linear density on tenacity of (a) Eli-Twist and (b) TFO yarns

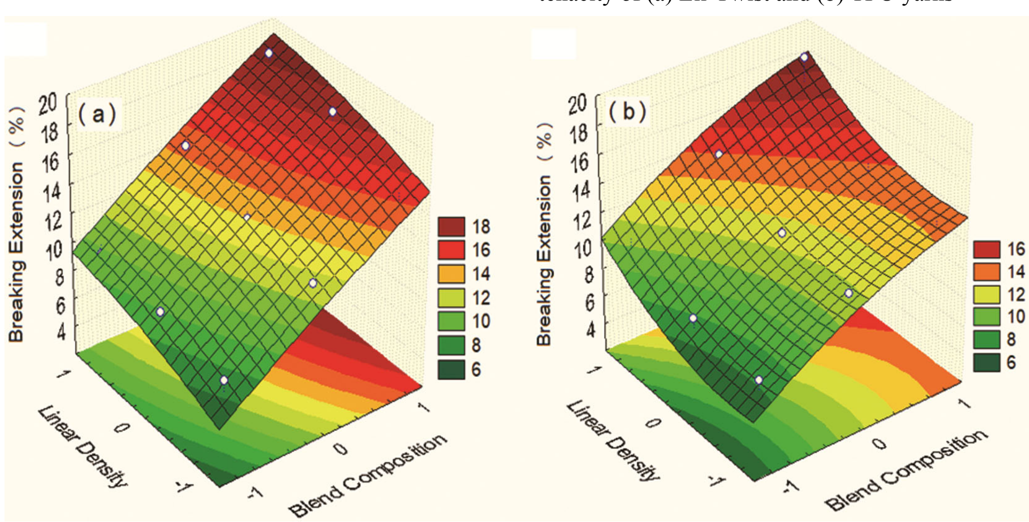

Fig. 7 — Influence of blend composition and linear density on breaking extension of (a) Eli-Twist and (b) TFO yarns

It is also observed from the Fig. 6 that the tenacity of Eli-Twist and TFO yarn reduces as the polyester content is reduced, irrespective of count. The tenacity of polyester fibre is higher than that of cotton fibre. So, when a stronger component reduces the tenacity of yarn is also expected to reduce.

The linear density, as evident from the result, shows significant increase in tenacity. As the yarn becomes coarser the number of load bearing components increases and the yarn uniformity improves, while number of imperfections goes down. As a result, coarser yarns show higher tenacity.

The ANOVA analysis also shows that the effect of spinning system on yarn breaking extension is significant. As explained earlier, participation of more fibres due to better integration in Eli–Twist yarn delay the failure process, thereby increasing both tenacity and extension.

It is also observed that the breaking extension of yarn steadily decreases with change in yarn composition from 100% polyester to 100% cotton, irrespective of count. The breaking extension of polyester fibre (12-18%) is higher than that of cotton fibre (7.5%). So, when a component with higher extensibility is reduced, the breaking extension of yarn should also reduce. As the polyester content reduces, the breaking extension of yarn also reduces. It is observed that the linear density shows significant increase in breaking extension. When the yarn becomes coarser, the yarn uniformity and imperfections improve. The stress distribution along the yarn length becomes more even. This increases both tenacity and breaking extension.

3.5 Abrasion Resistance (RRI) of Yarn

Abrasion causes a progressive loss of yarn integrity through removal of minute particle of fibrous material, as a result of continuing frictional contact with other surfaces. Besides durability of the product, the surface appearance deteriorates, leading to poor aesthetic value.

Arrangement of fibres on the surface of the yarn can influence its resistance to abrasion. It is observed from Fig. 8 that the abrasion resistance (RRI) is more in TFO yarn as compared to that in Eli-Twist yarn. The surface fibres of individual strand in a TFO yarn are trapped at the interface of the two yarns at regular intervals. The degree of trapping depends upon individual strand twist. In Eli-Twist yarn, this trapping of surface fibres is less, as individual drafted ribbons are not twisted to the extent that the individual single yarns are in classical twisting process. Thus, the removal of surface fibres by plucking during abrading process is less for TFO yarns which results in higher abrasion resistance.

It is also observed from Fig. 8 that the abrasion resistance of 100% cotton yarn is less than that of 100% polyester yarn. The blended yarn shows intermediate value. Polyester being stronger and more extendable shows greater resistance to abrasive stresses in comparison to cotton. Presence of 50% polyester fibre in the blended yarn helps in improving abrasion resistance as compared to 100% cotton yarn.

Figure 8 also depicts the effect of yarn linear density on abrasion resistance. Yarn abrasion resistance increases with increase in yarn linear density at any blend proportion. There are more fibres

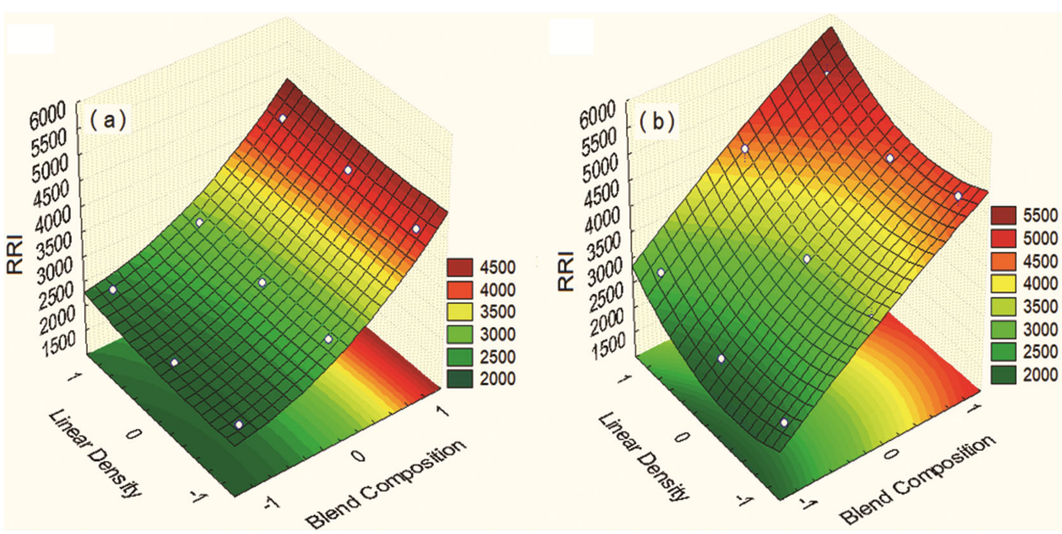

Fig. 8 — Influence of blend composition and linear density on RRI of (a) Eli-Twist and (b) TFO yarns

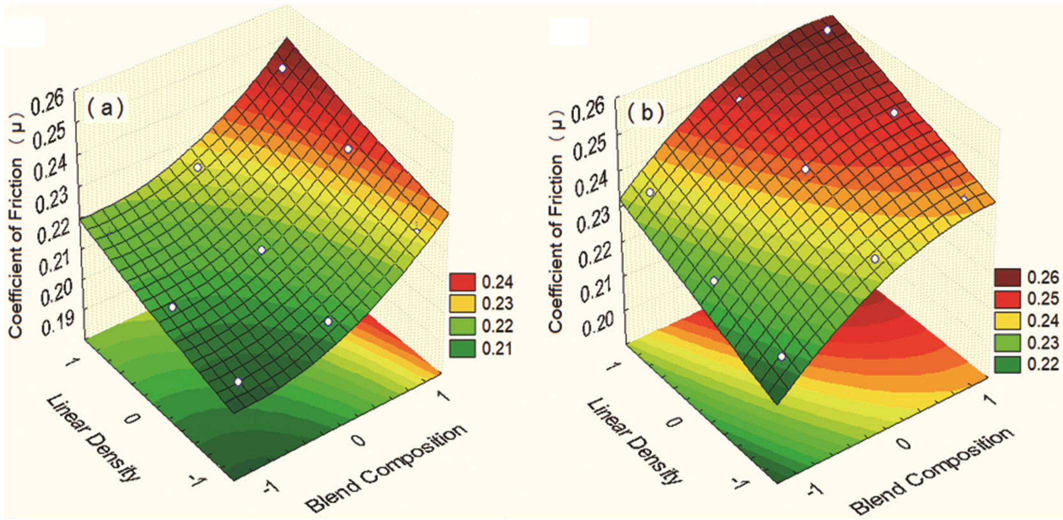

Fig. 9 — Influence of blend composition and linear density on coefficient of friction (μ) of (a) Eli-Twist and (b) TFO yarns

in the cross-section of coarser yarn to share the abrasive stresses. From ANOVA, it is observed that the effect of yarn linear density on yarn abrasion resistance is significant.

3.6 Coefficient of Friction of Yarn

Friction property of yarn mainly depends on the following factors:

- Area of contact: yarn diameter, roundness of fibre, yarn compression
- Wax/spin finish
- Static charge generation

The dependence of frictional behaviour of different yarns is shown in Fig. 9. It is observed from the figure that the coefficient of friction of Eli-Twist yarn is less than that of ring-spun TFO yarn. The ANOVA analysis has confirmed that the effect of spinning system on yarn friction is significant. The resistance to motion characterized by the coefficient of friction depends on the nature of contacting surfaces and area of contact. A surface devoid of protruded fibre is smooth in nature. Eli-Twist yarn has a compact structure with fewer projected fibres on its surface. The diameter of Eli-Twist yarn is also less and compact as compared to an equivalent TFO yarn. Thus, the smooth surface and possible lower contact area with metallic part are responsible for low value of coefficient of friction of Eli-Twist yarn.

It is also observed from the Fig. 9 that the coefficient of friction (μ) decreases with an increase in cotton component. The fibre-to-metal friction for polyester is higher than that between cotton and metal. Accordingly, addition of cotton will lead to a reduction in coefficient of friction of yarn.

It is observed from the figure that the coefficient of friction reduces as the yarn becomes finer. The ANOVA analysis also confirms that the effect of linear density on the coefficient of friction is significant. The coefficient of friction being the force required to overcome the resistance due to mutual contact of two surfaces, any change in contact area should lead to a variation in the coefficient of friction. As the linear density of yarn increases, its surface area of contact increases. This leads to an increase in the coefficient of friction for a coarse yarn.

4 Conclusion

Based on the results obtained, following conclusions are drawn:

4.1 The mass irregularity and imperfection are more or less similar for both types of yarns.

4.2 The diameter and hairiness of Eli-Twist yarn are less as compared to that of TFO yarn.

4.3 Tenacity and breaking extension of Eli–Twist yarn are more than that of TFO yarn. Polyester Eli-Twist yarns show greater tenacity, breaking extension and abrasion resistance in comparison to cotton yarns. Blended yarn shows intermediate values.

4.4 The abrasion resistance of TFO yarn is more as compared to that of Eli-Twist yarn due to greater degree of trapping of fibres at the interface of two single yarns.

4.5 The structure being relatively more compact with smooth surface, the coefficient of friction of Eli-Twist yarn is less than that of TFO yarn.

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