Comparative assessment of Eli-Twist and Siro yarn made from polyester and its blend with cotton

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An attempt has been made to compare the properties of Eli-Twist yarn with Siro yarn. Three yarns with three selective compositions using cotton and polyester are produced on both Eli-Twist and Siro spinning systems. Yarns of three counts (39.4, 29.5 and 23.6 tex) from each composition have been produced maintaining 4.2 TM for all. Unevenness, hairiness, tensile strength, breaking extension, diameter, abrasion resistance and coefficient of friction of yarns are measured and then compared. Eli-Twist yarns are found more uniform with less protruding fibres on the surface. It also produces stronger and more extensible yarn. Higher abrasion resistance and low coefficient of friction may widen the application field of Eli-Twist yarn.

Keywords: Abrasion resistance, Breaking extension, Coefficient of friction, Cotton, Eli-Twist yarn, Polyester, Siro yarn, Tenacity, Yarn hairiness, Yarn imperfections

1 Introduction

Ring spinning is the oldest spinning system, but still dominating the market[1]. In quest of improved product and process performance, people are looking for new technologies. The aim is to develop an alternative spinning system capable to challenge ring spinning system. Many developed technologies, however, have failed to pose any real challenge. Siro spinning, invented by the Division of Textile Industry Laboratories of CSIRO, is carried out in a conventional ring frame by simultaneous feeding of two rovings into the apron zone at a predetermined separation[2]. Siro-spun yarn was able to draw attention for its improved strength, evenness and low hairiness. Compact spinning system was later introduced in the market and it was able to draw attention primarily for producing yarns with further reduced hairiness and improved mechanical properties[3]. At a later stage, it also failed to find wide acceptance, despite its positive attributes. During the current decade, Eli-Twist spinning system, introduced by Suessen, has started penetrating the yarn market. In order to offer real challenge to the ring spinning and other existing systems, it is desired to develop a product superior to all the systems cited above.

Though, Siro-spun yarn exhibits improved physical and mechanical properties, it is reported to show non uniform fibre packing density across the yarn cross-section[4]. Subramaniam *et al.*[5] reported that in double rove spun yarn, the strand spacing results in a reduction in strength and strength CV below a particular twist level while it increases beyond a twist factor of 55. The strength and strength CV have also been reported to deteriorate with increase in spindle speed. The elongation is, however, affected by twist and spindle speed but not by strand spacing. Compact spinning, on the other hand, results in better integration of surface fibres, thereby showing not only a smoother surface but also a product with further improved mechanical properties. Sett *et al.*[6] reported that the importance of delta zone plays a significant role in forming the yarn structure. Eli-Twist spinning system has drawn considerable attention in the industry and is the latest addition in the direction of economic production of yarn[7-9].

The mechanical and physical properties of a 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 by suitable finishing process[10-12]. Eli-twist spinning system offers a unique opportunity to combine advantages of both Siro and compact spinning systems through fibre doubling during spinning while compaction of the

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structure is assisted by air suction. Ideally the Eli-Twist spinning system produces a structure similar to a plied yarn. In the Eli-Twist spinning system applied air suction which helps in reducing hairiness and better integration of fibre, resulting in improvement in mechanical properties as well [13, 14].

Keeping in view the growing attention of the industries towards Eli-Twist spinning, the objective of the present work has been to get its comparative assessment with Siro spinning system. Until date, no such comparative assessment is reported in the literature.

2 Materials and Methods

2.1 Materials

Polyester (1.2 denier, 38mm) and cotton (1.6 denier, 30mm) fibres were used to produce both homogeneous and blended yarns. The Eli-Twist yarns were produced on Elite compact set ring frame (model LR60/AX) of Suessen. Siro yarns were produced on a LMW short staple spinning line. In order to produce blended yarn, the blending of combed cotton fleece with polyester was done at the blow room stage. A twist multiplier of 4.2 was maintained in both the systems to produce the yarns. In Eli-Twist system, the distance between the two roving strands in drafting zone and negative pressure were kept as 8 mm and 28-35 mbar respectively. The design plan of experiment is given in Table 1. A total of 18 yarns were produced for the study.

2.2 Testing Methods

The yarns were conditioned for 24 h at standard tropical atmosphere of 65±2% RH and 27±2°C temperature. The number of tests for each parameter was taken to ensure the result to remain within 95% confidence limit.

The unevenness was measured on Uster evenness tester-5, which simultaneously measures the hairiness.

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).

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)
Composition	100% Cotton	50/50 P/C	100% Polyester

The abrasion resistance has been expressed in terms of number of strokes required to rupture the yarns completely. The abrasion resistance of the yarns was tested on yarn abrasion tester following ASTM D-4157. A 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 across the sheet at constant speed and stops when all the yarns break. Relative resistance index (RRI) was used to compare the abrasion resistance of yarns using the following formula:

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

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

Uster Zweigle friction tester 5 was used to measure the fibre-to-metal friction. The coefficient of friction (μ) was calculated using the formula $F_2 = \mu F_1$; where F_1 is the constant force applied to produce a defined force on the yarn in vertical direction, and F_2 is the force required to pull the yarn.

3 Results and Discussion

The present work embodies comparative analysis of Eli-Twist and Siro yarn properties. Assessment has been made with respect to mass irregularity, hairiness, tensile properties, abrasion resistance (RRI) and coefficient of friction of the yarns. An analysis of variance is carried out to find out the effect of different parameters on yarn properties. The ANOVA analysis of the parameters is given in Table 2. It is observed that the spinning system, linear density, blend composition significantly influence all the properties of the yarn.

3.1 Unevenness

The distribution of fibres in yarn influences both its physical and mechanical properties. Any variation in the distribution and arrangement of fibres negatively affect the mechanical and physical properties of yarn. Table 3 represents the effect of linear density and blend composition on the unevenness of both types of yarn.

Eli-Twist yarns have lower unevenness than Siro yarns. Feeding two roves in twisting zone results in doubling of drafted fleece of fibres for both Eli-Twist and Siro yarns. The drafting system consisting of drafting rollers, aprons and guides are of superior

Table 2 — ANOVA result

Parameter	Hairiness	Unevenness	Tenacity	Breaking extension	Diameter	RRI	Coefficient of friction
L D	s	s	s	S	s	s	s
C	s	s	s	S	s	s	s
S S	s	s	s	S	s	s	s
L D* C	ns	s	ns	S	ns	ns	ns
L D*S S	s	ns	s	ns	s	s	ns
C*S S	ns		ns	S	ns	s	s

L D−Linear Density, C−Composition, S S−Spinning system, s−Significant and ns−Non significant.

Table 3 — Influence of blend composition and linear density on different proportion of Eli-Twist and Siro yarn

Linear density, tex	Blend composition	Unevenness		Hairiness		Diameter mm		Tenacity cN/tex		Breaking extension, %		R R I		Coefficient of friction, μ	
		Eli	Siro	Eli	Siro	Eli	Siro	Eli	Siro	Eli	Siro	Eli	Siro	Eli	Siro
39.4	Cotton	7.45	8.74	5.43	7.45	0.26	0.285	20.22	17.96	9.4	8.8	2599	2510	0.215	0.235
	Cotton : Polyester (50:50)	7.19	11.76	5.22	6.77	0.26	0.265	24.0	22.12	14.5	12.5	3183	2938	0.225	0.246
	Polyester	6.35	7.88	4.52	6.09	0.25	0.261	33.02	31.47	18.6	18.6	4503	3952	0.245	0.253
29.5	Cotton	7.93	9.46	5.23	6.27	0.23	0.252	18.76	16.46	8.9	8.6	1844	1789	0.21	0.23
	Cotton : Polyester (50:50)	7.81	12.88	4.98	6.1	0.24	0.265	22.15	19.2	12.7	10.5	2260	2157	0.215	0.237
	Polyester	6.9	8.77	4.43	5.25	0.22	0.232	31.6	30.65	17.6	17.2	3066	2904	0.235	0.24
23.6	Cotton	8.98	11.62	5.02	5.87	0.175	0.215	17.95	17.1	8	7.6	1436	1387	0.205	0.223
	Cotton : Polyester (50:50)	8.89	13.91	4.72	5.78	0.18	0.21	21.5	18.16	11.8	10.2	1679	1597	0.21	0.227
	Polyester	7.02	11.08	4.12	4.93	0.17	0.19	30.9	30.69	14.2	14.1	2427	2247	0.225	0.229

quality and hence Eli-Twist yarns are more uniform than normal Siro yarns.

It is also observed from Table 3 that the mass variation of yarn varies with change in yarn composition. The unevenness of 50:50 blended yarn is higher than their 100% counter parts. The unevenness of all finer yarns is found to be more than the coarser yarns. This is due to decrease in number of fibres in the yarn cross-section, which increases limit irregularity.

3.2 Hairiness

The hairiness of a yarn is the result of fibre protrusion from the yarn surface. Table 3 represents the variation in hairiness with blend composition and linear density for both Eli-Twist and Siro yarns. It is observed that the spinning system has significant influence on the level of hairiness. The following observations can be made.

- Hairiness of Siro yarns is more than that of Eli-Twist yarn.
- Hairiness of all cotton yarns is more than that of polyester and blended yarn.

- Hairiness of coarser yarns is more than finer yarns

In Siro spinning, strand width at the front roller nip is much wider and as a result twist does not flow right up to nip of front roller. It fails to integrate edge fibres in twist triangle into the yarn structure. In Eli-Twist spinning system, air drawn through the inclined slot causes the suction to supress the projecting ends of the fibres in the drafted fleece and consolidates them before twisting. Thus, it helps to better integrate the fibres into the main strand.

During formation of yarn, the level of developed tension in each constituent fibre decides its position in the yarn. A fibre that develops more tension is likely to move towards the central region of the structure. Physical and mechanical properties of fibre and process parameters influence the placement of the fibre. Polyester, generally offers good uniformity in length distribution. Inter-fibre friction and other mechanical properties of polyester facilitates tension development and yields a compacted structure with less number of protruded fibres.

Cotton, on the other hand, exhibits higher length variability and low inter-fibre cohesion. The mechanical properties of cotton also do not support tension development much. Thus, cotton yarn is less compact than a polyester yarn. In a polyester-cotton blended yarn, cotton preferentially dominates the surface region of yarn. 100% cotton yarn contains more potential fibre ends to form hairs in presence of many short fibres. Similarly, coarser yarns have more fibres in the yarn cross-section than finer yarns, and hence there are more potential ends near the yarn surface to form hairs.

3.3 Surface Structure

The SEM images of the yarns are shown in Fig. 1. The Eli-Twist yarns are smoother than Siro spun yarns.

Very few protruded fibres are seen on its surface. The Siro yarn shows many loose fibres on its surface which fail to get integrated into the structure. When the two structures are compared, the Siro yarn appears to be more voluminous. The cotton yarns produced on both the systems are more voluminous than polyester yarns.

3.4 Diameter

In a yarn, the diameter is desired to be uniform. Yarn diameter influences both the appearance and properties of the fabric. The variation in diameter of the yarns is represented in Table 3. It is observed that the Eli-Twist yarn has lesser diameter than equivalent Siro yarn, irrespective of its composition and linear density. The applied suction in Eli-Twist spinning system helps in consolidation and integration of
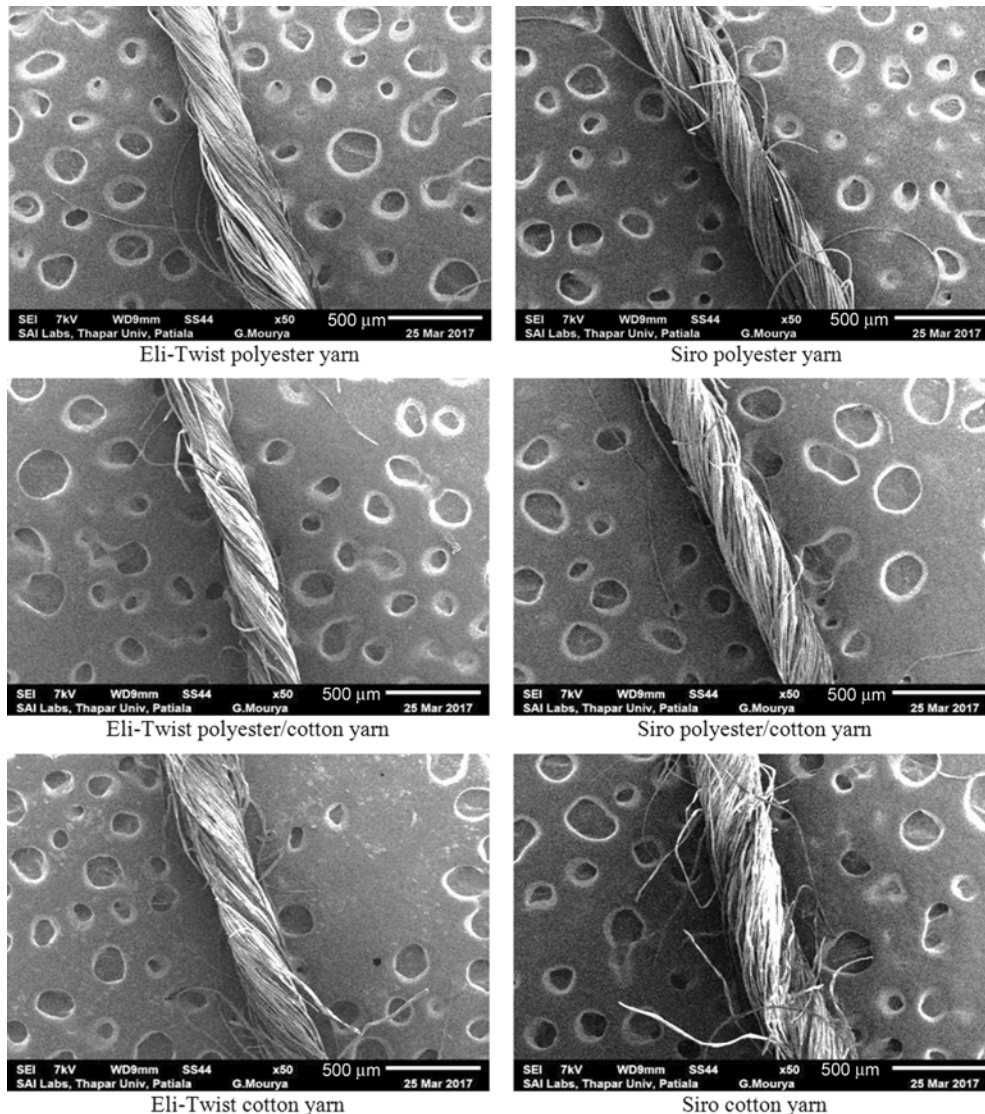

Fig. 1 — SEM images of yarns (29.5 tex)

fibres, leading to reduction in diameter. Yarn diameter steadily increases with change in yarn composition from 100% polyester to 100% cotton for both type of yarn. Lower bending rigidity, circular cross-section and lower friction facilitate polyester fibres to pack closely. On the other hand, non-circular cross section of cotton fibres does not allow close packing, and hence the diameter of 100% cotton yarn is more than that of 100% polyester yarn. In the blended yarn, fibre of two generic nature does not allow close association.

The diameter of both the yarns is found to increase with increase in linear density. As same twist factor is maintained for all the yarns, a coarser yarn will have less twist than a finer one. The number of fibres in the cross-section increases for a coarser yarn with a reduction in the level of twist. The combination of these two factors leads to an increase in yarn diameter with increase in linear density.

3.5 Tenacity and Breaking Extension

The tenacity and breaking extension of the yarns are represented in Table 3. The ANOVA analysis (Table 2) shows significant influence of linear density, spinning system and blend composition on tenacity and breaking extension.

It is observed that the tenacity and breaking extension of the Eli-Twist yarn are more than that of Siro yarn. In Eli-Twist spinning system, condensing zone helps the protruding fibres for their integration in yarn structure. This makes the yarn compact with a firmer body than the equivalent Siro yarn.
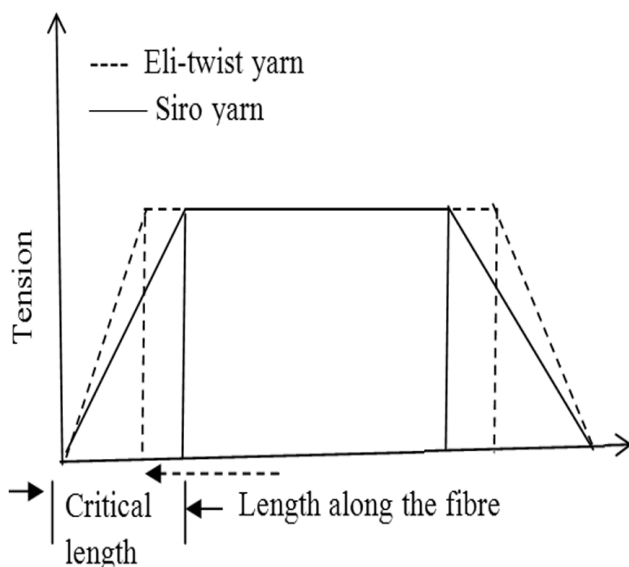

Fig. 2 — Tension development in fibre along its length

The tension distribution in a fibre during the yarn extension is depicted in Fig.2. The tension at the fibre tip is zero as a fibre needs certain minimum length (critical length) to be gripped for tension to build up gradually to a level decided by the extension of the yarn. The tension gradually rises from one end, reaches a maximum and continues over certain length and then declines thereafter at the other end.

The length over which the tension gradually rises is known as critical length for fibre gripping. The critical length depends upon the twist, fibre diameter, friction properties and compactness of yarn. In case of Eli-twist yarn, the compact structure reduces critical length required for tension to develop fully. A larger part of fibre length is made available to contribute to load sharing and thus the yarns become stronger.

Polyester yarns are strongest as the tenacity of polyester fibre is higher than that of cotton fibres. For a coarser yarn, an increased number of fibres in yarn cross-section leads to an improvement in tenacity.

Tenacity of a yarn has direct correlation with the tenacity of its constituent fibres. A reduction in the stronger component should negatively influence the tenacity of yarn. On the other hand, inability of developing higher tension by shorter cotton fibres and its higher bending rigidity results in less compaction of the fibres in yarn. A cumulative effect of the above factors leads to a reduction in tenacity with decrease in polyester component.

It is observed from the Table 3 that the breaking extension of the Eli-Twist yarn is higher than that of Siro yarn. This is due to the fibre being more firmly integrated in Eli- Twist yarn. The additionally integrated fibres not only act as protecting layer but also increase compactness of the structure delaying the failure.

The breaking extension of polyester yarn is more than that of cotton yarns. It is expected as polyester is more extendable than cotton. The breaking extension of polyester fibre is also higher than cotton fibre[15]. So, when a component with higher extensibility is reduced, the breaking extension of yarn is also expected to reduce. The breaking extension of blended yarn remains in between 100% polyester and cotton yarns.

With increase in the linear density, breaking extension also increases. When the yarn becomes coarser, uniformity improves and the number of load bearing component increases which tries to restrict the failure of the yarn. Hence, breaking extension of yarn increases with increase in linear density.

3.6 Abrasion Resistance (RRI) of Yarn

Textile products are subjected to repeated abrasive action in actual use. Abrasion causes a progressive loss of yarn integrity through removal of minute particle of fibrous material. Besides durability of the product, the surface appearance also deteriorates, leading to poor aesthetic value.

The resistance to abrasion of a staple yarn is dependent on its compactness and degree of fibre integration and mutual entanglement in the structure. The type of fibres, their arrangement and structural integrity of the yarn can influence the resistance to abrasion. It is observed (Table 3) that the abrasion resistance (RRI) is more in Eli-Twist yarn as compared to that in Siro yarn. The consolidation of fibres due to suction in Eli-Twist yarn results in higher resistance to abrasion.

The abrasion resistance in cotton yarn is less (almost half) than in polyester yarn, as polyester is more abrasive resistant than cotton. The abrasion resistance of blended yarn lies in between 100% polyester and cotton yarns. Polyester, being circular in cross-section, will assist coherence while cotton of non-circular cross-section may offer less inter-fibre cohesion. Addition of cotton fibre introduces a differential friction condition between the constituent fibres. Such a condition is responsible for reducing compactness and inter-fibre cohesion of the structure, which leads to lower abrasion resistance.

Yarn abrasion resistance (RRI) increases with increase in yarn linear density. Presence of more fibres in coarser yarn reduces abrasive stress per fibre and thus leads to a more resistant yarn.

3.7 Coefficient of Friction of Yarn

Friction properties of yarn mainly depend on the area of contact (yarn diameter, roundness of fibre, yarn compression), wax/spin finish and static charge generation.

The frictional behaviour of different yarns is represented in Table 3. It is observed that the coefficient of friction of Eli-Twist yarn is less than that of Siro yarn.

The resistance to movement, characterized by coefficient of friction, is dependent on the nature of two contacting surfaces and their actual area of contact. Eli-Twist yarns have a compact structure with few projected fibres on its surface as evident from the diameter data. The lower diameter and compacted structure leads to lesser flattening of the yarn in the contact zone and thus offering lower area of contact. Further surface being smooth, these yarns will show a lower value of coefficient of friction.

Between cotton and polyester, the coefficient of friction (μ) is less for cotton yarn. Polyester fibre's surface being smooth, results in larger area of contact and thus more friction for polyester yarn. The presence of a benzene ring in polyester fibre structure also increases the friction for polyester[13].

As the linear density of the yarn increases, the surface area of contact of yarn increases due to reduction in curvature of the yarn. This leads to an increase in the coefficient of friction for a coarse yarn.

4 Conclusion

A study has been carried out to compare Eli-Twist yarn with Siro yarn. The comparative assessment was made on the basis of physical and mechanical properties of the yarns. The inferences drawn are:

4.1 The mass irregularity of Siro yarns is more than that of Eli–Twist yarn.

4.2 Eli-Twist yarn shows less hairiness in comparison to Siro yarn. The diameter of Eli-Twist yarn is less in comparison to an equivalent Siro yarn.

4.3 The tenacity, breaking extension and abrasion resistance (RRI) of Eli-Twist yarn was also found to be higher than those of Siro yarn.

4.4 The coefficient of friction of Eli-Twist yarn is found to be less.

4.5 The comparative analysis reveals the superiority of Eli-Twist yarn in comparison to Siro ring yarn, irrespective of fibre type or count used.

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