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A novel approach to process cotton/long staple fibre blends on short staple ring frame

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An attempt has been made to blend cotton fibres with long staple fibre strands made of silk and polyester-wool using siro spinning system and to evaluate the samples produced for some physical properties. Blending of these fibres using siro spinning appears to be possible at low spindle speeds. Yarns produced in the modified drafting system show better moisture content, evenness and hairiness, and these properties are influenced by the cotton fibre content in the blended yarn.

Keywords: Hairiness, Index of irregularity, Moisture content, Poly-wool, Silk, Siro-spun yarn, Tenacity

1 Introduction

In siro spinning, two similar or different roving strands are fed into the drafting zone and maintained separately throughout the drafting process till the nip of the front roller, using suitable guides in the middle zone and also prior to delivery rollers. At the nip of the delivery roller, both the strands are condensed, twisted together and wound by the spindle. Convergence of strands at the delivery roller is governed by spinning speed, strand twists and fineness of the yarn; optimal convergence angle of the two strands in equilibrium is 90° with resonance at 127° (refs 1,2) Many attempts have been made earlier to process worsted roving materials on the cotton ring spinning system with suitable modifications in the drafting system, though the longer wool fibres are stretch-broken.[3,4] Also, extensive works have been carried out in the siro spinning using short staple spinning system, nevertheless the literatures related to siro spinning of cotton and long staple fibres are not available. Effects of strand spacing, apron spacing, yarn twist, spindle speed and break draft on yarn tenacity, elongation, evenness, hairiness have been studied earlier using cotton[5-7], viscose[8,9], acrylic[10], polyester-cotton[11], polyester-viscose[11], jute-cotton[12] blends in short staple spinning systems. Attempts have also been made to produce polyester-wool blends[13] with the optimized strand spacing in the drafting zones in the short staple fibre ring frame. In the present work, an attempt has been made to produce cotton/polyester-wool and cotton/silk blended yarns through short staple spinning process by modifying drafting zone of the short staple spinning system.

2 Materials and Methods

2.1 Materials

Cotton fibres (MCU-5) with 1.46 dtex (3.7 µg/inch) fineness, 29.4 mm span length (2.5%) and 13.9 mm span length (50%) were used to produce cotton roving with 0.369 ktex linear density through short staple spinning preparatory machines (M/s Ramakrishna Spinning Mills, Coimbatore). Silk roving was produced from mulberry silk with a linear density of 0.492 ktex (1.3 dtex per fibre, 94mm average length and CV% 23) through long staple spinning preparatory system (M/s Himatsinghka Filati, Bangalore). Long staple polyester-wool (75:25) blended roving with a linear density of 0.295 ktex was produced using the variable cut length polyester fibres (2.2 dtex) with a mean fibre length of 72 mm (CV% 4.2%) blended with merino wool of 22.5 micron diameter and Hauter average length of 75 mm (CV% 35%). The wool was procured from M/s Raymond India Limited, Vapi. Both silk and polyester-wool (here after poly-wool) blends were processed on NSC FM7N rubbing frame with 5 rubs/m.

2.2 Methods

2.2.1 Spinning

Double rove spinning of cotton/silk and cotton/poly-wool roving materials was carried out in

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the short staple ring frame (LR G5/1 with P 3-1 drafting system) with the total draft of 28.8 (break draft 1.28) to produce the nominal resultant count of 35 tex and 25 tex respectively with a metric twist multiplier of 120. The distance between two roving strands was maintained at 6 mm using a specially fabricated guide at the back, middle zones (Fig. 1) and grooves were made in the middle apron top roller in the drafting system to replicate the slip draft system adopted in long staple spinning systems [14] (Fig. 2). Cotton roving strand was made to pass through normal portion in the same roller, for drafting separately and throughout processing, the spindle speed was kept constant at 8000 rpm.

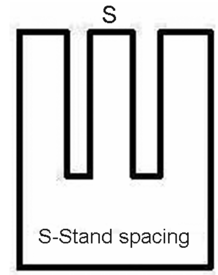

Fig. 1 — Twin roving guide

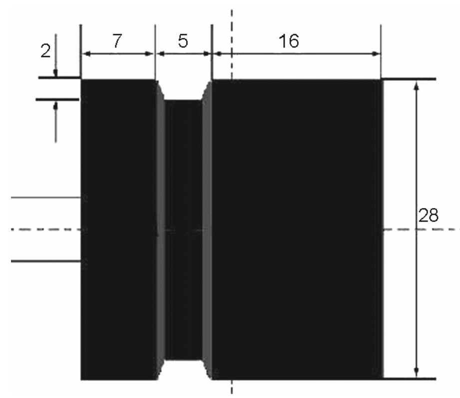

Fig. 2 — Drafting roller modifications for siro spinning (all units in mm)

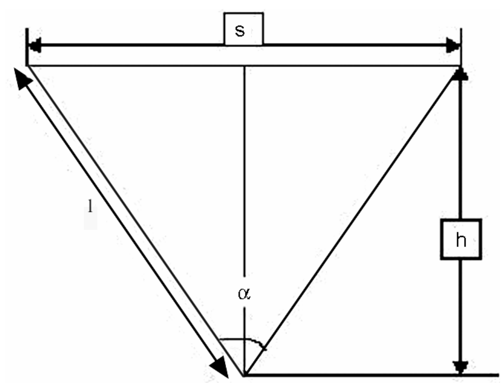

Fig. 3 — Spinning triangle [s—strand spacing, h—height, l—strand length, and α—strand angle]

2.2.2 Angle of Spinning Triangle

The angle of the spinning triangle was calculated theoretically using the strand spacing and height of the triangle measured during the processing (Fig. 3), as reported in the literatures.[1, 15] Roving strands of long staple fibres were used for the calculation of angle of spinning triangle, using a double grooved top roller (not shown here as it is not used for other purposes).

2.2.3 Linear Density

An automatic wrap reel with a perimeter of 1.5 yards was used to prepare the leas having a length of 120 yards. The skeins were conditioned and weighed for the calculation of linear density as per ASTM D1907-01 test method. Average of 20 measurements was taken for the calculation of linear density and coefficient of variation.

2.2.4 Unevenness

Unevenness of the yarns was measured as suggested in ASTM D1425-96 procedure using capacitance based Uster unevenness tester UT3. Spectrograms were obtained to assess the periodic faults and to take the remedial actions. Index of irregularity was calculated using the following formula:

$$\text{Index of irregularity} = U\,\%_{\text{Actual}} / U\,\%_{\text{Limit}}$$

2.2.5 Hairiness

Hairiness count and average hairiness values were calculated as stated in ASTM D5647-01 using photo-electric based testing system attached with the Zweigle G566 hairiness tester with a pretension of 5 cN. The test length of 100 m from each specimen was tested for the fibres having a length of 3mm at the speed of 50 m/min. An average of 5 readings was taken for the purpose. The instrument also gives the total number of protruding fibres having a length above 3mm (S3) and its variation over the mean value.

2.2.6 Moisture Content

Specimens were weighed and conditioned at 23°C±2°C temperature and 65±2% relative humidity to reach the equilibrium conditions. The tests were carried out using ISO 1833-1980 test method, Carbolite oven and Metler weighing balance system. The difference between the initial and the final weights was expressed as moisture content of the specimen.

2.2.7 Tensile Properties

Tensile properties were measured using Premier Tensomaxx 7000 tensile testing equipment and experiment was carried out as per ASTM D2256-02. Specimens with a length of 500mm at a strain rate of 250 mm/min were used to obtain the values of breaking tenacity and breaking elongation. For every sample, 200 tests were carried out. Mean values and coefficient of variation were taken for the report and analysis.

3 Results and Discussion

No observable end breaks while spinning have been recorded, though the spinning triangle formation at the delivery is not stable due to difference in the linear densities of roving materials used in the experiments. The increase in hairiness is observed in the delivered yarn, visibly, in the absence of twin roving guides in the drafting zone.

3.1 Unevenness

Twin roving condensers placed in the drafting zone facilitate the movement of roving strands in stable conditions, and in the absence of condensers the roving strands become dynamically unstable, as shown by higher horizontal vibrations at the delivery of strands. The angle of spinning triangle increases with the increase in strand spacing, but decreases at higher strand spacing (Fig. 4). A negative correlation with a coefficient of −0.967 is observed between height of the triangle and spinning angle. The linear density of the yarns produced through the double rove spinning shows the variation (Table 1) that is within the preferred tolerance levels.[16]

Lower unevenness values are observed in the case of silk yarns followed by cotton and poly-wool yarns. In the case of cotton blended yarns, unevenness values are found to be higher in the cotton/ poly-wool yarns than in cotton/silk blended yarns (Table 1). Very high values obtained in the case of poly-wool and cotton/poly-wool yarns could possibly be due to the lower number of fibres in the yarn cross-section, which also shows a perfect negative correlation (coefficient −0.995) with U%. Also, lower number of fibres in the yarn cross-section results in higher limiting irregularity and index of irregularity in these yarns, as compared to the silk and cotton/silk blended yarns, which could be an important parameter in this case rather than the linear density and its effect. Interestingly, even with more number of fibres in yarn cross-section, the observed unevenness values are found to be higher in the 100% cotton spun yarn, possibly due to the slip draft arrangement and wider

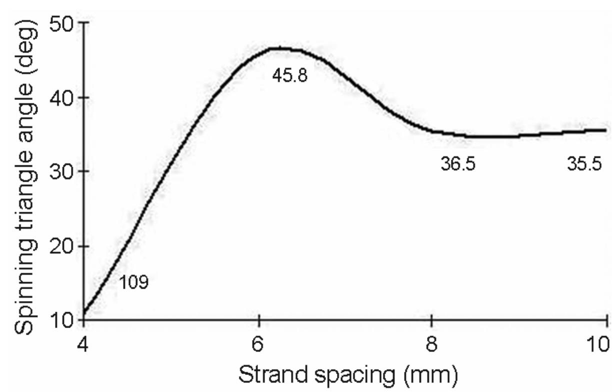

Fig. 4 — Effect of strand spacing on spinning triangle

Table 1 — Properties of siro yarns produced in short staple ring frame

Parameter	Cotton	Silk	Poly-wool	Cotton/silk	Cotton/poly-wool
Avg. count, tex	28.10	39.40	22.70	34.70	24.60
Count CV%	1.20	0.60	0.60	1.70	1.00
Moisture content, %	5.85	7.83	6.45	6.99	6.11
Avg tenacity, cN/tex	14.87	29.30	13.93	23.07	10.95
Tenacity CV%	6.93	3.16	10.09	4.63	6.76
Elongation, %	6.22	11.65	17.64	9.14	7.52
Elongation CV%	6.92	5.15	12.77	9.15	9.58
Number of fibres in cross-section	192	296	80	250	129
U%	11.02	7.09	14.75	8.33	13.45
Index of irregularity	1.80	1.28	1.38	1.39	1.61
Hairiness (3mm)	758	358	212	752	671

draft zone setting, originally set for processing long staple strands. Total imperfections, as calculated by the sum of thin places, thick places and neps, are found to be very less in the case of 100% silk (62) and cotton/silk (93) spun yarns, while high values are observed in the case of poly-wool and cotton/poly-wool spun yarns, i.e. 230 and 265 respectively.

3.2 Hairiness

Hairiness values measured in the yarn indicate the amount of short fibres and the variations in the fibre lengths, since the majority of the protruding hairs is contributed by the short fibres. Lower hairiness values are observed in the case of poly-wool spun yarn followed by silk yarn as compared to that in the case of cotton yarns (Table 1). The highest hairiness value observed for cotton could possibly be due to the wider roller setting and slip draft arrangement used in the process, which are not normally used in such systems. Marginally higher hairiness values are observed in the case of cotton/silk yarns followed by cotton/poly-wool yarns, which demonstrate the influencing role of the cotton fibres. Larger difference is found in mean fibre lengths of silk and cotton fibres as compared to that in poly-wool and cotton fibres. Lower values observed in the case of blended yarns could be, as stated in the literature, due to the trapping of the surface fibres in the individual strands, prior to the formation of the twisted strands.[1,7]

The S3 value is found to be very high in the case of 100% cotton yarn (S3 = 1007) compared to that in case of silk (539) and poly-wool (318) yarns. Cotton / silk (S3 = 960) and cotton/poly-wool (S3 = 959) blended yarns show marginal decrease in the S3 values as compared to cotton yarn, though the values are higher than that found without cotton content.

3.3 Moisture Absorption

The moisture content values of the conditioned samples are found to be lower in the case of cotton and poly-wool yarns and higher in the case of silk yarn (Table 1) and therefore the cotton / silk yarn shows higher moisture content than the cotton / poly-wool yarn. The value for poly-wool yarn is found to be lesser than that of silk yarn in spite of higher regain value of wool fibres, mainly due to higher proportion of polyester in the blend.

3.4 Tenacity and Elongation

The shape of the force-elongation curves shows distinct features, clearly dominated by the presence of different component fibres. Tensile properties of the blended yarns have been dealt elaborately in the past by many authors in terms of component fibres present in the yarn structure.[17] In the case of cotton spun yarn, no clear yield point is visible in all the tests while it is observed in the cases of silk and poly-wool yarns. However, the yield point is unidentifiable in the case of cotton/poly-wool blended yarn, though both polyester and wool fibres can exhibit clear yield points in the fibre form. This is not observed in the case of cotton/silk blended yarn, which shows a pronounced yield point before the onset of permanent deformation in the yarn. This is possibly due to the higher cotton fibre proportion (~55%) in the case of cotton/poly-wool blend as compared to that in case of silk / cotton blended (~ 45%) yarn.

As far as the tenacity values are concerned, poly-wool and cotton/poly-wool blended yarns exhibit lower values followed by cotton yarns (Table 1) while silk and cotton/silk blended yarns exhibit higher values. Tenacity values realized in the cases of poly-wool and silk yarns reduce by ~21% with the introduction of cotton in the yarn structure. In the case of elongation, higher values are obtained for poly-wool (~ 13.70-20.50%) and silk (~11.0-12.34%) spun yarns, while low values are obtained for cotton spun yarns (~6.10-6.90%). However, with the introduction of cotton component into the yarn structure, the elongation values of blended yarns also reduce considerably by 24.51% and 57.40% for cotton/silk and cotton/poly-wool yarns respectively. Changes in tenacity and elongation values, once again, demonstrate the influence of cotton fibre proportion in the measured properties of the resultant yarn.

4 Conclusions

Lower variation levels in the linear density of blended yarns show better compatibility among the different fibres used in the experiment. The unevenness of the yarns is found to vary with respect to the number of fibres present in the cross-section. Increase in the hairiness values is observed when cotton component is introduced in the yarn structure; however, no significant differences are observed in the case of total number of protruding hairs of 3 mm and above. Moisture content found in the cotton/poly-wool and cotton/silk samples is higher than that in cotton yarns, which promises comfort properties similar to that of cotton materials. Tensile properties of the yarns are dominated by the major fibre component present in the yarn structure in all the samples.

Above attempt reveals a possibility for blending long staple fibres and short staple fibres through spinning process, which definitely could be a value proposition. But, the above system requires installation of two different preparatory set-ups for producing long staple and short staple roving strands, which needs to be borne in mind before making commercial attempts. However, a wide scope exists for further research in terms of reducing the incidences of single strands in the yarn structure due to strand breakage, rigidity and other structural aspects of the yarn produced in the above system.

Industrial Importance: On account of certain commercial limitations in terms of maintaining two different spinning preparatory machine set-ups for long staple and short staple fibres, processing of this novel product could be attempted by outsourcing one component. Fabrics made out of these yarns could help the processors to develop products that suit tropical climatic conditions.

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