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Characteristics of acrylic-cotton yarns produced on ring and rotor spinning systems

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Acrylic-cotton rotor-spun yarns are substantially weaker, more even and extensible, and have lower abrasion resistance than the equivalent ring-spun yarns. The difference in tenacity of ring- and rotor-spun yarns is much less for coarse yarns. An increase in twist factor significantly increases the abrasion resistance of rotor yarns. However, with 70:30 acrylic- cotton ring yarns, the abrasion resistance does not show any change with increasing twist factor. Acrylic content in the fibre mix should be more than 50% for improvement in yarn characteristics.

Keywords : Acrylic-cotton yarn, Ring-spun yarn, Rotor-spun yarn, Spinning, Twist loss, Tex twist factor

1 Introduction

The innovations in textile substrates demand also the innovation in machinery/equipment and rotor spinning is no exception to it. Especially in last two decades, various machine builders have been active in research and development of rotor spinning, and the consequences thereof may be witnessed by the improvement in yarn quality and machine performance. Innovations have made it possible to spin man-made fibres on rotor spinning machines after careful optimization of process parameters. More than 60,000 rotors are now in operation in Indian mills and shipments are steadily increasing. Forecasts suggest that by the year 2000 more than 50% of the yarn production will be shared by this system. The experience gained so far confirms that manmade fibres can be successfully spun on this system[1-5]. However, the production of acrylic fibre yarn in blends, especially with cotton, on rotor spinner is still in embryo state. As per the consumer's demand for sophisticated products, there is direct need for developing such yarns for sportswear, especially for sweat shirts and track suits. This is particularly so because rotor yarns are not well accepted for conventional substrates produced from ring-spun yarns owing to their structural differences. Although some brands of acrylic fibre process particularly well on rotor spinner, many lend to rotor spinning at low twists. The inclusion of cotton in acrylic fibre mix minimizes static accumulation and protects the acrylic fibre goods against whole melting. This paper aims at exploring the characteristics of acrylic-cotton yarns produced on ring- and rotor-spinning systems using different yarn compositions, twist factors, linear densities and rotor speeds.

2 Materials and Methods

2.1 Preparation of Yarn Samples

Two sets of yarn of 29.5 and 49.2 tex were spun from blends of acrylic and cotton fibres on ring- and rotor-spinning machines with different twist factors ranging from 37.41 to 45.32. The specifications of acrylic and cotton fibres used are given in Table 1. For blending acrylic and cotton fibres, the cotton was first combed and then mixed with acrylic in

Table 1—Specifications of acrylic and cotton fibres

Fibre	Fibre length mm	Fibre linear density d/tex	Bundle strength g/tex	Breaking extension %
Acrylic	38.0	1.66	23.18	30.5
Cotton	25.1[a]	1.66	20.70	5.0

[a]2.5% span length

opening room. The proportion of acrylic fibre was kept 1.5% higher than the ultimate required proportion in the yarn. The conversion to drawn sliver was carried out by using a MMC carding machine and a Laxmi Rieters' draw frame DO/6. Two drawing passages were given to card slivers. The drawn slivers (linear density, 3.0 ktex) were spun into yarns on Ingolstadt Rotor Spinner RU11/RU80(4620). The process parameters used to produce these yarns are given in Table 2. The machine parameters used for the spinning of rotor yarns were: 48 mm rotor, a saw-tooth opening roller (type of clothing, OS/21; teeth/cm^2, 24; face angle, 100°), an opening roller speed of 7000 rpm, and a notched nozzle with exterior diam. 15.5 mm and interior diam. 3 mm. For ring yarns, the drawn slivers were converted into suitable rove of 1.5 hank on Texmaco Howa Simplex. Equivalent ring yarns were spun on Laxmi Rieters' ring frame G5/1 using a spindle speed of 12500 rpm.

2.2 Tests

All the yarns were tested for single strand strength and breaking extension on an Instron, 500 mm test specimen being elongated at 200 mm/min extension rate. Mean breaking strength and extension were averaged from 30 observations for each yarn sample. Yarn unevenness and imperfections were recorded using an Uster evenness tester. Yarn diameter was measured by a projectina microscope and the yarn twist on a Eureka twist tester using the detwist-retwist method. Flat abrasion resistance of yarns was determined by Custon scientific abrasion tester.

Table 2—Spinning parameters for rotor-spun yarns

Yarn ref. No.	Yarn linear density tex	Acrylic : cotton	Rotor speed rpm	Tex twist factor
S1	29.5	15:85	50	37.41
S2	29.5	15:85	50	41.11
S3	29.5	15:85	50	45.32
S4	29.5	30:70	50	37.41
S5	29.5	30:70	50	41.11
S6	29.5	30:70	50	45.32
S7	29.5	70:30	50	37.41
S8	29.5	70:30	50	41.11
S9	29.5	70:30	50	45.32
S10	29.5	70:30	60	37.41
S11	29.5	70:30	60	41.11
S12	29.5	70:30	60	45.32
S13	49.2	70:30	50	37.41
S14	49.2	70:30	50	41.11
S15	49.2	70:30	50	45.32

3 Results and Discussion

3.1 Apparent Twist Loss

Unlike in ring yarns, the actual twist in rotor yarns is considerably lower than the machine twist (Table 3). The apparent twist loss has been assigned to the fibre slippage at the point of yarn formation within the rotor[6]. The twist loss increases with the increasing acrylic content owing to the higher torsional rigidity of this fibre; the torsional rigidity being proportional to the ratio of fibre linear density to fibre specific gravity. The increase in twist loss occurs because the stiffer fibres increase the incidence of wrapper fibres, which, in turn, decreases the twist translation efficiency. Apart from fibre composition, rotor speed and twist factor also exert a significant influence on twist loss, which tends to increase linearly when both rotor speed and twist

Table 3—Twist loss in acrylic-cotton rotor-spun yarns

Yarn ref. No.	Twist level			Twist loss %	Twist efficiency %
	Tex twist factor	TPM			
		Nominal	Actual		
S1	37.41	688.7	611.9	11.15	88.85
S2	41.11	756.9	655.0	13.46	86.54
S3	45.32	834.4	703.8	15.65	84.35
S4	37.41	688.7	603.0	12.48	87.52
S5	41.11	756.9	649.5	14.18	85.82
S6	45.32	834.4	696.7	16.50	83.50
S7	37.41	688.7	588.8	14.50	85.50
S8	41.11	756.9	634.7	16.14	83.86
S9	45.32	834.4	684.8	17.92	82.08
S10	37.41	688.7	586.2	14.88	85.12
S11	41.11	756.9	629.1	16.89	83.11
S12	45.32	834.4	679.7	18.54	81.46
S13	37.41	533.3	448.2	15.95	84.05
S14	41.11	586.0	479.2	18.22	81.78
S15	45.32	646.1	522.1	19.19	80.81

factor increase. The higher twist loss at high twist factor and high rotor speed occurs due to the greater incidence of wrapper fibres. Further, the twist loss is higher in coarse yarns due to their greater sensitivity to slippage.

3.2 Tenacity

Table 4 shows that rotor yarns are 11.45-26.25% weaker than the ring-spun yarns depending upon yarn composition, twist factor, yarn linear density and rotor speed. The difference in tenacity of ring- and rotor-spun yarns decreases as the yarns become coarse. For both ring- and rotor-spun yarns, the lowest tenacity corresponds to 30:70 acrylic-cotton yarns and it increases significantly with the increase in acrylic content owing to the higher tenacity and breaking extension of this fibre. However, the lower tenacity of 30:70 acrylic-cotton yarn results from the poor load sharing. Preliminary trials suggest that acrylic content should not be less than 50% for improvement in yarn tenacity. Surprisingly, an increase in rotor speed has no significant effect on yarn tenacity, although yarns spun at 60,000 rpm exhibit slightly lower strength. Further, the tenacity indices of various yarns reflect distinct trends with respect to twist factor. The tenacity of 15:85 acrylic-cotton yarns increases with the increasing twist factor due to the increased surface cohesion. However, the tenacity of acrylic-majority yarn consistently decreases as twist factor is increased from 37.41 to 45.32. Such a trend occurs because the optimum twist factor changes with the change in the proportion of blend constituents. Apart from this, the incidence of wrapper fibres also affects the yarn strength. An increase in twist factor is associated with more wrapper fibres which adversely affect yarn strength. Further, the number of wrapper fibres are more in acrylic- majority yarn than in cotton-majority yarn owing to the higher torsional rigidity of acrylic fibre. Therefore, the higher incidence of wrapper fibres is also responsible for lower yarn strength.

3.3 Breaking Extension

Table 4 shows that the breaking extension of rotor yarns is, in general, higher than that of ring yarns and it continues to follow the same trend as by strength with twist factor. Table 4 also shows that the yarns spun with higher proportion of acrylic fibres have higher breaking extension at all levels of twist. Further, the values of breaking extension are substantially higher for coarse yarns, as expected. With increase in rotor speed, the breaking extension drops due to increase in centrifugal force which ultimately makes the yarn more compact[7]. This compactness results in loss in breaking extension. Apart from this, an increase in the incidence of wrapper fibres also leads to unequal distribution of yarn strain on fibres along its length, leading to loss in breaking extension[5].

3.4 Yarn Count CV%

The values of count CV% of rotor yarns are much lower than that of ring-spun yarns. It ranges between 1.48 and 3.51 in ring yarns and between 1.05 and 2.11 in rotor yarns. The lower value of count CV% in rotor yarns results from the suppression of draft-

Table 4—Effect of fibre composition, yarn linear density, twist factor and rotor speed on tenacity, breaking extension, count CV% and diameter of acrylic-cotton ring- and rotor-spun yarns

Yarn ref. No.	Rotor-spun yarn					Ring-spun yarn				
	Tenacity mN/tex	Lea CSP	Breaking extension %	Count CV%	Diam. mm	Tenacity mN/tex	Lea CSP	Breaking extension %	Count CV%	Diam. mm
S1	90.15	1279.7	6.98	1.69	0.2114	107.12	1746.6	5.73	3.15	0.1867
S2	92.01	1339.9	7.18	1.80	0.2020	109.67	1776.6	5.81	3.45	0.1690
S3	93.78	1456.3	7.27	2.11	0.1841	113.10	1783.7	6.12	3.51	0.1594
S4	82.20	1234.9	7.38	1.56	0.2176	103.78	1732.5	6.13	2.68	0.1973
S5	85.44	1301.8	7.59	1.55	0.2078	105.84	1753.1	6.27	3.01	0.1786
S6	87.70	1352.5	7.74	1.59	0.2000	106.04	1776.6	6.41	3.26	0.1710
S7	97.31	1442.0	20.74	1.44	0.2323	116.73	1877.0	19.20	1.65	0.2106
S8	95.94	1439.3	19.55	1.47	0.2166	116.44	1852.8	18.31	2.47	0.1943
S9	95.05	1417.8	19.27	1.50	0.2032	114.77	1814.2	16.98	2.58	0.1803
S10	96.62	1410.6	19.85	1.48	0.2281	116.73	1877.0	19.20	1.65	0.2106
S11	95.54	1398.8	18.87	1.50	0.2051	116.44	1852.8	18.31	2.47	0.1943
S12	94.17	1380.0	18.32	1.54	0.1864	114.77	1814.2	16.98	2.58	0.1803
S13	108.79	1708.4	23.27	1.05	0.3151	121.25	1910.9	22.24	1.48	0.2843
S14	104.37	1664.7	22.20	1.37	0.2908	119.87	1897.6	21.09	1.96	0.2475
S15	101.33	1621.9	21.99	1.37	0.2755	116.64	1813.5	19.94	2.08	0.2259

Table 5—Effect of fibre composition, yarn linear density, twist factor and rotor speed on unevenness, imperfections and abrasion resistance of acrylic-cotton ring- and rotor-spun yarns

Yarn ref. No.	Rotor-spun yarn						Ring-spun yarn					
	U%	Imperfections/125 m				Abrasion resistance cycles	U%	Imperfections/125 m				Abrasion resistance cycles
		Thick places + 50%	Thin places —50%	Neps + 200 %	Total			Thick places + 50%	Thin places —50%	Neps + 200 %	Total	
S1	10.6	2	0	7	9	274	12.4	9	5	25	39	438
S2	11.0	3	0	9	12	465	12.8	13	6	27	46	784
S3	11.3	4	1	10	15	797	13.4	15	6	28	49	1325
S4	10.2	2	0	8	10	478	12.2	8	5	22	35	645
S5	10.5	4	0	12	16	504	12.6	11	5	24	40	1006
S6	11.0	6	1	13	20	709	12.8	13	6	26	45	1447
S7	9.3	3	1	11	15	613	11.1	8	3	19	30	1158
S8	9.9	5	2	14	21	651	11.9	9	4	21	34	1153
S9	10.5	8	2	16	26	737	12.2	12	5	24	41	1136
S10	9.5	5	2	14	21	625	11.1	8	3	19	30	1158
S11	10.2	6	3	16	25	660	11.9	9	4	21	34	1153
S12	10.8	10	4	20	34	741	12.2	12	5	24	41	1136
S13	8.8	2	0	8	10	917	10.5	5	2	17	24	1403
S14	9.1	3	1	10	14	987	10.7	6	3	19	28	1386
S15	9.6	5	1	11	16	1019	10.9	7	3	20	30	1331

ing wave. Apart from this, the elimination of undue stretch normally associated with rove and ring spinning operations also contributes to the lower count CV% of rotor yarns. For both ring- and rotor-spun yarns, the yarn count CV% is slightly higher for fine yarns but shows no consistent trend with increase in acrylic content and twist factor.

3.5 Diameter

Table 4 shows that acrylic-cotton rotor yarns exhibit bigger optical diameter than the equivalent ring yarns. The diameter of both ring- and rotor-spun yarns tends to increase with the increase in both acrylic content and yarn linear density. As twist factor increases, the yarn diameter decreases. However, the decrease is less in rotor yarns spun with higher proportion of acrylic fibre than that in equivalent ring yarns. This is because increased acrylic content and twist factor lead incompletely bound fibres to be surfaced on yarn periphery in the rotor that are insufficiently ordered. With the increase in rotor speed, the yarn diameter decreases due to the increased centrifugal force which ultimately makes the yarn more compact.

3.6 Yarn Unevenness

Table 5 shows that the rotor yarns are more regular and have fewer imperfections than the corresponding ring yarns. However, fibre composition, yarn linear density, twist factor and rotor speed may play a significant role in determining the yarn evenness. For both types of yarn, there is a significant increase in U% as the yarn linear density is decreased. With regard to fibre composition, the yarn unevenness reflects similar trends for both ring- and rotor-spun yarns. Yarn unevenness is lower, as usual, for yarns spun from fibres of higher acrylic content. The use of higher rotor speed causes a deterioration in yarn evenness. This is due to progressive increase in spinning tension and incidence of belts at higher rotor speed. Interestingly, yarn evenness drops sharply with increase in twist factor. For higher twist factors, the twist translation efficiency also becomes low. Since the decrease in twist translation efficiency is closely associated with that in yarn evenness, it is suggested to choose the optimum twist factor according to the circumstances.

3.7 Imperfections

Table 5 shows that acrylic-cotton rotor yarns have fewer imperfections as compared to their ring-spun counterparts. Yarn linear density significantly affects the imperfections, which increase as the yarn linear density is decreased. Further, an increase in neps with increase in acrylic content in rotor yarns results due to the increased disorientation of fibres (as these lie in the rotor groove) and the increase in the number of wraps per unit length[7]. A regular increase in thick places and neps with increase in both twist factor and rotor speed may also be observed. This may again be accounted for by the reasons given for yarn unevenness.

3.8 Abrasion Resistance

The number of abrasion cycles to rupture acrylic-cotton ring- and rotor-spun yarns with respect to different fibre compositions, yarn linear densities, twist factors and rotor speeds are given in Table 5. The rotor-spun yarns show less resistance to abrasion than the ring-spun yarns, possibly due to the high tension used during the abrasion testing which results in quick rupture of surface fibres, causing exposure of core fibres and thereby lowering the abrasion resistance. This agrees well with the earlier finding by Mukherjee *et al.*[8]. Rotor yarns, in general, register an increase in abrasion resistance with increasing twist factor. This increase in abrasion resistance occurs because sheath fibres which effectively shield the core increase with the increase in twist factor, resulting in high flexing cycles to rupture[9]. Apart from this, more yarn flattening occurs due to the presence of sheath fibres, whereby abrasive load per unit area would be reduced[10]. This could be partly held responsible for higher abrasion resistance of rotor yarns at higher twist factors. With regard to twist factor, ring yarns exhibit quite a distinct behaviour in the sense that cotton- majority yarns show a consistent increase in abrasion resistance with increasing twist factor. However, for 70:30 acrylic-cotton yarns, an increase in twist factor has no significant effect on abrasion resistance.

The increase in the proportion of acrylic fibre increases the abrasion resistance. The fact that acrylic-majority yarns are stronger and more extensible as compared to cotton-majority yarns is true for all the twist factors. Also, acrylic-majority yarns have more sheath fibres as compared to cotton-majority yarns. These three factors would be responsible for the higher abrasion resistance of acrylic-majority yarns as comapred to that of cotton-majority yarns through the range of twist factors used. Interestingly, the behaviour of 70:30 acrylic-cotton rotor yarns in relation to abrasion resistance as a function of rotor speed is totally different from their behaviour in relation to tensile strength. When the acrylic content is increased to 70%, the abrasion resistance does not show any change with increase in rotor speed. This indicates that any excessive level of sheath fibres at high rotor speed does not offer any further gain due to the weakening of yarn core. A weak core would cause rapid breakdown of the yarn towards the end.

4 Conclusions

4.1 The twist loss is higher in acrylic-majority yarns and it increases with the increase in yarn linear density, twist factor and rotor speed.

4.2 Acrylic-cotton yarns process well on ring- and rotor-frame. Rotor-spun yarns are substantially weaker and more extensible than ring-spun yarns. However, the difference in tenacity of ring- and rotor-spun yarns is much less for coarse yarns. Acrylic content in the acrylic-cotton mix should be more than 50% for improvement in yarn tenacity.

4.3 Rotor yarns are more even and have lower count CV% and fewer imperfections than the equivalent ring yarns. For both types of yarn, unevenness and imperfections, particularly thick places and neps, increase with the increase in both twist factor and rotor speed, and at the same time with the decrease in yarn linear density. However, an increase in acrylic content lowers the yarn unevenness.

4.4 Rotor yarns possess bigger optical diameter than their ring counterparts. The use of higher twist factor and rotor speed decreases the yarn diameter. However, the diameter increases with the increase in both acrylic content and yarn linear density.

4.5 Acrylic-cotton rotor yarns have lower abrasion resistance than the corresponding ring yarns which hardly alters with the increase in rotor speed. For both types of yarn, abrasion resistance markedly improves with the increase in acrylic content and yarn linear density. An increase in twist factor significantly increases the abrasion resistance of rotor yarns, the increase being more in cotton-majority yarns. However, for acrylic- majority ring yarns, the abrasion resistance does not show any change with increase in twist factor.

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