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# Variations in the characteristics of acrylic-cotton ring and OE rotor yarns as a consequence of steam-relaxation treatment

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The steam-relaxation treatment of acrylic-rich yarns reduces their tenacity and abrasion resistance, but increases extensibility and bulk. The adverse effects associated with steaming are more pronounced on OE rotor yarns than ring yarns and become larger with increase in both acrylic content and yarn tex. Yarns produced from the cotton-majority mix, on the other hand, show slightly higher tenacity and lower breaking extension, residual shrinkage and abrasion resistance after steaming.

**Keywords:** Acrylic-cotton yarn, Residual shrinkage, Rotor-spun yarn, Tex twist factor, Wrapper fibres

## 1 Introduction

The OE rotor spinning technology is the most common method of spinning coarse yarns and can produce perfectly satisfying yarns for knitting. In both natural and synthetic fibre sectors, OE rotor spinning system is perfect to spin yarns which are ideal for knitted substrates used to make underwears, towels, velours and sport shirts. Initially, the structure of OE rotor yarns differed from the structure of ring-spun yarns, the fibres being randomly distributed in the former. Thanks to the creativity and innovations in machine engineering terms to help produce novel structure yarns. The present day high speed OE rotor spinning machines produce yarns at spinning speeds in excess of 130,000 rpm with yarn delivery at 200 m/min. But these yarns are quite stiff in nature and result in unacceptable spirality and harsh handle in fabrics, which render them unattractive for apparel applications. Steam-relaxation treatment can be used effectively to overcome these deficiencies. When steam is used as a medium, the strains imposed during spinning become cohesively set which are later released when the yarn is subjected to steaming. There have been numerous studies on spirality reduction through steaming[1-2], but none so far has addressed the question of the extent to which the steam-relaxation treatment influences the yarn characteristics. This paper reports the variations in the characteristics of acrylic-cotton ring and OE rotor spun yarns caused by steam-relaxation treatment.

## 2 Materials and Methods

### 2.1 Preparation of Yarn Samples

Two sets of yarns of 29.5 and 49.2 tex were spun from the blends of acrylic and cotton fibres on ring and OE rotor spinning machines. The specifications of acrylic and cotton fibres used are given in Table 1. 49.2 tex acrylic-cotton yarns with blend proportions 30:70, 70:30 and 100:0, and 29.5 tex acrylic-cotton yarns with blend ratios 70:30 and 100:0 were spun with three different tex twist factors (37.41, 41.11 and 45.32). The combed cotton was mixed with acrylic in the opening room. The proportion of acrylic fibre was kept 1.5% higher than the ultimate required proportion. The conversion to drawn sliver was carried out by using a MMC card and a Lakshmi Rieters' draw frame DO/2S. Two drawing passages were given to the carded sliver. The linear density of drawn slivers was adjusted to 3.0 ktex. The drawn slivers were spun into yarns on Ingolstadt Rotor Spinner RU 11/RU 80 (4602). The process parameters used to produce these yarns are given in Table 2. The machine parameters used for the spinning of OE rotor yarns were: 48 mm rotor, a saw-tooth opening roller (type of clothing, OS/21; teeth/$cm^2$, 24; face angle, 100°), and a notched nozzle with 15.5 mm exterior diam. and 3 mm interior diam..

Table 1—Specifications of acrylic and cotton fibres

| Fibre | Length mm | Linear density dtex | Before steaming | | After steaming | |
|---|---|---|---|---|---|---|
| | | | Tenacity cN/tex | Breaking extension % | Tenacity cN/tex | Breaking extension % |
| Acrylic | 38.0 | 1.66 | 22.73 | 30.55 | 21.79 | 34.02 |
| Cotton | 25.1[a] | 1.66 | 20.30 | 5.00 | 21.45 | 4.58 |

[a]2.5% Span length

Table 2—Spinning parameters for rotor-spun yarns

| Yarn ref. no. | Yarn linear density, tex | Blend ratio (Acrylic/Cotton) | Rotor speed $\times 10^3$, rpm | Opening roller speed $\times 10^3$, rpm | Tex twist factor |
|---|---|---|---|---|---|
| S1 | 49.2 | 30:70 | 50 | 7 | 37.41 |
| S2 | 49.2 | 30:70 | 50 | 7 | 41.11 |
| S3 | 49.2 | 30:70 | 50 | 7 | 45.32 |
| S4 | 49.2 | 70:30 | 50 | 7 | 37.41 |
| S5 | 49.2 | 70:30 | 50 | 7 | 41.11 |
| S6 | 49.2 | 70:30 | 50 | 7 | 45.32 |
| S7 | 49.2 | 100:00 | 50 | 7 | 37.41 |
| S8 | 49.2 | 100:00 | 50 | 7 | 41.11 |
| S9 | 49.2 | 100:00 | 50 | 7 | 45.32 |
| S10 | 29.5 | 70:30 | 50 | 7 | 37.41 |
| S11 | 29.5 | 70:30 | 50 | 7 | 41.11 |
| S12 | 29.5 | 70:30 | 50 | 7 | 45.32 |
| S13 | 29.5 | 100:00 | 50 | 7 | 37.41 |
| S14 | 29.5 | 100:00 | 50 | 7 | 41.11 |
| S15 | 29.5 | 100:00 | 50 | 7 | 45.32 |

To produce the equivalent ring yarns, the drawn slivers were converted into a suitable rove of 390 tex on a Texmaco Howa Simplex. The rove was then fed to a Lakshmi Rieters' ring frame G 5/1 using a spindle speed of 12,500 rpm.

### 2.2 Steam-relaxation Treatment

Steam-relaxation of both ring and OE rotor-spun yarns under relaxed condition was carried out in the skein form in a laboratory Strazor machine. Skeins, each of 100 m, were prepared on a wrap reel of 2 m circumference. Three different places of skeins were tied loosely with cotton threads so that the lacing does not affect shrinkage and buckling during steaming. Skeins were then treated with steam. The temperature of steam and residence period were maintained at 102°C and 30 min respectively. The skeins were then air-dried.

### 2.3 Tests

All the yarns were tested according to standard ASTM procedures. Tensile properties of all the yarns, before and after steaming, were measured on an Instron using a gauge length of 50 cm and a cross-head speed of 20 cm/min. The mean tenacity and breaking elongation were averaged from fifty observations for each yarn sample. A projection microscope was used to determine yarn diameter. Resistance to abrasion was assessed by a Custom Scientific abrasion tester. Skeins were first prepared on wrap reel. From each skein, 2.54 cm wide and 23 cm long specimen was cut. The yarns were then kept in contact with a reciprocating abradant under a load of 500 g, and the number of rubs needed to break the specimen was taken as a measure of abrasion resistance. Residual shrinkage of yarns was determined according to ASTM D 2259-83.

## 3 Results and Discussion

### 3.1 Tenacity

In general, the acrylic-cotton ring-spun yarns record 14.89-29.20% higher tenacity values than corresponding OE rotor yarns (Table 3). When these yarns are steamed, the tenacity of 100 % acrylic and 70:30 acrylic-cotton yarns show a decreasing trend at all levels of twist. The decrease in tenacity is caused by the loosening of the yarn structure, which arises mainly as a result of bending and buckling of core fibres. Apart from this, the decrease in the tenacity of acrylic fibre through steaming (Table 1) also partly contributes to the lower strength of steamed yarns. Like ring yarns, the decrease in the tenacity of OE rotor yarns is more marked in the yarns spun from higher proportion of acrylic fibres and it reduces with the increase in tex twist factor. The decrease in tenacity loss results from the higher incidence of wrapper fibres/belts in high twisted yarns. These wrapper fibres shrink on steaming and tend to restrict the slippage of fibres during tensile loading, thereby decreasing the tenacity loss. In contrast, 30:70 acrylic-cotton yarns show slight increase in tenacity after steam-relaxation treatment. A possible cause for such an increase in the tenacity of 30:70 acrylic-cotton yarns may be the removal of natural oils, fats and waxes, which possibly increase inter-fibre friction[3]. Further, Table 3 shows slightly greater loss in tenacity of OE rotor yarns (6.76-13.26%) than ring-spun yarns (6.13-11.66%) after steaming. The high bulk of OE rotor yarns, which allows easier and quick penetration of steam, is obviously the contributing factor for greater loss in tenacity.

### 3.2 Breaking Extension

Steam-relaxation causes a marked increase in the breaking extension of ring and OE rotor yarns spun from higher proportion of acrylic fibres (Table 3). This may be due to the rearrangement of molecular structure and yarn shrinkage[4]. The increase in breaking extension is 13.41-46.62% for ring yarns and 17.51-51.30% for OE rotor yarns. In the case of 30:70 acrylic-cotton yarns, there is a decrease in breaking extension, possibly due to the molecular disorientation of fibres, which offsets both the breaking extension and tenacity. Further, the percentage increase in steamed yarns in relation to the parent yarns shows an increasing trend with increasing twist factor. Higher twist leads to higher inter-fibre friction owing to

Table 3—Influence of fibre composition, yarn linear density, twist factor and steam-relaxation treatment on tenacity and breaking extension of acrylic-cotton ring and rotor-spun yarns

| Yarn ref. no. | Tenacity, cN/tex | | | | | | Breaking extension, % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Rotor yarn | | | Ring yarn | | | Rotor yarn | | | Ring yarn | | |
| | Grey | Steamed | % Change | Grey | Steamed | % Change | Grey | Steamed | % Change | Grey | Steamed | % Change |
| S1 | 7.48 | 7.88 | +5.34 | 10.57 | 11.00 | +4.06 | 7.89 | 7.53 | -4.44 | 6.79 | 6.58 | -3.04 |
| S2 | 8.08 | 8.45 | +4.57 | 10.99 | 11.36 | +3.36 | 7.98 | 7.57 | -5.06 | 7.11 | 6.83 | -3.87 |
| S3 | 8.56 | 8.89 | +3.85 | 11.50 | 11.83 | +2.86 | 8.68 | 8.13 | -6.26 | 7.32 | 6.98 | -4.51 |
| S4 | 10.87 | 9.93 | -8.64 | 13.13 | 12.17 | -7.31 | 23.27 | 29.95 | +24.42 | 22.60 | 27.83 | +20.51 |
| S5 | 10.43 | 9.63 | -7.67 | 12.88 | 12.00 | -6.83 | 22.20 | 28.16 | +26.86 | 21.88 | 26.61 | +21.65 |
| S6 | 10.13 | 9.44 | -6.81 | 12.66 | 11.88 | -6.16 | 21.99 | 28.08 | +27.70 | 21.51 | 26.44 | +22.94 |
| S7 | 13.11 | 11.33 | -13.57 | 15.40 | 13.60 | -11.68 | 26.26 | 38.89 | +48.10 | 25.59 | 36.96 | +44.45 |
| S8 | 12.57 | 10.99 | -12.56 | 14.98 | 13.32 | -11.08 | 25.76 | 38.69 | +50.20 | 24.68 | 35.80 | +45.09 |
| S9 | 12.35 | 10.89 | -11.82 | 14.70 | 13.12 | -10.74 | 24.27 | 36.72 | +51.30 | 23.72 | 34.77 | +46.62 |
| S10 | 9.73 | 8.97 | -7.81 | 11.67 | 10.89 | -6.68 | 20.74 | 24.37 | +17.51 | 19.20 | 21.87 | +13.41 |
| S11 | 9.59 | 8.93 | -6.88 | 11.64 | 10.87 | -6.61 | 19.55 | 23.34 | +19.40 | 18.31 | 20.96 | +14.48 |
| S12 | 9.50 | 8.87 | -6.63 | 11.47 | 10.77 | -6.10 | 19.27 | 23.22 | +20.54 | 16.98 | 19.66 | +15.82 |
| S13 | 12.14 | 10.73 | -11.61 | 14.49 | 12.91 | -10.90 | 25.08 | 35.66 | +42.20 | 24.48 | 33.41 | +36.49 |
| S14 | 11.23 | 10.03 | -10.68 | 14.03 | 12.58 | -10.33 | 24.80 | 35.63 | +43.70 | 24.24 | 33.22 | +37.56 |
| S15 | 10.99 | 9.89 | -10.00 | 13.78 | 12.45 | -9.65 | 23.94 | 34.76 | +45.20 | 23.63 | 32.76 | +38.67 |

swelling and shrinkage of fibres within the yarn after steaming.

### 3.3 Yarn Linear Density

It may be seen from Table 4 that the linear density of both types of yarn tends to increase after steam-relaxation treatment. Such an increase is caused by the shortening of fibre length, which is mainly due to structural changes in the yarn[5]. The increase in linear density becomes more with the increase in acrylic content in the blend due to the higher shrinkage potential of this fibre. Further, the increase in linear density is more marked in OE rotor yarns than in ring yarns and it increases with the increase in yarn tex owing to the lower packing density of the former, which facilitates the absorption of steam into the body of yarn.

### 3.4 Diameter

Table 4 shows that OE rotor yarns, in general, exhibit considerably larger optical diameter than ring-spun yarns, which increases after steam-relaxation treatment. Higher twist levels tend to reduce bulk levels attained in the yarn structures during steaming. Increasing acrylic content increases the diameter of both ring and OE rotor yarns at all twist levels.

### 3.5 Residual Shrinkage

It is seen from Table 5 that the residual shrinkage for OE rotor yarns is considerably higher than that for ring yarns. The observed difference in residual shrinkage can be attributed to the difference in the spinning tensions. Both types of yarn behave similarly with respect to twist factor. In general, for both the yarn structures, the minimum residual shrinkage corresponds to the lowest twist level and it increases with the increase in tex twist factor. Further, coarse yarns exhibit higher residual shrinkage which further increases with the increase in the proportion of acrylic fibres in the fibre mix.

### 3.6 Abrasion Resistance

The acrylic-cotton OE rotor yarns, in general, show a lower value of abrasion resistance than their ring-spun counterparts (Table 5). The experimental behaviour may result from the quick rupture of the surface fibres due to high tension used during abrasion testing, which could lead to early exposure of core fibres and thereby lowering the abrasion resistance. This accords well to the earlier finding by Tyagi *et al.*[6]. Invariably, the abrasion resistance of both types of yarn decreases after steam-relaxation treatment. As mentioned earlier, steaming causes fibres to buckle, resulting

Table 4—Influence of fibre composition, yarn linear density, twist factor and steam-relaxation treatment on diameter and linear density of acrylic-cotton ring and rotor-spun yarns

| Yarn ref. no. | Diameter, mm | | | | Linear density, tex | | | |
|---|---|---|---|---|---|---|---|---|
| | Rotor yarn | | Ring yarn | | Rotor yarn | | Ring yarn | |
| | Grey | Steamed | Grey | Steamed | Grey | Steamed | Grey | Steamed |
| S1 | 0.291 | 0.297 | 0.267 | 0.272 | 47.11 | 49.97 | 48.33 | 51.11 |
| S2 | 0.280 | 0.288 | 0.263 | 0.268 | 48.08 | 51.42 | 49.13 | 51.69 |
| S3 | 0.264 | 0.273 | 0.248 | 0.254 | 49.10 | 53.31 | 50.84 | 54.02 |
| S4 | 0.315 | 0.334 | 0.284 | 0.295 | 47.70 | 53.74 | 48.66 | 53.49 |
| S5 | 0.290 | 0.311 | 0.247 | 0.258 | 48.65 | 56.01 | 49.57 | 55.00 |
| S6 | 0.275 | 0.297 | 0.225 | 0.238 | 49.75 | 58.40 | 50.30 | 57.94 |
| S7 | 0.368 | 0.412 | 0.329 | 0.359 | 48.57 | 61.02 | 49.44 | 59.90 |
| S8 | 0.353 | 0.398 | 0.312 | 0.341 | 49.84 | 63.50 | 49.68 | 60.98 |
| S9 | 0.340 | 0.387 | 0.301 | 0.332 | 50.75 | 65.64 | 50.50 | 62.46 |
| S10 | 0.232 | 0.242 | 0.210 | 0.215 | 29.40 | 33.27 | 29.16 | 30.97 |
| S11 | 0.216 | 0.227 | 0.194 | 0.201 | 29.69 | 33.40 | 29.52 | 32.85 |
| S12 | 0.203 | 0.216 | 0.180 | 0.188 | 30.11 | 34.49 | 29.80 | 33.50 |
| S13 | 0.312 | 0.343 | 0.278 | 0.295 | 28.16 | 34.63 | 29.51 | 35.10 |
| S14 | 0.301 | 0.334 | 0.262 | 0.279 | 29.52 | 36.37 | 30.43 | 36.65 |
| S15 | 0.273 | 0.304 | 0.237 | 0.254 | 30.74 | 38.77 | 31.24 | 38.04 |

Table 5—Influence of fibre composition, yarn linear density, twist factor and steam-relaxation treatment on abrasion resistance and residual shrinkage of acrylic-cotton ring and rotor-spun yarns

| Yarn ref. no. | Abrasion resistance, cycles | | | | Residual shrinkage, % | |
|---|---|---|---|---|---|---|
| | Rotor yarn | | Ring yarn | | Rotor yarn | Ring yarn |
| | Grey | Steamed | Grey | Steamed | | |
| S1 | 832 | 794 | 1049 | 1004 | 5.54 | 3.56 |
| S2 | 925 | 894 | 1156 | 1116 | 6.38 | 4.14 |
| S3 | 990 | 961 | 1264 | 1229 | 7.40 | 5.37 |
| S4 | 917 | 862 | 1403 | 1343 | 11.20 | 8.36 |
| S5 | 987 | 938 | 1386 | 1337 | 12.72 | 9.47 |
| S6 | 1019 | 976 | 1351 | 1301 | 14.38 | 10.37 |
| S7 | 1074 | 1029 | 1566 | 1515 | 20.37 | 16.66 |
| S8 | 1134 | 1094 | 1551 | 1506 | 21.40 | 17.71 |
| S9 | 1182 | 1146 | 1537 | 1498 | 22.57 | 18.05 |
| S10 | 613 | 565 | 1160 | 1103 | 9.20 | 7.22 |
| S11 | 651 | 609 | 1153 | 1098 | 9.96 | 8.62 |
| S12 | 737 | 697 | 1136 | 1090 | 11.67 | 9.74 |
| S13 | 670 | 631 | 1240 | 1195 | 17.50 | 15.07 |
| S14 | 705 | 669 | 1226 | 1186 | 18.75 | 15.85 |
| S15 | 752 | 716 | 1202 | 1164 | 20.25 | 16.69 |

in loosening of the structure, which, in turn, facilitates easy pull-out of the fibres from the yarn matrix during abrasion. This could partly explain the lower abrasion resistance of the steamed yarns.

## 4 Conclusions

4.1 Tensile behaviour of acrylic-cotton ring and OE rotor yarns is predominantly influenced by steam-relaxation treatment. On steaming, acrylic-rich yarns register a marked decrease in tenacity accompanied by an increase in breaking extension. The decrease in tenacity is more in OE rotor yarns than in ring yarns. The tenacity loss increases with the increase in acrylic content and yarn tex and decrease in twist factor. Yarns produced with cotton-majority mix, on the other hand, show slightly higher tenacity and lower breaking extension after steaming.

4.2 OE rotor yarns possess larger optical diameter, which decreases with the decrease in acrylic content and increase in twist factor but increases after steam-relaxation treatment.

4.3 Residual shrinkage is considerably higher for acrylic-cotton OE rotor yarns compared to ring-spun yarns. Residual shrinkage increases when both yarn linear density and twist factor increase, the increase being more prominent for blends having higher acrylic content.

4.4 Acrylic-cotton OE rotor yarns show lower abrasion resistance than their ring-spun counterparts. The abrasion resistance of both types of yarn decreases on steaming.

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