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Response of polyester-viscose ring and MJS yarns to heat treatment under relaxed condition

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The impact of heat treatment under relaxed condition on the mechanical characteristics of polyester-viscose ring and MJS yarns has been studied. Heat treatment markedly decreases the rigidity of both ring and MJS yarns, but the loss in tensile strength is also considerably higher. The decrease in rigidity is highly dependent on the blend ratio, yarn tex and type of spinning system. Some other changes in yarn properties include remarkably enhanced breaking extension accompanied by deterioration in evenness.

Keywords : Annealing, Murata-jet spinner, Polyester-viscose yarn, Ring yarn, Wrapper fibres

1 Introduction

In view of the growing demand for quality textiles throughout the world, the production of man-made fibre yarns on air-jet spinning machines is receiving increasing attention. The past few years have witnessed intensive research on the technological effects of material and system variables on yarn characteristics[1-3]. Numerous reports have been published on the comparison of the characteristics of fasciated yarns with those of ring-spun yarns[4,5]. There is a consensus that jet-spun yarns are more rigid than the equivalent ring and rotor yarns. Yarn rigidity, which directly influences the handle of the fabrics, is needed to be reduced for certain end uses and merits investigation. Several researchers have investigated the aspect of yarn rigidity and concluded that the use of lower feed ratio[6], reduction in main draft and lower injector-jet pressure bring down rigidity[7]. It stands to logic that the use of heat may also play an important role in controlling rigidity. Sengupta *et al.*[8] gave an account of the influence of heat treatment on flexural rigidity, besides tenacity and breaking extension, of ring and jet-spun yarns. However, this study was confined only to 100% polyester-fibre yarn. The present investigation is aimed at studying the rigidity of more commonly used polyester-viscose blend yarns and the influence of heat treatment on the general properties of these yarns.

2 Materials and Methods

2.1 Preparation of Yarn Samples

Two sets of yarns of 12.3 and 29.5 tex were spun from blends of polyester and viscose rayon fibres on ring and air-jet spinning machines. The specifications of polyester and viscose rayon fibres used are given in Table 1. Laps were made on a Lakshmi Rieter's blowroom line and carded on a MMC card. The carded slivers were given three passages of drawing on a Lakshmi Rieter's drawframe DO/2S to produce a finisher sliver of 3.0 ktex. The drawn slivers were spun on the Murata air-jet spinner 802MJS. The process parameters used to produce jet yarns are given in Table 2. For ring yarns, the drawn slivers were converted into suitable roving of 390 tex on Texmaco Howa Simplex and spun on Lakshmi Rieter's ring frame G5/1 using a spindle speed of 13500 rpm.

2.2 Heat Treatment

All ring and MJS yarns were heated at 160°C for 5 min in a laboratory curing-setting chamber under relaxed condition.

Table 1—Specifications of polyester and viscose rayon fibres before and after heat treatment

Fibre	Length mm	Linear density dtex	Tenacity, cN/tex		Breaking extension, %	
			Before treatment	After treatment	Before treatment	After treatment
Polyester	51	1.66	45.7	43.3	29.5	36.3
Viscose	51	1.66	29.2	28.2	18.2	21.6

Table 2—Spinning parameters for MJS yarns

Yarn ref. no.	Yarn linear density tex	Yarn composition (P:V)	Spinning speed m/min	Ribbon width nm	Feed ratio	NP1 kg/cm^2	NP2 kg/cm^2
S1	12.3	35:65	200	3	0.97	3.0	4.5
S2	12.3	65:35	180	3	0.97	3.0	4.5
S3	12.3	65:35	190	3	0.97	3.0	4.5
S4	12.3	65:35	200	3	0.97	3.0	4.5
S5	12.3	85:15	200	3	0.97	3.0	4.5
S6	29.5	35:65	200	3	0.97	3.0	4.5
S7	29.5	65:35	180	3	0.97	3.0	4.5
S8	29.5	65:35	190	3	0.97	3.0	4.5
S9	29.5	65:35	200	3	0.97	3.0	4.5
S10	29.5	85:15	200	3	0.97	3.0	4.5

NPI—First jet pressure ; NP2—Second jet pressure; P—Polyester ; V—Viscose

2.3 Tests

Yarn tenacity and breaking extension, before and after heat treatment, were measured on an Instron tensile tester using 500 mm test specimen and 20 cm/min extension rate. Yarn unevenness was tested on an Uster evenness tester. The flexural rigidity of yarns was tested on weighted ring yarn stiffness tester by ring loop method[9]. Yarn diameter was measured on a projection microscope and the residual shrinkage of yarns was estimated as per BSI method.

3 Results and Discussion

3.1 Tenacity

Polyester and viscose fibres taken out from loose heated stock showed a decrease in tenacity and an increase in breaking extension (Table 1). The tenacity of polyester fibre reduces due to the weakening of inter-molecular forces. This is born out by the fact that the birefringence, which can be taken as an indication of molecular orientation, decreases after heat treatment. For 51mm, 1.66 dtex polyester fibre, the birefringence was found to be 0.266 and 0.262 respectively for grey and treated fibres. Besides this, the crystalline/amorphous ratio for polyester fibre also increases from 1.07 to 1.22 as a result of heating which signifies the occurrence of chain folding, leading to a loss in fibre tenacity. Harrison[10] also reported a loss in tenacity of polyester staple fibre due to decrease in birefringence. Table 3 shows that the heat treatment considerably decreases the tenacity of polyester-viscose ring and MJS yarns over the whole range of process variables. The percentage decrease in tenacity ranges between 5.99 and 12.61 in MJS yarns, and between 6.85 and 14.49 in ring yarns. A higher production speed results in slightly higher tenacity of MJS yarns and lesser decrease in tenacity on heat treatment. In both types of yarn, the decrease for 35/65 (polyester/viscose) blend is minimum and it increases with increasing polyester content. This can be attributed to the higher shrinkage potential of polyester fibre which leads to loosening up of yarn structure. Apart from this, the decrease in fibre tenacity as a consequence of heat treatment (Table 1) may also be contributing to the decrease in tenacity of treated yarns.

The reduction in tenacity on heat treatment decreases with decreasing yarn linear density for both ring and MJS yarns. In fine MJS yarn, the higher incidence of wrapper fibres restricts the loosening of yarn structure owing to the higher resistance imposed by these fibres to the longitudinal shrinkage of core fibres.

3.2 Breaking Extension

Table 3 shows a significant increase in breaking extension of ring and MJS yarns after heat treatment. This increase in breaking extension is the outcome of yarn shrinkage and increased fibre extension. However, the improvement in breaking extension is more marked in ring yarns as compared to MJS yarns owing to the higher tension used during spinning of ring yarns. Consequently, the fibres in ring yarns shrink more and thus result in higher extensibility. With regard to blend ratio and yarn linear density, the breaking extension shows a similar trend as for yarn tenacity. The effect of ribbon width is marginal.

3.3 Residual Shrinkage

The values of residual shrinkage for ring and MJS yarns of different compositions and linear densities and ribbon width are given in Table 4. The comparatively higher residual shrinkage of ring yarns can be attributed to its higher spinning tension. For both types of yarn, the extent of shrinkage increases with increasing proportion of polyester fibres and increase in yarn linear density. The MJS yarn shows a slightly lower shrinkage as the production speed is increased.

3.4 Yarn Linear Density

The linear density of both types of yarn tends to increase after heat treatment due to fibre shrinkage (Table 4). The increase in linear density is more in coarse yarns which further increases when the proportion of polyester fibres is increased, obviously due to the higher shrinkage potential of polyester fibre.

3.5 Yarn Diameter

Table 3 shows that all yarns register a significant increase in diameter after heat treatment. In case of MJS yarns, the diameter of 29.5 tex yarn spun from 85/15 (polyester/viscose) blend shows an increase of about 26% over the untreated yarn, whereas the diameter of 29.5 tex yarn spun with 35% polyester content shows

Table 3—Effect of heat treatment on tenacity, breaking extension and diameter of polyester-viscose ring and MJS yarns

Yarn[a] ref. no.	Tenacity, cN/tex			Breaking extension, %			Diameter, mm		
	Parent yarn	Treated yarn	% Change	Parent yarn	Treated yarn	% Change	Parent yarn	Treated yarn	% Change
S1	16.19	15.22[c]	−5.99	11.22	13.92[b]	+24.06	0.1070	0.1192	+11.4
S2	17.63	16.40[b]	−6.97	12.57	15.86[b]	+26.17	0.1111	0.1279	+15.1
S3	18.29	17.17[c]	−6.12	12.70	15.97[b]	+25.74	0.1095	0.1252	+14.3
S4	18.92	17.90[c]	−5.39	12.89	16.04[b]	+24.43	0.1088	0.1235	+13.5
S5	19.87	18.28[b]	−8.00	14.69	19.05[b]	+29.74	0.1178	0.1407	+19.4
S6	15.24	13.80[b]	−9.44	10.90	13.94[b]	+27.88	0.1857	0.2161	+16.4
S7	16.57	14.76[b]	−10.92	12.26	16.15[b]	+31.72	0.1933	0.2339	+21.0
S8	17.24	15.55[b]	−9.80	12.38	16.21[b]	+30.93	0.1903	0.2286	+20.1
S9	17.92	16.36[b]	−8.70	12.49	16.29[b]	+30.42	0.1864	0.2222	+19.2
S10	18.98	16.58[b]	−12.61	13.54	18.55[b]	+37.00	0.2013	0.2538	+26.1
S11	17.47	16.22[c]	−7.15	9.88	13.05[b]	+32.08	0.1005	0.1134	+12.8
S12	19.64	18.07[b]	−7.99	10.93	14.76[b]	+35.04	0.1054	0.1242	+17.8
S13	22.20	20.17[b]	−9.14	12.05	16.50[b]	+36.92	0.1098	0.1337	+21.8
S14	19.84	17.85[b]	−10.03	10.25	13.95[b]	+36.09	0.1710	0.2021	+18.2
S15	23.44	20.48[b]	−12.62	11.38	15.91[b]	+39.80	0.1764	0.2172	+23.1
S16	24.91	21.30[b]	−14.49	12.71	18.26[b]	+43.66	0.1817	0.2339	+28.7

[a]S11-S13—Ring yarns spun with 35/65, 65/35 and 85/15 polyester-viscose blends (12.3 tex) respectively; and S14-S16—Ring yarns spun with 35/65, 65/35 and 85/15 polyester-viscose blends (29.5 tex) respectively.
[b]Significant ; [c]Non-significant

Table 4—Effect of heat setting on flexural rigidity, linear density, residual shrinkage and unevenness of polyester-viscose ring and MJS yarns

Yarn[a] ref. no.	Linear density, tex		U%		Flexural rigidity $\times 10^3$, g cm^2			Residual shrinkage %
	Parent yarn	Treated yarn	Parent yarn	Treated yarn	Parent yarn	Treated yarn	% Change	
S1	12.11	13.11	12.2	12.6	8.47	7.54	−11.0	6.96
S2	12.22	13.24	11.5	12.2	9.50	8.27	−13.0	7.49[b]
S3	11.69	13.65	11.7	12.1	10.03	8.81	−12.2	7.00[c]
S4	12.23	13.30	12.0	12.3	10.49	9.27	−11.6	6.78[c]
S5	12.35	13.51	11.4	11.9	11.12	9.36	−15.8	8.32[b]
S6	28.30	31.22	10.2	11.0	9.11	7.95	−12.7	8.93
S7	29.33	32.36	9.9	10.8	10.29	8.68	−15.6	9.74[b]
S8	30.36	33.53	10.4	11.3	10.67	9.06	−15.1	9.32[c]
S9	30.26	33.39	10.9	11.9	11.13	9.51	−14.6	9.00[c]
S10	30.38	34.04	9.8	10.6	11.87	9.83	−17.2	10.56[b]
S11	12.56	13.63	13.5	13.9	7.05	6.70	−5.0	7.47
S12	13.09	14.53	13.3	13.7	8.11	7.68	−5.3	8.02[b]
S13	12.40	13.72	13.1	13.6	9.45	8.62	−8.8	9.20[c]
S14	29.51	32.59	11.7	12.7	7.28	6.85	−5.9	9.77[b]
S15	31.40	35.20	11.1	12.2	8.47	7.76	−8.4	10.54[b]
S16	30.40	34.41	10.5	11.5	9.87	8.95	−9.3	11.49[b]

[a]S11-S16 correspond to the yarns given in Table 3.
[b]Significant; [c]Non-significant

an increase of only 16.5%. The corresponding increase in diameter obtained for ring yarn is about 28% for 85/15 (polyester/viscose) and 18% for 35/65 (polyester/viscose) blend. Table 3 also indicates that the production speed plays a significant role in influencing the diameter of MJS yarns. In the production speed range of 180-200 m/min, the increase in diameter on heating steadily decreases with increase in speed. As explained earlier, the wrapper fibres influence the longitudinal shrinkage as they restrict the bending and buckling of core fibres[11].

3.6 Flexural Rigidity

Table 4 shows that polyester-viscose MJS yarns are considerably more rigid than their ring-spun counterparts. The higher rigidity of MJS yarns has been attributed to its unique structure. Though heat treatment decreases the flexural rigidity of both ring and MJS yarns, the decrease in flexural rigidity is relatively higher for MJS yarns. Table 4 also shows that the decrease in flexural rigidity is influenced by the blend ratio, yarn linear density and production speed. Around 11% decrease in flexural rigidity is observed for 12.3 tex polyester-viscose (35/65) yarn which increases to around 16% with the increase in polyester fibre content to 85%. Surprisingly, the increase in production speed has considerable influence on the flexural rigidity of annealed yarns. The yarns produced at higher production speeds exhibit lesser decrease in flexural rigidity. Such a behaviour can be ascribed to the higher incidence of wrapper fibres which restrict the fibre relaxation[12]. Moreover, the decrease in flexural rigidity also increases when the yarn linear density is increased from 12.3 to 29.5 tex.

3.7 Unevenness

Table 4 shows that the unevenness of polyester-viscose MJS yarns is considerably lower than that of the equivalent ring-spun yarns. The MJS yarns spun at a speed of 200 m/min show higher unevenness than those spun at 180 m/min . This is due to the progressive increase in the number of wrapper fibres as the production speed goes up[4]. For both ring and MJS yarns, the yarn irregularity is slightly lower for yarns having higher proportion of polyester fibres. The irregularity decreases with the increase in yarn linear density. On heat treatment, a slight increase in unevenness is noticed in all cases. This deterioration in yarn evenness occurs because heat treatment increases permittivity and dielectric constant[12], which, in turn, alters the capacitance of the condenser. Therefore, the Uster evenness tester records apparently higher values.

4 Conclusions

4.1 The flexural rigidity of MJS yarns significantly decreases as a result of heat treatment. The decrease is highly dependent on the yarn tex and blend ratio. The yarns either having higher linear density or relatively higher polyester content or produced at lower speed show higher decrease in rigidity.

4.2 The heat treatment results in tenacity loss of 6-12% for MJS yarns and 7-14.5% for ring yarns. The loss is greater for coarse yarns or yarns having higher polyester content. In all cases, the loss is comparatively lower for MJS yarns. The loss is seen to decrease when MJS yarns are produced at higher speeds.

4.3 The breaking extension of polyester-viscose ring and MJS yarns increases on heat treatment. The increase in breaking extension is comparatively higher for ring yarns and it decreases with increasing viscose content.

4.4 Heat treatment causes a marked increase in diameter of both ring and MJS yarns, the increase being slightly more for ring yarns.

4.5 Ring yarns exhibit somewhat higher residual shrinkage than equivalent MJS yarns. The shrinkage increases with increasing polyester content and yarn linear density for both ring and MJS yarns.

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