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Effect of Twist and Fibre Denier on Characteristics of Polyester-Viscose Core-spun Yarns

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The effect of sheath-fibre denier and twist on the characteristics of core-spun yarns, with a constant polyester core, was studied. Core-spun yarns with the same core component but with finer-denier viscose sheath fibre gave a higher strength and an overall higher yarn quality index. Alteration of twist did not affect the number of neps, which however decreased with increase in fibre denier. Thick places increased with increase in fibre denier. Flex abrasion resistance decreased with decrease in twist, but was higher for yarns spun with finer-denier sheath fibre.

Keywords: Core-spun yarn, Fibre denier, Polyester-viscose yarn, Viscose-polyester yarn, Yarn characteristics, Yarn twist

1 Introduction

Several researchers have studied, theoretically and experimentally, the effect of twist, core-sheath ratio, single or double rove fed, or pretension on the characteristics of core-spun yarns separately. Not much work, however, has been done on the combined effect of various process variables. Hence the present study on the effect of fibre linear density and twist on the characteristics of core-spun yarns with non-elastic cores.

2 Materials and Methods

2.1 Preparation of Yarn Samples

Three core yarn samples of 16s nominal count were spun from 100% polyester core (72 denier/24 filaments) and 100% viscose (sheath) of three different deniers, 1.5, 2.0 and 4.0. Four twist multipliers, 2.8, 3.2, 3.5 and 3.8, were used for each yarn sample with Z twist.

Pure viscose staple of different deniers was hand-opened and sandwiched well to obtain a homogeneous mixing. The samples were then processed on a M – M – C card followed by two passages of O.K.K. draw frame. The drawn slivers were processed on a O.K.K. Simplex to prepare a roving of 1.62 hank with a total draft of 10.5. The specifications of viscose fibres are given in Table 1. The pretension core component (polyester) was guided to the front roller nip between two rovings, which were kept separated until drawing, on a Texmaco ring frame. All the three core yarns of 16s nominal count were spun with four different levels of twist multipliers.

2.2 Tests

The yarn breaking strength and elongation were determined on an Uster single yarn tester. The yarn irregularity (U%) was measured on an Uster evenness tester. The lea strength was found out by using half leas, as the preliminary trials showed that in some cases the full lea strength exceeded 200 lb, which is the maximum range of lea strength available in the tester in our laboratory. The yarn hairiness and yarn diameter were measured on a Projectina. The abrasion resistance of yarns was determined on a Taber abrasion tester by using flex abrasion mechanism. The yarn count was determined with a Knowle's balance.

3 Results and Discussion

3.1 Breaking Strength and Breaking Elongation

Table 2 shows that breaking strengths and TM values agree with the theoretically determined values given by Balasubramanian and Bhatnagar[1]. In core-spinning, reduction in optimum twist is obtained and, as a result, there is an improvement in strength at low twist levels. The peculiar nature of the relationship may be attributed to two opposing factors. With core yarns the presence of a continuous filament reduces the slippage of sheath components, and consequently leads to improvements in strength mainly at low twist. With increase in twist the improvement in strength vanishes because of the diminishing influence of friction and increasing effects of non-simultaniety in the occurrence of breaks.

Table 1 – Specifications of Viscose Fibres

Fibre denier	Fibre length mm	Fibre tenacity g/denier	Breaking elongation %
1.5	51	1.96	19.34
2.0	51	1.87	18.00
4.0	51	1.89	18.28

Table 2 – Effect of Twist and Fibre Linear Density on Yarn Breaking Strength, Breaking Elongation, Count CV%, Lea Strength CV%, Yarn Quality Index and Lea CSP

Yarn ref. No.	Yarn count		TM	Breaking load g	Tenacity g/tex	Breaking extension %	Count CV%	Lea strength lb	Lea CSP	Lea strength CV%	YQI
	Nominal	Actual									
	16s	15.78	2.8	729.80	19.75	13.67	1.91	174.00	2745.72	4.09	26.085
	16s	15.63	3.2	787.80	21.34	13.80	2.01	178.50	2789.95	5.89	26.445
S1	16s	15.55	3.5	717.80	19.44	13.70	2.03	117.33	2757.48	6.63	24.596
	16s	15.62	3.8	705.30	19.10	13.20	2.10	169.33	2644.94	6.40	21.664
	16s	15.59	2.8	690.30	18.70	11.90	2.34	170.60	2659.65	5.11	19.278
	16s	15.64	3.2	706.55	19.17	14.48	2.05	171.70	2685.39	7.38	22.974
S2	16s	15.56	3.5	690.30	18.70	13.55	2.86	171.70	2671.65	7.17	22.725
	16s	15.50	3.8	686.55	18.50	12.42	2.20	167.12	2590.36	7.80	22.570
	16s	15.78	2.8	583.64	13.76	11.60	2.40	162.64	2566.46	6.04	10.880
	16s	15.58	3.2	547.80	14.84	12.23	2.23	167.16	2604.35	7.21	12.260
S3	16s	15.68	3.5	627.80	17.01	11.17	2.27	164.60	2580.43	7.12	13.100
	16s	15.80	3.8	609.05	16.50	11.30	2.32	160.29	2532.58	6.98	13.220

S1, S2, and S3 – Core-spun yarns spun with 1.5, 2.0 and 4.0 denier viscose fibres in sheath respectively.

The strength loss at higher twist levels is also due to the difference in breaking extension because of which the polyester filament and viscose fibre do not break simultaneously. At the time of breakage of viscose fibre the stress shared by polyester filament is much lower and thus in such conditions the addition of filaments should lead to a fall in strength because it does not contribute in any other way to higher strength.

In the case of core-spun yarns the break is of catastrophic type and the first break and rupture are indistinguishable except at low twist and short-specimen lengths. At low twist there is not sufficient cohesion between the filament and staple fibre, which allows the tension to fall as a result of slippage. With a short specimen length, because of reduced overlap the frictional load is expected to be smaller and the extension of core.filament takes place over a greater part of specimen length. At normal gauge length, on account of long-staple overlap, frictional forces are very high and the grip of filaments is firm except at the point where fibres (staple) have ruptured. The small strand of filament which is free from frictional grip extends and completes the rupture of yarn.

Further, with regard to the influence of fibre denier on yarn tenacity, yarns with the same core components and viscose of finer denier seem to give a higher strength than the yarn spun with a fibre of coarse denier, for all levels of twist. Such a trend can be attributed to the cohesiveness of the fibres in the yarn that depends on inter-fibre friction (influenced by twist), which, in turn, is a function of the total area of fibre contact, i.e. fibre specific surface, and the fibre coefficient friction. Thus, fibres with a larger specific surface, i.e. finer fibres, other factors being the same, require a lesser twist than those with a smaller specific surface, i.e. coarse fibres, to prevent slippage in yarn.

While studying the influence of fibre properties on twist required to produce maximum strength in twisted yarns, Gregory[2] suggested that the twist factor for maximum strength is a function of fibre length, coefficient of friction and surface area per unit mass. Empirically, the maximum strength is expressed as: $B = L_1 US$, where L_1 is the fibre length; U, the coefficient of friction; and S, the surface area per unit mass.

As shown by this relationship, for a given fibre length the maximum yarn strength depends upon the specific surface, which accords well with test results.

On the other hand, the breaking elongation is low in weak yarns (Table 2) and continues to follow the same trend as strength with twist. The increasing breaking extension may be attributed to the contraction of yarn following the release of twist and tension; the fibres on the surface of the yarn following a longer path are assumed to be under strain during twisting and then subsequently to contract to under-strained length with the resultant buckling of the centre core, leading to additional extension of centre core before they are extended to break[3].

The breaking extension increases with fibre fineness for all levels of twist. The test results (Table 2) show 13.67% extension for yarn spun with 1.5 denier sheath in comparison with 11.9% and 11.6% breaking extensions for the yarns spun with 2.0 and 3.0 denier sheath fibres respectively. This can be attributed to the resistance to torsion which increases with increase in fibre fineness, i.e. decrease in fibre denier.

3.2 Yarn Count and Strength CV

Table 2 shows no significant change in yarn count CV with alteration in twist. This can be attributed to the fact that an increase in twist level has very little effect on the contraction factor of constant core-spun yarn, which restricts the high twist contraction of sheath, and the resultant twist contraction is of a lower magnitude. Apart from twist the yarn count variation is affected by the linear density of sheath fibres. It is observed that CV% of yarn strength increases as fibre denier increases.

The results on the effect of twist and fibre denier on strength CV show that strength CV increases with increase in twist level.

3.3 Yarn Quality Index

To investigate the effect of twist and fibre linear density on the overall yarn quality, a composite yarn quality index (YQI), based on Barella's formula[4] (as given below), was calculated:

$$YQI = \frac{\text{Single thread tenacity} \times \text{Breaking elongation (\%)}}{\text{Uster U \%}}$$

where thread tenacity is in g/tex.

Table 2 shows that the overall YQI follows a trend similar to that of yarn tenacity.

3.4 Yarn Evenness

Table 3 shows a consistent trend of deterioration in yarn evenness (PMD)[a] with increase in twist level. The high twist level gives a higher crimp to the yarn which offsets the effect due to the mechanical hindrance, resulting in higher values of yarn PMD. Yarns spun from sheath fibres of finer denier give better evenness than the yarns constituting the coarse fibre in sheath, for all twist levels. This finding accords with the equation given by Peirce[5], relating the number of fibres in the cross-section to the variation in the linear density of strand, which is as follows:

$$V_r = \frac{100}{\sqrt{n}}$$

where V_r is the coefficient variation of linear density of strand; and n, the number of fibres in yarn cross-section.

An examination of the yarn imperfection test results shows that alteration of twist does not have any effect on the number of neps, which however decreases with increase in fibre denier (sheath). The decreased nepping tendency with increased fibre denier may be attributed to the higher resistance to bending of a coarse fibre than that of a fine fibre.

Further, the number of thick places is also found to increase with increase in fibre denier. This may due to the poor control of fibre exercised during the drafting on account of decreased cohesive force, which decreases directly in proportion to the number of fibres in strand cross-section. Yarn sample S1, being spun from the finer-denier staple, has a higher number of fibres per unit yarn cross-section, resulting in higher cohesive forces during drafting.

3.5 Yarn Diameter

Table 3 gives the results of a comparative study of the effect of twist and fibre linear density on the diameter of core-spun yarns. The table shows that yarn diameter, in general, decreases with increase in twist level in core-spun yarns owing to the increased packing

[a]percentage mean deviation

Table 3 — Effect of Twist and Fibre Linear Density on Yarn Evenness and Imperfections, Diameter, Hairiness and Abrasion Resistance

Yarn ref. No.	Nominal count	TM	Imperfections/125 m			U%	Yarn diam. cm	Yarn hairiness (Av. no. of protruding ends/3 cm) No. of fibres between			Abrasion resistance cycle
			Thick places	Thin places	Neps			0-1.5 cm	1.5-3 cm	3 cm and above	
	16s	2.8	5	Nil	19	10.35	0.0227	74	42	20	184
	16s	3.2	4	Nil	20	10.73	0.0222	67	39	16	190
S1	16s	3.5	9	Nil	15	10.82	0.0220	71	34	18	198
	16s	3.8	7	Nil	19	10.95	0.0212	65	34	14	208
	16s	2.8	6	Nil	17	11.00	0.0229	68	41	12	170
	16s	3.2	8	Nil	18	11.15	0.0223	62	37	15	180
S2	16s	3.5	9	Nil	16	11.23	0.0221	59	29	8	188
	16s	3.8	10	Nil	20	11.32	0.0214	53	31	11	202
	16s	2.8	27	Nil	9	14.10	0.0267	45	27	10	156
	16s	3.2	29	Nil	6	14.50	0.0239	43	24	7	172
S3	16s	3.5	34	Nil	15	14.80	0.0224	51	29	9	180
	16s	3.8	37	Nil	15	—	0.0221	47	22	6	190

Yarns S1-S3 correspond to the yarns given in Table 2.

coefficient, which, in turn, reduces the yarn specific volume and yarn diameter[6].

On the other hand, the yarn diameter is affected by fibre denier for all levels of twist. As shown in Table 3, the yarn diameter is higher for yarns spun with a coarse-denier fibre in sheath against that of finer denier, which is due to the fact that coarse fibre gives low packing density and low yarn density, which ultimately increase the yarn diameter or vice versa.

3.6 Yarn Hairiness

Table 3 shows that fibre linear density has a direct bearing on the hairiness of core-spun yarns, which in the present study was measured in terms of the number of protruding ends per unit length.

The effect of twist on the hairiness of core-spun yarns was also studied. No specific relationship between the number of protruding ends per unit length and yarn twist was observed. This is in agreement with the theory of Pillay[7] and Barella *et al*[8] that the number of protruding ends is independent of twist.

However, it may be noted that yarn hairiness of spun yarns decreases with increase in twist, which can be explained by assuming that twist in the yarn will run close to the front roll nip in the case of higher twist than that of the lower twist, resulting in an improved control over the emerging fibres, i.e. reduction in yarn hairiness[7].

The effect of fibre denier on hairiness shows a consistent trend of reduction in the number of protruding fibres for yarns spun with a sheath component of coarser denier. This may be attributed to the greater weight of fibres of coarser denier. The number of protruding ends per unit length is inversely proportional to fibre weight:

$$\text{Number of protruding ends per unit length} = \frac{\text{Constant}}{\text{Mean fibre length} \times \text{Mean fibre weight}}$$

3.7 Abrasion Resistance

Backer[9], while studying the abrasive character of textile materials, stated that the rupture of material takes place mainly because of frictional wear, which also drags out the fibres from the yarn structure as described by Peirce[10]. The abrasion test results (Table 3) show a consistent trend of reduction in flex abrasion resistance with decrease in twist due to the fact that a lower twist decreases the coherence of individual fibres within the structure resulting in reduced abrasion resistance, as explained by Peirce[10]. Apart from twist, the flex abrasion resistance of processed yarn is also governed by fibre linear density. As observed from Table 3 the flex abrasion resistance is high for yarns spun with finer denier sheath fibre in comparison with that of yarns spun with coarse-denier sheath fibre. This may be attributed to increased cohesive force on account of increased number of fibres in yarn cross-section, which is governed by fibre denier. Thus, the yarn sample S1, spun with 1.5 denier viscose, shows a higher flex abrasion resistance than the yarn samples S2 and S3 spun from 2 and 4 denier fibres respectively.

4 Conclusions

4.1 In core-spinning, a lower optimum twist is obtained which leads to improvement in strength. Core-spun yarns with the same core component but with finer-denier viscose sheath fibres give a higher strength than yarns spun with coarse-denier fibres, for all levels of twist.

4.2 The breaking elongation is low in weak yarns and continues to follow a trend similar to that of strength with twist. It increases with fibre fineness for all levels of twist.

4.3 Yarn count CV does not change significantly with twist but increases as the sheath fibre dênier increases.

4.4 Full lea strength CV % of core-spun yarns increases with increase in twist.

4.5 The overall yarn quality index shows a trend similar to that of yarn tenacity.

4.6 There is a consistent trend of deterioration in yarn evenness with increase in twist level. Yarns spun from finer-denier sheath fibres give better evenness than yarns constituting coarse fibres in sheath, for all twist levels.

4.7 Alteration in twist does not affect the number of neps, which however decreases with increase in fibre denier. The number of thick places increases with increase in fibre denier.

4.8 In core-spun yarn, yarn diameter, in general, decreases with increase in twist level and is higher for yarns spun with coarse-denier fibres in sheath.

4.9 There is no relationship between the number of protruding ends per unit length and yarn twist, but there is a consistent reduction in the number of protruding fibres for yarns spun with a sheath fibre of coarser-denier.

4.10 Flex abrasion resistance decreases with decrease in twist level; it is higher for yarns spun with finer-denier fibres in sheath.

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