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Migration Behaviour of Polyester/Viscose Blended Rotor Spun Yarns

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ABSTRACT

Many researchers have reported the fibre migration behaviour of blended ring yarns; but very few researchers have studied the phenomenon of fibre migration in blended spun yarns produced in new spinning systems like; rotor and air-jet spinning. The earlier studies on blended rotor spun yarns were represented by the average behaviour of the different components; which motivated to study the migration behaviour of individual components along with their average behaviour in the rotor spun blended yarns in terms of three parameters, Mean Fibre Position (MFP), Mean Migration Intensity (MMI) and Root Mean Square Deviation (RMSD)-using tracer fibre technique. Five blend proportions; 100% polyester, 67/33 polyester/viscose, 50/50 polyester/viscose, 33/67 polyester/viscose and 100% viscose was considered for analysis of effect of blend proportion on the migration behaviour of rotor spun yarns. Statistical analysis was carried out at 95% confidence level to bring out the specific trend executed by the yarns. Six number of contrasting tracer colours was established and exploited to study the migration behaviour with higher precision. The studied migration behaviour showed that the migration parameters don't follow any specific trend with increase in the viscose or polyester content. 100% polyester yarn has lower MFP and higher MMI than the 100% viscose yarn. The polyester/viscose 33/67 has highest value of RMSD than the other blends.

Key words: Blend proportion, mean fibre position, mean migration intensity, root mean square deviation, rotor yarn

INTRODUCTION

In spun yarn, a cohesive force between the fibres within the yarn structure is necessary to convert discontinuous fibres into a continuous yarn. Two factors are necessary to obtain optimum cohesion in the yarn structure, namely (1) yarn twist to create transverse forces pressing the fibres together and (2) fibre migration to stitch the helical assembly of fibres into a single unit. The fibre should migrate during twisting from one radial position to another, so that each fibre will be gripped by a number of other fibres. If the yarn is assembled without fibre migration then the cohesion in the yarn would be maximum at the centre and decrease from the core to the edge of the yarn. The fibre at the yarn surface would not be attached to any other fibres and would tend to fall out from the structure one by one when the yarn is put to use. Thus, it is clear that the fibre migration is necessary for the stability of the yarn (Murugesan and Nayar, 2007).

The dependence of yarn properties on fibre migration in the yarn structure is well established. A number of researchers have studied the fibre migration in yarn structure in terms of three well-known parameters proposed by Hearle and Gupta (1965). These parameters are Mean Fibre

Position (MFP), Mean Migration Intensity (MMI) and Root Mean Square Deviation (RMSD). A collective study of these three parameters helps in understanding the profile of the fibres inside the yarn structure (Kumar *et al*., 2006). A good number of researchers have studied the effect of process parameters of the ring spinning machines on the fibre migration behaviour in ring yarn (Pillay, 1964; Gupta, 1970; Ishtiaque and Vijay, 1994). Many researchers have reported the fibre migration behaviour of blended ring yarns (El-Behery and Batavia, 1971; Godfrey and Rossettos, 2001; Chollakup *et al*., 2008), but very few researchers have studied the phenomenon of fibre migration in yarn spun on new spinning systems like; rotor and air-jet spinning (Salhotra *et al*., 1981; Huh *et al*., 2002). As the migration studies is carried out based on the tracer fibre technique, the number of tracer colours utilized for tracing out the fibre path inside the yarn body is highly important. In most of the research, only two tracer colours was used for the blended yarns, which raise the question of distinguishing of the exact tracer fibre path and reliability and accuracy of the data collection. Therefore, in this present study, the fibre migration in blended yarns made from rotor spinning system was studied using six tracer colours with varying the contribution of tracer colours from polyester and viscose components based on the blend proportion.

MATERIALS AND METHODS

The study is carried out at Department of Textile Technology, I.I.T. Delhi in 2005.

Sample preparation: Viscose fibres of 1.5 denier and 44 mm length and polyester fibres of 1.4 denier and 44 mm length were spun to produce polyester/viscose blended yarns (0/100, 33/67, 50/50, 67/33, 100/0) on rotor spinning system. The blend of polyester and cotton is the most common material, because these blends couple the good strength properties of polyester with the good feel and absorption properties of cotton to produce fabrics which exhibit both good crease retention and excellent wrinkle resistance, while remaining soft and pleasing to the touch. The choice of viscose fibres replacing the cotton fibre in the blend decision has the advantage of similar tensile properties with better comfort behaviour and facilitates the analysis of tracer fibres, since cotton fibres have length variability. The motivation behind the decision of selecting polyester and viscose fibres leaving behind other fibres blending options is that the refractive index of the both the polyester and viscose fibres are similar, which gives the advantage of analysing both the tracer colours under projection microscope using the same immersion liquid; benzyl alcohol. The fibre properties of polyester and viscose fibres utilised for sample production is reported in Table 1. The nominal

Table 1: Fibre properties

		Materials	
Fibre parameters	Test method	Polyester	Viscose
Fibre denier	ASTM D-1577:1996	1.40 (8.5)	1.52 (12.2)
Breaking strength (g)	ASTM D-3822: 2001	8.30 (9.0)	3.10 (12.1)
Tenacity (g tex^{-1})	ASTM D-3822: 2001	53.46 (8.3)	18.45 (8.3)
Breaking elongation (%)	ASTM D-3822: 2001	19.8 (27.5)	20.1 (12.6)
Fibre modulus (g tex^{-1})	ASTM D-3822: 2001	338.4 (28.9)	291.6 (24.8)
Energy-to-break (g-mm)	ASTM D-3822: 2001	20.22 (41.1)	6.94 (20.0)
Crimp (Arcs cm^{-1}) (grey)	ASTM D-3937	3.52	2.89
Crimp (Arcs cm^{-1}) (dyed)	ASTM D-3937	2.59	2.89
Crimps (%) (grey)	Vibrotex	13.69 (36.83)	9.67 (32.22)
Crimps (%) (dyed)	Vibrotex	2.61 (59.86)	9.60 (42.98)

counts of rotor spun yarns used for the study is 22 Ne. The details of the spinning parameters employed for yarn was those that are considered appropriate by commercial spinners, based on their experience. The tracer fibres were mixed before opening operation in blow-room in such a proportion, to have an average of 6 tracers of different colours in a yarn cross-section. The proportion of tracer colours of individual components (polyester and viscose) mixed during blow room stage is decided by the blend proportion of the yarn.

Test methods: Migration means the variation in the radial position from near the yarn axis to near the yarn surface as the fibre follows the helical path defined by the yarn twist. Migration parameters were calculated in terms of Mean Fibre Position (MFP), Root Mean Square Deviation (RMSD) and Mean Migration Intensity (MMI), as proposed by Hearle and Gupta (1965) as given below:

- Mean Fibre Position (MFP) which represents the tendency of the fibre to be near the yarn surface or in the centre of the yarn, given by:

$$MFP(Y) = 1/Z_n \int_0^{Z_n} y dz = (\sum_{1=1}^{n} y_i)/n \quad (1)$$

$$y_i = (\frac{r_i}{R_i})^2 \quad (2)$$

where, n is the number of observations of y made over a length Z_n, R_i and r_i are ith value of yarn radius and helix radius, z_i corresponding values of length along the yarn (Fig. 1). A total of 400 tracer fibres have been studied for migration parameters.

- Root mean square deviation (amplitude of migration), which represents the deviation from mean fibre position, given by:

$$RMSD(D) = [1/Z_n \int_0^{Z_n} (y - Y)^2 dz]^{1/2} = \{\sum_{i=1}^{n} (y_i - Y)^2 / n\}^{1/2} \quad (3)$$

- Mean migration intensity, which represents the change of radial position of the fibre, given by:

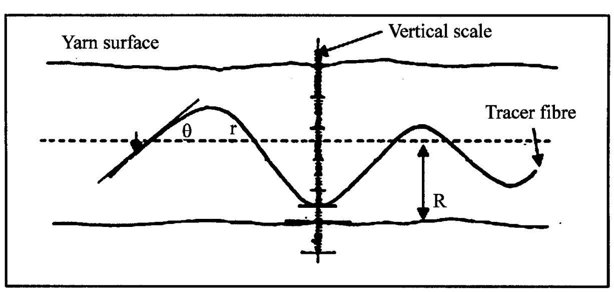

Fig. 1: Schematic view of a tracer fibre seen under projection microscope

$$\mathrm{MMI(I)} = [1/Z_n \int_0^{Z_n} (dY/dz)^2 dz]^{1/2} = \{[\sum_{i=2}^{n} (y_i - y_{i-1})^2 / (z_i - z_{i-1})^2] / n\}^{1/2} \quad (4)$$

Statistical analysis: The prediction of the population behaviour from the sample behaviour involves probability factor, which is statistically called as confidence level. The confidence intervals comprising the population mean is as follows:

$$\bar{x} - Z \times S/\sqrt{n} \le \mu \le \bar{x} + Z \times S/\sqrt{n} \quad (5)$$

Where:

$\bar{x}$ = Sample mean
Z = Standard Normal Variate (SNV)
S = Sample standard deviation
n = No. of samples
μ = Population mean

The confidence interval for 95% confidence level is as follows:

$$\bar{x} - 1.96 \times S/\sqrt{n} \le \mu \le \bar{x} + 1.96 \times S/\sqrt{n} \quad (6)$$

This infers that there is 95% chances that the population mean will occur between $\bar{x} - 1.96 \times S/\sqrt{n}$ and $\bar{x} + 1.96 \times S/\sqrt{n}$. When comparison has to be drawn between two populations parameter based on the mean values of the sample parameter, hypothesis testing is followed. The details of the hypothesis testing is mentioned below (for sample strength, n>30).

H_0: Null hypothesis: There is no difference between the sample means.
H_1: Alternate hypothesis: $\overline{x_1} \ge \overline{x_2}$, where $\overline{x_1}, \overline{x_2}$ are sample means. The calculated Z statistics is defined as follows:

$$Z = \frac{|\overline{x_1} - \overline{x_2}|}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}} \quad (7)$$

where, S_1, S_2 are sample standard deviations and n_1, n_2 are number of samples.

Inference: The calculated Z value is compared with the Z value obtained from the statistical table. If the calculated Z value is higher than the Z value obtained from the table, then the null hypothesis will be rejected and alternate hypothesis will be accepted. The statistical analysis is carried out at 95% confidence level for single tail test, so the Z value obtained from the table is constant for all the analysis (Z = 1.67). The calculated Z value for various experiments is compared with 1.67 to draw the conclusion about the specific trend followed by the polyester/viscose blended yarns with increase in the viscose content.

RESULTS AND DISCUSSION

With the rotor spun yarn structure, the vast majority of fibres appear to lie almost parallel to each other with the same helix angle of twist. Around these are the wrapper fibres with varying angles of wrap; some show almost a 90° wrapping angle. Basically, the rotor spun yarn shows three-zone structure comprising a core of fibres that are aligned with the helix of the inserted twist and form the bulk of the yarn (Fig. 2) and then loose surface fibres held by the compressive forces of wrapper fibres present on the outer zone of the yarn that occurs irregularly along the yarn length. This kind of structure is formed due to its inherent mechanism of yarn formation, i.e., twist insertion from inward to outward. The various measured migration parameters of rotor spun yarns are expressed in Table 2 and statistical analysis was carried out on the above dataset at 95% confidence level to trace out the specific trend followed by the blends with increase in the viscose content. The statistical inference of effect of increase in the viscose content on the migration parameters; Mean Fibre Position (MFP), Root Mean Square Deviation (RMSD) and Mean Migration Intensity (MMI) is expressed in Table 3.

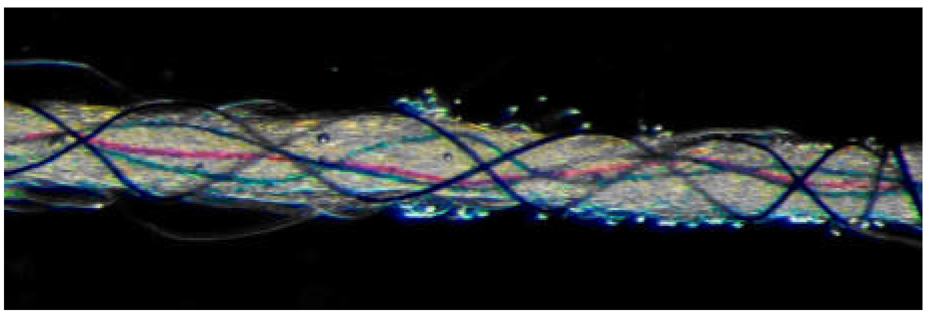

Fig. 2: Representative image of rotor spun yarn

Table 2: Migration parameters of polyester/viscose blended rotor yarns

Blend proportion	MFP	RMSD	MMI
Polyester	A(0.321)	A(0.218)	A(0.883)
Polyester/viscose (67/33)	P(0.329)	P(0.234)	P(0.879)
	V(0.369)	V(0.265)	V(0.805)
	A(0.343)	A(0.245)	A(0.853)
Polyester/viscose (50/50)	P(0.347)	P(0.249)	P(0.872)
	V(0.362)	V(0.255)	V(0.864)
	A(0.355)	A(0.252)	A(0.868)
Polyester/viscose (33/67)	P(0.359)	P(0.263)	P(0.870)
	V(0.345)	V(0.256)	V(0.874)
	A(0.350)	A(0.258)	A(0.873)
Viscose	A(0.379)	A(0.224)	A(0.776)

Table 3: Statistical inference on migration parameters

	MFP		Components		RMSD		MMI (mm^{-1})	
Blend ratio	Z value	Inference	Z value	Inference	Z value	Inference	Z value	Inference
Polyester/viscose (67/33)	1.34	IS	2.26	S	5.19	S	1.32	IS
Polyester/viscose (50/50)	0.68	IS	0.84	IS	1.38	IS	0.65	IS
Polyester/viscose (33/67)	0.28	IS	0.76	IS	1.13	IS	0.21	IS
Viscose	1.40	IS			6.36	S	4.48	S
100% polyester vs. 100% viscose	3.71	S			1.17	IS	5.24	S

Mean fibre position: Rotor spun blended yarns display the lowest value of MFP, as shown in Table 2. This is because in the yarn formation zone, the fibre tension is low and more evenly distributed along the length of the yarn. As a result, fibre migration and fluctuation of the fibre position from their mean value are lower in rotor yarns (Pillay *et al.*, 1975; Oxtoby, 1987). Also, the twist flows in rotor yarn from core to the sheath so that the fibres falling on the tail integrate to the yarn structure and thus have less freedom to move out to the surface due to differential radial twist structure. Further, the fibres in the core are at higher tension due to more twist and for moving out they have to describe a longer curvature that would further lead to increase in tension in the fibres. So, for the core fibres to move out is quite difficult. The mean fibre position of 100% polyester yarn is significantly lower than the mean fibre position of 100% viscose yarn at 95% confidence level, as shown in Table 3. Both the viscose and polyester fibres have similar elongation%, but they widely differ in their initial modulus value. The higher tensile modulus of a component would lead to a greater hoop tension in the fibre helices, tending to induce inward migration for that component. The initial modulus of polyester fibre is considerably higher than the modulus of viscose fibres (Polyester fibre = 338.4 g tex^{-1} and Viscose fibre = 291.6 g tex^{-1}), as shown in Table 1. The high modulus polyester fibres pushed the low modulus viscose fibres to the outside, so 100% polyester yarn has lower MFP compared to 100% viscose yarns. Viscose component gives higher MFP compared to polyester component for the blends polyester/viscose 67/33 and polyester/viscose 50/50, which could be attributed to the lower tensile modulus of viscose fibres compared to polyester fibres, but the polyester component gives higher MFP compared to viscose component for polyester/viscose 33/67; this result reconfirms the earlier findings (Sengupta *et al.*, 1977). They have stated that the migratory behaviour of a component fibre cannot stand independently of the influence of the migratory of the companion fibres. It was noticed during their examination of the projected cross-sections that the two components are arranged throughout the sections in small groups or clusters consisting of one fibre type. If the competition for the core is not between individual fibres but between clusters of two fibre types, the predominant fibre type would strongly influence the other fibre to assume a relatively more strained path. Thus the polyester, a minor component, finds itself pushed outside towards the yarn surface when it is grossly outnumbered by the viscose component in the blend. Hence, the polyester/viscose 33/67 blend has the exceptional incidence of viscose fibres in the core (low MFP) and polyester at the surface (high MFP). Though the MFP value of polyester and viscose components are statistically significant for the blend proportions; 67/33, 50/50 and 33/67, but the average out of the individual components in MFP calculation of yarns make no difference at 95% confidence level, as shown in Table 3.

Root mean square deviation: The Root Mean Square Deviation (RMSD) indicates the spreading of the fibre helical path across the yarn body. The higher spreading of the helical path assists the fibre to be intersected by many numbers of fibres across the yarn-cross section and stitches the helical assembly of the fibres into a single unit. It is noticed from the Table 2 that rotor yarns display lower value of RMSD, which is due to the restriction imposed by the inward-outward twist insertion. This shows that the fibre in the rotor yarn structure tends to lie on the same cylindrical layer throughout its length. The lower value of RMSD indicates that the fibre helix stitches a lower number of fibre bundles across the yarn cross-section. Statistical analysis carried out on the dataset mentioned in Table 2 infers that, the RMSD increases with the increase in the viscose content up to 33%, remain constant up to 50%, then increase up to 67% and finally decreases for 100% viscose yarn. The low modulus viscose fibres generate lower tension compared to the high modulus polyester fibres. The comparatively relaxed viscose fibres would lead to more variation in their radial position, so the RMSD increases with the increase in the viscose content of the blend up to 33% of viscose content. One more reason supporting the claim may be the inherent crimp present on the viscose fibre surface, which has rare chance of removal during manufacturing, as shown in Table 1. There is statistically no difference between the RMSD values of polyester/viscose 67/33 and polyester/viscose 50/50, which could be due to similar type of positioning of the viscose and polyester fibres in yarn cross-section (viscose in the outer side and polyester in the inner side). It is indicated from the Table 3 that there is no difference between the RMSD values of polyester/viscose 67/33 and polyester/viscose 50/50 blend, but in both the cases the viscose components are having higher RMSD than polyester components. The exceptionally higher RMSD of the polyester/viscose 33/67 blended yarn may be due to the reversal of positioning of viscose and polyester fibres in core and surface. The rapid increase in RMSD of polyester fibres along with higher RMSD of viscose fibres is the reason for exceptionally higher RMSD of this particular blend polyester/viscose 33/67.

Mean migration intensity: Mean Migration Intensity (MMI) indicates the rate of change of the fibre radial position on the yarn body. Rotor yarns display a higher value of change of radial position along the yarn axis. This is due to twist inserted to the fibres which are relatively at lower tension in the twisting band of the rotor groove during yarn formation. Also, there is twist differential in radial twist structure of rotor yarn. These factors lead to higher values of MMI in rotor yarn. The MMI is generally influenced by the bucking of the fibres in the core position. The buckled core fibres tend to open up the structure and thus allow the fibre to be displaced more easily. The buckled fibre may even be nipped by the fibres in the next layer and virtually, pulled out of its central position and migrate towards the surface of the yarn. The MMI is ultimately decided by the compromising effect of fibre radial position and buckling of the fibres in the yarn core. The both effects are favoured in the rotor spun blended yarns because the fibres follow a lower radial path and many folded fibres observed in the yarn body, so it display higher value of MMI. Statistical analysis was carried out on the MMI dataset as shown in Table 2 at 95% confidence level and observed that 100% polyester and polyester/viscose 33/67 rotor spun yarn has higher MMI than 100% viscose yarn. This can be ascribed to the lower helical diameter followed by the polyester fibres compared to the viscose fibres due to its higher bending rigidity. The higher bending rigidity of the core polyester fibres restricts the fibres to pursue larger bending deformation with the exerted tension, so these fibres follow smaller helical path with higher rate. The similar kind of findings was also observed by Hearle and Goswami (1970). According to them, the MMI is appreciably higher for the centre position, suggesting that migration becomes more rapid when the tracer is in the centre of the ribbon. The higher MMI of polyester/viscose 33/67 yarn than the 100% viscose yarn is due to the reversing of positioning of the viscose fibres in the core and polyester fibres in the surface. The obvious higher MMI value of polyester fibres compared to viscose fibres along with the reverse in positioning of viscose fibres in core and polyester fibres in surface causes the higher MMI value of polyester/viscose 33/67 blend than the 100% viscose rotor spun yarn.

CONCLUSIONS

The mean fibre position of 100% polyester rotor yarn is significantly lower than the mean fibre position of 100% viscose rotor yarn at 95% confidence level. The MFP value of 100% viscose yarn is highest among the all blends. Viscose component gives higher MFP compared to polyester component for the blends polyester/viscose 67/33 and polyester/viscose 50/50 and vice versa for the blend polyester/viscose 33/67. The difference between the MFP values of polyester/viscose 67/33, polyester/viscose 50/50 and polyester/viscose 33/67 blended yarns are statistically insignificant at 95% confidence level. There is no specific trend of increase in the viscose content on the MFP value of polyester/viscose blended yarns. The RMSD value increases with the increase in the viscose content up to 33%, remain constant up to 50%, then increase up to 67% and finally decreases for 100% viscose yarn. The polyester/viscose 33/67 blended yarn displays the highest value of RMSD among all the blends. The MMI value of polyester/viscose 33/67 blended rotor yarn is highest among all the blends. The MMI value of 100% polyester and 100% viscose and 100% viscose and polyester/viscose 33/67 are statistically different at 95% confidence level. There is no specific trend of increase in the viscose content on the MMI values of polyester/viscose blended rotor yarns.

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