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Influence of add-on spin finish on yarn quality in the OE spinning of polyester fibre yarns

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The influence of add-on spin finish and opening roller speed on the properties of polyester OE rotor yarns spun from fibres of different cross-sectional shapes and linear densities has been studied. The level of spin finish appears to have highest influence on the yarn characteristics followed by the opening roller speed and fibre linear density. Higher level of spin finish offers significant advantages in respect of yarn tenacity, breaking extension, work of rupture, abrasion resistance and hairiness but adversely affects regularity and flexural rigidity. Each of these quality parameters deteriorates to different degrees with the increasing opening roller speed. There is also decline in properties when yarns are made from a trilobal fibre. Such a decline in properties at high opening roller speeds is, however, less marked in yarns spun from fine denier fibres .

Keywords: Fibre friction, Opening roller speed, Polyester yarn, Spin finish, Wrapper fibres

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1 Introduction

Fibre friction plays a vital role in determining the deformation behavior of fibres and in controlling fibre flow during processing. In apparel manufacturing processes, fibre friction is very important for predicting fabric behavior during automated handling and in high speed operations.[1] Various studies have been made on the factors that affect fibre, yarn and fabric frictional properties, including creation of models of fibre friction, yarn friction and fabric friction mainly on the basis of experimental observations. A comprehensive literature in this field can be found in the publication by Hong and Jayaraman.[2] Much of this literature is focused on the investigation of relationships between friction and other important properties including tensile strength, abrasion resistance, bending, shear, wear, and tear.[3-9] Since frictional properties of the substrates are determined by the fibre friction and yarn structure, the add-on finish and lubricants may affect the geometry of the fibre surface and thus fibre friction. This is already apparent in cotton, viscose, wool and aramid yarns, the mechanical properties of which are changed by the low or high levels of add-on finish. This not only modifies the fibre-to-fibre, fibre-to-metal and fibre-to-air frictions but also determines the spinning performance, yarn structure, and yarn properties.[10,11] Although, in the case of ring-spun yarns, these relationships have been known for a long time, very little is known concerning the influence of add-on spin finish on rotor yarn characteristics.[12,13] This study aims to fill this void by investigating the influence of add-on spin finish on the mechanical and regularity characteristics of OE rotor yarns spun from polyester fibres of different cross-sectional shapes and linear densities at varying opening roller speed.

2 Materials and Methods

2.1 Preparation of Yarn Samples

Three sets of polyester fibres, having the specifications as given in Table 1, were used to spin 29.5 tex yarns. The polyester fibres used were essentially given the same spin finish. Each group of fibre was hand opened and separated into four lots of 5 kg each. Spin finish LV 40 was dissolved in water and sprayed as uniformly as possible on three lots of polyester of each group. Three different add-on finish levels, viz. 0.05%, 0.10% and 0.15% (owf), were used. The conversion to drawn sliver was carried out by using Platts's carding machine and Lakshmi Rieters' draw frame DO/2S. Two drawing passages were given to carded slivers to produce a finisher

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Table 1 — Specifications of polyester fibres

Fibre profile	Length mm	Linear density dtex	Level of spin finish, %	Breaking strength, cN/tex	Breaking extension, %	Coefficient of fibre friction	
						Fibre-fibre (μ_{ff})	Fibre-metal (μ_{fm})
Circular	44	1.66	Nil	46.49	29.5	422	250
			0.05	46.81	29.6	433	265
			0.10	47.13	29.6	450	283
			0.15	47.55	29.7	468	292
Circular	44	2.22	Nil	45.02	29.2	395	210
			0.05	45.34	29.2	405	226
			0.10	45.56	29.4	419	240
			0.15	45.58	29.6	434	256
Trilobal	44	2.22	Nil	40.61	30.0	380	197
			0.05	40.77	30.2	388	205
			0.10	40.84	30.4	397	216
			0.15	40.98	30.4	410	229

sliver of 4.5 ktex Ne. The drawn slivers were spun on the Ingolstadt rotor spinner RU11/80(4602) into 29.5 tex yarns with 700 TPM using three opening roller speeds, viz. 116.66, 133.33 and 150 rps. The spinning trials for all the yarns included a 48 mm rotor running at 1000 rps, a saw-tooth opening roller type of clothing (OS/21; teeth/cm^2, 24; and face angle, 100°), and a notched nozzle (exterior diam.,15.5 mm and interior diam., 3 mm).

2.2 Test Methods

2.2.1 Fibre Friction Coefficients

The coefficients of fibre-to-fibre and fibre-to-metal frictions were measured on an Instron tensile tester using the attachment developed by Sengupta *et al*[14]. Two fibre tufts of uniform density were placed one above the other. A weight of 40 g was placed on the tufts. One tuft was attached by an inextensible cord to the load cell of the Instron. The cross-head was made to move up and the maximum frictional force developed between the fibre tufts was recorded. In the case of fibre-to-metal friction, a single tuft was laid on a bare metal plate and the same procedure was repeated. From the recorded value, the values of coefficients of fibre-to-fibre and fibre-to-metal frictions were determined using Amonton's law.

2.2.2 Yarn Properties

All the yarns were tested according to standard ASTM procedures. Tensile properties of all the yarns were measured on an Instron using 500mm test specimen and 200 mm/min cross-head speed. The mean yarn tenacity and breaking extension were averaged from 50 observations for each yarn sample. Zweigles hairiness meter (Model G 565) was used to record yarn hairiness and an Uster evenness tester to measure unevenness and imperfections of the yarns. The yarn abrasion resistance was determined on CSI abrasion tester and yarn flexural rigidity on Shirley weighted ring tester using ring loop method.[15] The work of rupture was calculated from the following expression:

Work of rupture = 1/2[Tenacity (g/den) × Breaking extension (expressed in decimal)]

3 Results and Discussion

The influence of four experimental factors, viz. fibre linear density , cross-sectional shape of the fibre, level of spin finish and opening roller speed, on the yarn properties was assessed for significance using ANOVA analysis (Table 2); the confidence level used was 99%.

3.1 Tensile Properties

Table 3 lists the values of tenacity indices with respect to different process parameters. It is seen that as the fibre linear density is increased from 1.66 dtex to 2.22 dtex, there is a significant decrease in yarn tenacity. As is well known, an increase in yarn tenacity when level of spin finish increases has been observed. The increase in yarn tenacity results from the increased inter-fibre friction obtained as a result of add-on spin finish (Table 1), which, in turn, causes the fibres to cohere, leading to increased yarn strength. The higher twist translation efficiency with higher fibre-to-metal friction also favours the increase in yarn tenacity. Indeed, twist translation efficiency was 83.61% in polyester OE rotor yarns spun from 1.66 dtex fibres at 150 rps with 0.15% spin finish, as compared to 78.6% and 81.8% efficiency in yarns spun with 0.05% and 0.10% spin finish. The results show that there are marked differences in yarns spun

Table 2 — ANOVA test results

Process parameter	F-ratios						
	Tenacity	Breaking extension	Work of rupture	Abrasion resistance	Flexural rigidity	Hairiness	Irregularity
Fibre linear density	24.8(21.2)	227.7(34.1)	630.5((34.1)	39.9(34.1)	1089.0(98.4)	21.5(21.2)	81.0(34.1)
Fibre cross-section	28.1(21.2)	8.8(34.1)	38.8((34.1)	970.2(34.1)	116.0(98.4)	20.0(21.2)	17.0(34.1)
Level of spin finish	349.2(21.2)	452.2(34.1)	3757.6((34.1)	1970.7(34.1)	961.0(98.4)	86.0(21.2)	289.0(34.1)
Opening roller speed	52.1(21.2)	79.5(34.1)	490.9((34.1)	37.2(34.1)	11.1(98.4)	58.3(21.2)	441.0(34.1)

Figures in parentheses indicate table values.

Table 3 — Influence of fibre profile, spin finish and opening roller speed on tenacity, breaking extension and work of rupture of polyester OE rotor – spun yarns

Fibre profile	Fibre linear density dtex	Level of spin finish %	Tenacity, mN/tex			Breaking extension, %			Work of rupture × 10 $^{-3}$, g/den		
			116.66[a]	133.33[a]	150[a]	116.66[a]	133.33[a]	150[a]	116.66[a]	133.33[a]	150[a]
Circular	1.66	Nil	178.5	167.7	160.8	20.6	19.4	19.0	208	184	172
	1.66	0.05	199.1	186.3	179.5	21.7	21.0	20.7	244	221	210
	1.66	0.10	214.8	194.2	185.4	22.6	22.0	21.5	274	242	225
	1.66	0.15	221.7	233.4	200.9	23.0	23.4	22.1	288	308	261
Circular	2.22	Nil	169.7	161.8	153.0	18.3	17.9	16.2	175	164	140
	2.22	0.05	177.5	170.6	158.9	19.6	19.3	18.8	200	186	169
	2.22	0.10	200.1	182.4	176.5	20.4	19.9	19.0	233	205	190
	2.22	0.15	206.9	215.8	198.1	21.0	21.5	20.4	250	268	228
Trilobal	2.22	Nil	163.8	152.0	141.2	18.6	18.3	17.4	172	157	139
	2.22	0.05	169.7	160.8	152.0	20.1	19.6	19.0	193	178	162
	2.22	0.10	181.4	171.6	157.9	20.6	20.2	19.4	206	196	173
	2.22	0.15	190.3	200.1	184.4	21.5	21.8	21.0	231	249	219

[a]Opening roller speed (rps).

at different opening roller speeds, particularly in yarn tenacity. Increasing opening roller speed from 116.66 rps to 150 rps for 0, 0.05 and 0.10% spin finish leads to a marked but consistent decrease in yarn tenacity, as expected. However for 0.15% spin finish, statistical analysis of the data shows that the yarn tenacity does not show much change with opening roller speed. Since the polyester fibres taken out from the rotor groove do not show significant change in tenacity and breaking extension, the decrease in yarn tenacity at high opening roller speeds is expected in consequence of the deterioration in fibre straightness and degree of alignment along the yarn.[16] Invariably, the drop in tenacity is comparatively more marked in yarns spun with a lower level of spin finish than the equivalent yarns spun with a higher add-on spin finish. There is a trend towards further reduction in tenacity loss when yarns are spun with circular polyester fibre.

Table 3 shows the results for yarn breaking extension. As expected, fine fibres improve yarn breaking extension. In the case of polyester spun yarns, the breaking extension is remarkably dependent on the level of spin finish, and the yarns spun with higher add-on spin finish show substantially higher breaking extension. The influence of opening roller speed on the breaking extension is similar to that on yarn tenacity. However, the influence of opening roller speed is less critical for the yarns spun from 1.66 dtex fibres. Under all experimental conditions, the yarns spun from a trilobel fibre possess marginally higher breaking extension owing to the low tenacity, high breaking extension and low toughness of this fibre.[17]

The association of work of rupture of polyester OE rotor yarns with processing factors is shown in Table 3. Expectedly, coarse fibres produce yarns of substantially lower work of rupture. However, the work of rupture shows an ascending trend with the increase in the level of spin finish. In regard to opening roller speed, work of rupture reflects a similar trend as yarn tenacity and breaking extension. The use of non-circular polyester fibre results in considerably lower work of rupture, irrespective of the level of spin finish and opening roller speed.

3.2 Abrasion Resistance

Table 4 clearly shows that the spin finish can seriously affect the abrasion resistance of polyester OE rotor-spun yarns. Generally, the abrasion resistance shows a marked increase with the level of spin finish regardless of the fibre profile and linear density. This is obvious result of the increased fibre-to-fibre friction due to the higher level of spin finish which reduces the slippage of core fibres. The opening roller speed-abrasion resistance relationship shows a maximum that coincides with the maximum for opening roller-work of rupture. For all levels of spin finish, except 0.15%, the abrasion resistance decreases steadily with the increase in opening roller speed and attains a least value at 150 rps. In the case of yarns spun with 0.15% spin finish, the abrasion resistance initially increases with increasing opening roller speed and then reduces at an opening roller speed of 150 rps. The fewer sheath fibres and high fibre breakage at high opening roller speed[18] contribute greatly to the abrasion resistance of these yarns. The effect of fibre linear density on yarn abrasion resistance is also along the expected lines, a decrease in fibre linear density greatly improves abrasion resistance. Nevertheless, the yarns made with a trilobal polyester fibre withstand fewer abrasion cycles as compared with their circular fibre counterparts.

3.3 Flexural Rigidity

Table 4 shows that the values of flexural rigidity for the yarns spun from a non-circular fibre are substantially higher than those for the equivalent yarns spun from a fibre of circular cross-section. In quantitative terms, the values of flexural rigidity for the yarns spun from 2.22 dtex trilobal polyester fibre are 8.4-22.8% higher than that for the yarns spun from 2.22 dtex circular fibre. Increasing fibre linear density from 1.66 dtex to 2.22 dtex increases flexural rigidity due to higher rigidity of coarse fibres. Besides, higher incidence of wrapper fibres in yarns spun from coarse fibres also impairs the freedom of fibre movement. It is intriguing that while the flexural rigidity of polyester rotor yarns is hardly changed by opening roller speed, it increases appreciably with the increase in level of spin finish. This is quite understandable and arises due to increased fibre-to-fibre friction with higher level of spin finish which limits the fibre separation and hence demands for higher opening roller speed. The add-on spin finish therefore needs to be chosen carefully because high level of spin finish increases the fibre-to-fibre friction which could elevate the problem.

Table 4 — Influence of fibre profile, spin finish and opening roller speed on abrasion resistance, flexural rigidity and hairiness of polyester OE rotor – spun yarns

Fibre profile	Fibre linear density dtex	Level of spin finish %	Abrasion resistance, cycles			Flexural rigidity $\times 10^{3}$, gcm^2			Hairs / m		
			116.66[a]	133.33[a]	150[a]	116.66[a]	133.33[a]	150[a]	116.66[a]	133.33[a]	150[a]
Circular	1.66	Nil	495	466	435	2.41	2.32	2.44	260	284	308
	1.66	0.05	602	548	522	2.52	2.71	2.75	246	270	292
	1.66	0.10	668	643	616	2.60	2.92	3.08	214	256	280
	1.66	0.15	688	710	670	2.82	3.16	3.19	184	246	262
Circular	2.22	Nil	456	436	402	3.01	2.90	3.27	234	252	280
	2.22	0.05	520	494	464	3.23	3.53	3.58	204	214	242
	2.22	0.10	620	614	600	3.63	3.84	3.96	170	182	211
	2.22	0.15	650	672	634	3.92	4.16	4.28	156	168	208
Trilobal	2.22	Nil	350	320	282	3.53	3.44	3.94	230	245	275
	2.22	0.05	386	372	350	3.71	3.83	4.18	201	208	235
	2.22	0.10	458	438	420	4.11	4.35	4.52	165	177	208
	2.22	0.15	492	510	454	4.31	4.76	5.26	148	164	201

[a]Opening roller speed (rps).

Table 5 — Influence of fibre profile, spin finish and opening roller speed on mass irregularity and imperfections of polyester OE rotor – spun yarns

Fibre profile	Fibre linear density dtex	Level of spin finish %	Irregularity, U% 116.66[a]	Irregularity, U% 133.33[a]	Irregularity, U% 150[a]	Imperfections/125m 116.66[a] Thick places +50%	116.66[a] Thin places -50%	116.66[a] Neps +200%	133.33[a] Thick places +50%	133.33[a] Thin places -50%	133.33[a] Neps +200%	150[a] Thick places +50%	150[a] Thin places -50%	150[a] Neps +200%
Circular	1.66	Nil	11.5	11.7	12.8	2	1	4	1	1	11	3	1	16
	1.66	0.05	11.9	10.9	11.6	10	3	6	10	5	4	6	1	7
	1.66	0.10	12.4	10.7	11.1	3	2	12	2	1	8	3	6	9
	1.66	0.15	12.9	11.0	10.6	4	2	20	3	1	8	2	0	9
Circular	2.22	Nil	11.8	12.5	13.0	3	4	3	5	6	10	4	6	11
	2.22	0.05	12.1	10.8	11.8	12	8	4	11	8	4	7	5	6
	2.22	0.10	12.8	11.0	11.3	4	4	8	3	3	7	3	2	8
	2.22	0.15	13.1	11.4	10.8	5	6	11	4	4	8	2	4	6
Trilobal	2.22	Nil	12.4	12.7	13.2	5	8	4	4	6	7	4	11	12
	2.22	0.05	12.7	11.3	12.5	14	10	3	5	4	5	5	13	6
	2.22	0.10	13.2	11.8	12.1	7	5	12	4	4	8	3	4	7
	2.22	0.15	13.4	12.1	11.7	8	11	20	5	8	7	2	3	8

[a]Opening roller speed (rps).

3.4 Hairiness

Table 4 summarizes the hairiness results of polyester OE rotor-spun yarns measured by Zweigles hairiness meter. Invariably, the yarns spun from 1.66 dtex fibres exhibit more hairiness than the yarns made from 2.22 dtex fibres. The differing flexural rigidities of both these fibres could help explain this behavior. Also, the change of hairiness related to add-on spin finish is evident in both types of yarns; the higher the add-on spin finish, the lesser is the hairiness. Change in fibre cross-sectional shape does not cause an appreciable change in hairiness. In all trials, however, higher opening roller speed significantly increases hairiness. The higher hairiness observed at higher opening roller speeds could possibly be due to the greater friction of opened fibrous mass , which, in turn, results in more severe abrasion of the yarn against the naval and the doffing tube, leading to more hairiness .

3.5 Mass Irregularity and Imperfections

The values of yarn irregularities, such as U%, thick places (+50%), thin places (-50%), and neps (+200%), of polyester OE rotor-spun yarns are shown in Table 5. Although no striking differences in the irregularity values of yarns spun from circular and trilobal fibres are observed, the yarns spun from a trilobal fibre are slightly less regular and have more imperfections than the equivalent yarns made from a circular fibre under all experimental conditions. The lesser regularity of the trilobal fibre yarns is ascribed to the higher incidence of wrapper fibres caused by the high bending rigidity of this fibre. Both fibre linear density and opening roller speed play a significant role in determining the mass irregularity of polyester OE rotor-spun yarns. Yarn unevenness and imperfections, as expected, are lower for yarns spun with a fine fibre. In regard to spin finish, the imperfection indices reflect no consistent trend. Significantly high opening roller speed tends to give slightly lower unevenness and imperfections with added spin finish. The higher finish generates greater frictional contact between fibres, which, in turn, demands for high opening roller speed for better individualization of the fibres.

4 Conclusions

4.1 The mechanical and hairiness characteristics of polyester OE rotor-spun yarns change significantly as a consequence of fibre cross-section. Generally, the yarns produced with a circular fibre show higher tenacity, enhanced abrasion resistance with increasing work of rupture, while those made with a trilobal fibre show lower tensile strength but improved breaking extension for almost all experimental combinations. The extent of change in these characteristics is more marked in yarns constituting fine denier fibres and increases with increasing spin finish. In particular, hairiness is greatly reduced, and tensile strength and abrasion resistance are greatly increased with increasing spin finish. High opening roller speed leads to a marked deterioration in these properties.

4.2 The cross-sectional shape of the fibre has a profound influence on the yarn flexural rigidity. The highest flexural rigidity is obtained with trilobal fibres and it reduces with the decrease in polyester fibre denier and level of spin finish.

4.3 The use of either too low or too high opening roller speed markedly increases the mass irregularity and imperfections. Higher level of added spin finish also has a destructive effect on yarn irregularities. However, the yarns spun with a circular fibre are more regular and have fewer imperfections than the equivalent yarns made with a trilobal fibre.

Industrial Importance: Spin finish is used to facilitate successful processing of synthetic fibres during manufacturing. Its level is very important factor in practical spinning and is known to affect yarn properties. Such a study would be useful for establishing the optimal spin finish for successful processing of polyester fibre yarns and for the production of good quality fabrics.

References

1 Clapp T G, Timble N B & Gupta B S , *J Appl Polym Sci*, 47 (1991) 373.
2 Hong J & Jayaramann S, *Text Prog*, 34 (1/2) (2003) 35.
3 Offermann P, Rosel B, Rodewald P & Reumann R D, *Melliand Textilber*, 74 (1993) E347.
4 Thorndike G H & Varley L, *J Text Inst* , 52 (1961) 255.
5 Amirbayat J & Cooke W D, *Text Res J*, 59 (1989) 469.
6 El Gaiar M N & Cusick C E, *J Text Inst* , 67 (1976) 141.
7 Ajayi J O, *Text Res J*, 62 (1992) 52.
8 Drafler P, *Proceedings, 2nd International Conference on Man Made Fibres,* Bejing, China, 1987, 27.
9 Ishtiaque S M, *Indian J Fibre Text Res*, 17 (1992) 423
10 El Moyahzy Y E & Broughton R M, *Text Res J*, 63 (1993) 465.
11 Nield R & Ali A R A, *J Text Inst*, 68 (1977) 110.
12 Sprenkmann W, *Melliand Textilber,* 56 (1975) 751.
13 Sengupta A K, Chattopadhyay R & Majumdar P, *Proceedings, 33rd Joint Technological Conference of* ATIRA, BTRA, SITRA & NITRA (BTRA, Bombay), 1992, 53.
14 Sengupta A K, Chattopadhyay R, Venkatachelapathi G S & Padmanabhan A R, *Melliand Textilber*, 73 (1992) 83
15 Owen J D & Riding G, *J Text Inst* , 55 (1964) T414.
16 Ulku S, Ozipek B & Acar M, *Text Res J* , 65 (1995) 557.
17 Tyagi G K, Kaushik R C D & Chatterjee K N, *Indian J Fibre Text Res*, 15 (1990) 120.
18 Salhotra K R, *Text Res J*, 51 (1981) 710.