Fibers and Polymers 2005, Vol.6, No.3, 250-258

Effect of Opening Roller Speed, Drums Speed Difference and Suction Air Pressure on Properties of Open-End Friction Spun Polyester and Acrylic Yarns

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(Received May 4, 2005; Revised July 19, 2005; Accepted August 4, 2005)

Abstract: The present paper is concerned with the influence of opening roller speed, drum speed difference and suction air pressure on properties of polyester and acrylic open-end friction spun yarns. The results shows that the opening roller speed and the suction air pressure have considerable influence on the characteristics of polyester and acrylic open-end friction spun yarns. In case of polyester yarns the unevenness, imperfection and hairiness decreases and the yarn tenacity increases with the increase in opening roller speed and suction air pressure. However for acrylic yarns the unevenness and imperfections decreases and tenacity increases with the increase in opening roller speed and suction air pressure.

Keywords: Acrylic fibre, Drums speed difference, Opening roller speed, Polyester fibre, Suction air pressure

Introduction

Friction spinning has attracted, to a great extent, the textile engineers due to its very high delivery speed. In this system the fibres, after individualization by opening roller, are collected at the nip of the two rotating drums. The fibre assembly is twisted by the frictional forces between the fibres and the drums [1]. In friction spinning machines the opening roller assembly plays an important role in creating a stream of individualized fibres and is quite similar to rotor spinning. Ulku *et al.* [2] studied the influence of opening roller speed (4000-9000 rpm) on the fibre and yarn properties in open-end friction sinning machine for cotton, viscose rayon, polyester and acrylic fibres. They have reported that increasing opening roller speeds beyond certain limits increase fibre breakage and reduces yarn tenacity. Yarn unevenness and imperfections initially reduces with the increase in opening roller speed and then increases. Dhamija *et al.* [3] reported that for DREF-2 friction spinning machine the acrylic fibre has no influence on tenacity but mass irregularity and imperfection decrease upto the opening roller speed of 3450 rpm and then increases. However no work has been done in this area on DREF-III friction spinning machine. In this system, a pair of saw-tooth covered opening rollers is used, which rotates at fixed speed of 12,000 rpm [4]. However fixed rotational speed may not be a general advantage as the desired intensity of opening and severity of treatment could vary from fibre to fibre.

On DREF-III friction spinning machine the speed of the front friction drum is kept 9 % higher than the rear friction drum [4]. It is expected that this difference in drum speed helps in effective binding of fibres to the core. This is reported to avoid squeezing of the yarn in the nip and helps in tension free yarn delivery. However no information is available to explain the influence of difference in drum speed on yarn properties and yarn structure.

Suction air pressure influences the twisting rate, yarn properties and structure to a large extent. The effect of suction air pressure on yarn properties has been investigated by several researchers [5-11]. Konda *et al.* [5] observed that for cotton fibres the increase in suction air pressure is accompanied by decrease in yarn diameter, and improved fibre extent, twisting efficiency, yarn tenacity and mass regularity. Zhu *et al.* [6] have shown that increasing air-force magnitude, the fibre crimp increases during the landing process. However fibres of low crimp rigidity tend to fold or crimp more than a more rigid fibre. Ibrahim [7,8] reported that back suction improves the fibre orientation and twist-tensile characteristics of polyester open-end friction spun yarns. Ishtiaque *et al.* [9] reported that increase in suction air pressure for cotton DREF-III yarn leads to increase in yarn unevenness and imperfection and improved yarn tenacity. Salhotra *et al.* [10] studied the influence of suction air pressure on yarn twist. Merati *et al.* [11] observed that increase in yarn twist and reduction in yarn diameter with increase in suction air pressure. However there were conflicting results in terms of yarn tenacity, evenness etc. Therefore opening roller speed, difference in friction drum speed together with suction air pressure has been selected to study the influence of these parameters on yarn quality characteristics of open-end friction spun yarn on DREF-III machine.

Experimental

Preparation of Yarn Samples

Polyester fibres (34 mm long, 1.4 denier linear density, 46.35cN/tex tenacity, and 21.6 % breaking elongation) and acrylic fibres of (38 mm long, 1.5 denier linear density, 24.84 cN/tex tenacity, and 44.9 % breaking elongation) were processed through Laxmi Rieter blow-room line and carded

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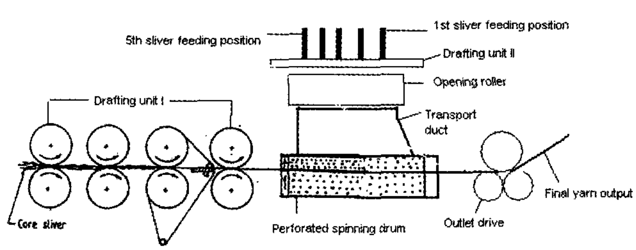

Figure 1. Schematic diagram of DREF-III friction spinning machine.

Table 1. Box and Behnken design for three variables and three levels

Experimental combination no.	Variables X_1	X_2	X_3
1	−1	−1	0
2	1	−1	0
3	−1	1	0
4	1	1	0
5	−1	0	−1
6	1	0	−1
7	−1	0	1
8	1	0	1
9	0	−1	−1
10	0	1	−1
11	0	−1	1
12	0	1	1
13	0	0	0
14	0	0	0
15	0	0	0

Table 2. Actual values of variables corresponding to coded variables

Variables	Coded levels −1	0	+1
Opening roller speed (rpm) X_1	10,000	12,000	14,000
Drum speed difference (%) X_2	5	9	13
Suction air pressure (mbar) X_3	−15	−20	−25

on Laxmi Reiter C1/3 card. The card sliver was given two draw-frame passages to produce a finished sliver of 2.9 ktex. Yarns of 55 tex were spun on a DREF-III spinning machine keeping sliver feed from drafting Unit-I inoperative to produce open-end friction spun yarn. Figure 1 shows the schematic diagram of DREF-III spinning machine. Yarn delivery rate and friction drum speed were kept 200 m/min and 4750 rpm respectively. Yarn samples were prepared for all the combinations by using three variables three level design proposed by Box-Behken as shown in Tables 1 and 2.

Testing

Polyester and acrylic fibres were tested on Kissoki classifibre to estimate the influence of opening roller speed on fibre length. The yarn samples were tested for single yarn strength and extension on Uster Tensorapid 3 (UTR-3) using 500 mm tests length and 5000 mm/min extension rate. Mean single yarn strength and breaking extension were averaged from 100 observations for each yarn sample. Yarn unevenness imperfections and hairiness index were tested on Uster evenness tester (UT-3). Yarn twist was measured by Statex twist tester, based on de-twist-re-twist principle. The results were statically analysed and response surface equation were obtained at 95 % level of significance.

Results and Discussion

The effect of opening roller speed on the length related properties of polyester and acrylic fibres has been shown in Table 3. It is observed that there is no significant change in fibre length with the increase in opening roller speed. The experimental results for various polyester and acrylic yarn characteristics are given in Table 4 and 5 respectively. The response surface equations showing the effects of experimental variables on the quality of open-end friction-spun yarns for polyester and acrylic fibres have been shown in Tables 6 and 7. From the Tables 3-7 it may be observed that the opening roller speed and suction air pressure play significant role on

Table 3. Influence of opening roller speed on polyester and acrylic fibre length

No.	Fibre	Opening roller speed (rpm)	2.5 % SL	50 % SL	SFC	ML	UHML
	Polyester fibre						
1	Feed sliver		32.1	19	2.2	33.53	33.53
2		10000	32.1	19.2	2.1	34.05	34.07
3		12,000	32.1	18.65	2.5	33.35	33.4
4		14,000	32.2	18.22	2.75	32.82	33.7
	Acrylic fibre						
5	Feed sliver		35.3	21.3	0.9	36.9	36.9
6		10000	35.2	21	1.2	36.8	38.6
7		12,000	34.4	19.6	1.6	36	36.0
8		14,000	34.6	19.7	1.5	35.8	36.0

2.5 % SL: 2.5 % span length, 50 % SL: 50 % span length, SFC: short fibre content, ML: mean length, UHML: upper half mean length.

Table 4. Properties of polyester open-end friction spun yarn

No.	Yarn unevenness (U %)	Thin places/km (−50 %)	Thick places/km (+ 50 %)	Neps/km (+200 %)	Total imperfections /km	Hairiness index H	Tenacity (cN/tex)	Breaking elongation %	Twist per inch
1	13.41 (0.3)	93 (4.5)	74 (24.2)	1148 (4.7)	1315 (3.5)	11.60 (0.7)	11.84 (7.9)	14.50 (5.8)	13.73 (12.8)
2	10.15 (0.7)	4 (91.6)	3 (43.3)	69 (17.8)	76 (19.4)	9.82 (0.6)	14.29 (9.9)	14.90 (6.2)	15.33 (12.1)
3	13.35 (1.1)	91 (13.2)	78 (18.0)	913 (8.8)	1082 (9.3)	11.83 (1.1)	12.65 (10.5)	14.59 (6.4)	14.64 (10.7)
4	10.46 (0.9)	8 (52.6)	3 (151)	73 (19.4)	149 (20.00)	10.11 (0.1)	15.56 (9.5)	15.46 (6.2)	15.21(10.4)
5	14.26(1.3)	191 (16.8)	166 (18.1)	1226 (8.1)	1583 (13.0)	12.85 (0.3)	11.90 (12.2)	13.90 (7.7)	13.36 (8.4)
6	10.64 (2.5)	12 (132.0)	7 (86.7)	126 (24.6)	145 (18.61)	10.42 (0.6)	13.91(10.15)	14.46 (5.4)	14.03 (7.8)
7	10.81(1.0)	15 (29.5)	12 (35.5)	92 (17.5)	119(13.4)	10.94 (2.1)	12.81 (10.0)	15.35 (10.0)	15.79 (7.0)
8	9.90 (0.6)	2 (12.0)	4(59.8)	46 (16.8)	52 (17.0)	9.12 (0.9)	14.82 (12.4)	15.76 10.2)	16.46 (8.6)
9	11.64 (1.5)	32 (23)	19 (40.7)	284(10.2)	335 (12.4)	11.54 (0.4)	14.24 (8.1)	14.71 (4.7)	13.94 (8.4)
10	11.80 (1.2)	35 (24.7)	26 (42.5)	226 (19.6)	287 (20.3)	11.68 (1.1)	13.96 (9.9)	14.62 (5.9)	13.72 (8.1)
11	10.50 (1.1)	2 (81.6)	5 (70.7)	169 (47.6)	214 (20.6)	9.64 (0.7)	13.66 (12.0)	16.18 (7.2)	17.74 (6.6)
12	11.00 (1.0)	9 (57.2)	11 (46.2)	194 (17.9)	176 (19.9)	9.90 (0.5)	13.71 (10.9)	15.74 (9.8)	16.79 (5.1)
13	11.18 (0.6)	13 (24.2)	8 (29.9)	209 (17.9)	230 (9.5)	10.68 (1.4)	14.19 (8.6)	14.96 (5.1)	14.72 (9.3)
14	11.11(0.7)	9 (42.6)	10 (35.3)	218 (9.5)	233 (9.3)	10.94 (0.8)	14.68 (8.5)	15.19 (4.9)	14.97 (7.2)
15	10.94 (0.9)	8 (65.0)	9 (16.1)	166 (4.8)	183 (7)	10.71 (0.5)	14.63 (8.6)	15.42 (5.6)	14.87 (9.1)

Values in parentheses indicate CV %.

Table 5. Properties of acrylic open-end friction spun yarn

No.	Yarn unevenness (U %)	Thin places/km (−50 %)	Thick places/km (+ 50 %)	Neps/km (+200 %)	Total imperfections /km	Hairiness index H	Tenacity (cN/tex)	Breaking elongation %	Twist per inch
1	14.98 (0.8)	568 (5.6)	504 (3.1)	720 (8.4)	1792 (4.6)	17.34 (0.5)	7.22 (10.7)	12.09 (11.6)	9.34 (6.7)
2	12.49 (0.6)	125 (5.7)	155 (12.9)	490 (7.8)	773 (7.6)	17.47 (2.7)	7.90 (9.5)	13.24 10.3)	9.28 (6.5)
3	15.42 (2.6)	666 (14.0)	638 (17.8)	712 (13.9)	2016 (11.9)	17.98 (0.3)	6.95 (10.8)	11.80 (12.6)	9.08 (5.3)
4	12.67 (0.8)	150 (5.7)	182 (15.0)	398 (8.0)	730 (6.9)	18.22 (0.7)	7.85 (8.8)	12.88 (10.2)	8.96 (6.9)
5	14.64 (0.6)	493 (3.8)	488 (8.2)	628 (3.8)	1609 (2.7)	20.15 (0.9)	6.60 (11.4)	12.17 (12.7)	7.96 (8.2)
6	12.83 (0.4)	150 (5.9)	201 (6.7)	485 (8.0)	836 (3.2)	20.07 (0.3)	7.28 (9.6)	13.34 (11.0)	8.93 (8.1)
7	15.65 (0.8)	758 (7.1)	648 (6.1)	658 (5.9)	2064 (5.0)	15.69 (0.9)	7.40 (11.6)	12.16 (13.2)	10.20 (7.4)
8	12.57 (0.7)	144 (16.5)	158 (14.3)	464 (10.6)	766 (11.0)	15.89 (1.3)	8.10 (13.5)	13.52 (11.6)	10.14 (5.7)
9	13.19 (0.9)	182 (13.7)	254 (14.4)	542 (6.1)	978 (7.2)	19.07 (1.1)	7.36 (9.5)	13.04 (11.7)	8.26 (8.3)
10	13.30 (1.5)	232 (24.1)	246 (7.7)	376 (7.6)	854 (11.1)	20.66 (0.2)	6.88 (11.5)	12.39 (13.4)	8.34 (7.1)
11	13.15 (0.5)	202 (12.6)	208 (7.3)	479 (9.2)	889 (5.4)	15.11 (0.6)	8.00 (9.0)	12.83 (11.2)	10.16 (5.7)
12	13.41 (0.5)	255 (11.8)	287 (12.8)	392 (10.1)	934 (5.0)	15.96 (0.8)	7.80 (11.3)	12.59 (12.1)	9.84 (4.9)
13	13.13 (0.4)	200 (9.9)	232 (7.3)	460 (9.1)	892 (5.4)	17.65 (1.3)	7.60 (12.9)	12.87 (10.0)	9.42 (5.6)
14	13.24 (0.5)	221 (11.1)	248 (14.2)	478 (5.2)	947 (5.4)	17.50 (1.1)	7.41 (11.9)	12.59 (12.2)	9.34 (6.9)
15	13.08 (1.0)	192 (19.1)	228 (6.9)	418 (8.0)	838 (9.5)	17.39 (0.9)	7.56 (9.4)	12.89 (10.4)	9.27 (6.3)

Values in parentheses indicates CV %.

the properties of polyester and acrylic yarns followed by drum speed difference.

Yarn Unevenness and Imperfection

Contour diagram in Figures 2 and 3 shows the influence of opening roller speed and suction air pressure on polyester yarn unevenness and imperfections respectively. The contours clearly show that polyester yarn unevenness and imperfection significantly reduces with the increase in opening roller speed and suction air pressure. The decrease in yarn unevenness and imperfection with the increase in opening roller speed is partly in agreement with the findings of Ulku *et al.* [2] and Dhamija *et al.* [3], where reduction in yarn unevenness is observed upto certain range, and thereafter deterioration in yarn quality. However in case of open-end friction spun yarn on DREF-III machine there is continuous improvement in

Table 6. Response surface equations for polyester open-end friction spun yarn

No.	Parameters	Response surface equations	Coefficient of determination R^2
1	Uster %	$11.41 - 1.34 \times X_1 - 0.77 \times X_3 + 0.68 \times X_1 \times X_3$	0.897
2	Thin places/km (–50 %)	$15.43 - 45.5 \times X_1 - 30.3 \times X_3 + 36.6 \times X_1 \times X_1 + 41.5 \times X_1 \times X_3$	0.936
3	Thick places (+50 %/km)	$12.57 - 39.1 \times X_1 - 23.2 \times X_3 + 30.8 \times X_1 \times X_1 + 37.8 \times X_1 \times X_3$	0.917
4	Neps (+200 %/km)	$209.4 - 383.1 \times X_1 - 170.1 \times X_3 + 252.2 \times X_1 \times X_1 + 263.5 \times X_1 \times X_3$	0.860
5	Imperfections/km	$237.4 - 459.6 \times X_1 - 223.6 \times X_3 + 327.8 \times X_1 \times X_1 + 342.7 \times X_1 \times X_3$	0.887
6	Hairiness index (H)	$10.785 - 0.97 \times X_1 - 0.86 \times X_3$	0.971
6	Tenacity (cN/tex)	$14.153 + 1.17 \times X_1 - 0.68 \times X_1 \times X_1$	0.793
7	Elongation %	$15.26 + 0.28 \times X_1 + 0.67 \times X_3 - 0.39 \times X_1 \times X_1$	0.920
10	Twist per inch	$15.00 + 1.43 \times X_3$	0.783

Table 7. Response surface equations for acrylic open-end friction spun yarn

No.	Parameters	Response surface equations	Coefficient of determination R^2
1	Uster	$13.12 - 1.27 \times X_1 + 0.12 \times X_2 + 0.10 \times X_3 + 0.69 \times X_1 \times X_1 - 0.32 \times X_3 \times X_1$	0.991
2	Thin (–50 %/ km)	$212 - 239 \times X_1 + 28.2 \times X_2 + 37.8 \times X_3 + 169.8 \times X_1 \times X_1 - 67.6 \times X_3 \times X_1$	0.987
3	Thick (+50 %/km)	$243.3 - 197.4 \times X_1 + 28.6 \times X_2 + 128.8 \times X_1 \times X_1 - 50.8 \times X_3 \times X_1$	0.976
4	Neps (+200 %/km)	$449.3 - 110.1 \times X_1 - 44.1 \times X_2 + 120.1 \times X_1 \times X_1$	0.914
5	Imperfections/km	$904.6 - 547 \times X_1 + 418.7 \times X_1 \times X_1 - 131.3 \times X_1 \times X_3$	0.974
5	Hairiness index (H)	$17.33 + 0.73 \times X_2 - 1.92 \times X_3 + 0.52 \times X_1 \times X_1 - 0.68 \times X_2 \times X_3$	0.949
6	Tenacity (cN/tex)	$7.46 + 0.57 \times X_1 - 0.13 \times X_2 + 0.40 \times X_3$	0.943
7	Elongation %	$11.96 + 1.97 \times X_2 - 2.70 \times X_1 \times X_3$	0.472
8	Twist per inch	$9.28 + 0.86 \times X_3 - 0.26 \times X_1 \times X_3$	0.923

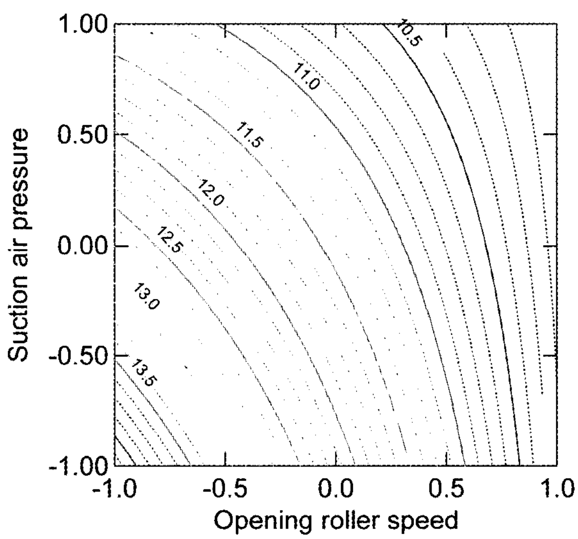

Figure 2. Unevenness (%) of polyester yarns.

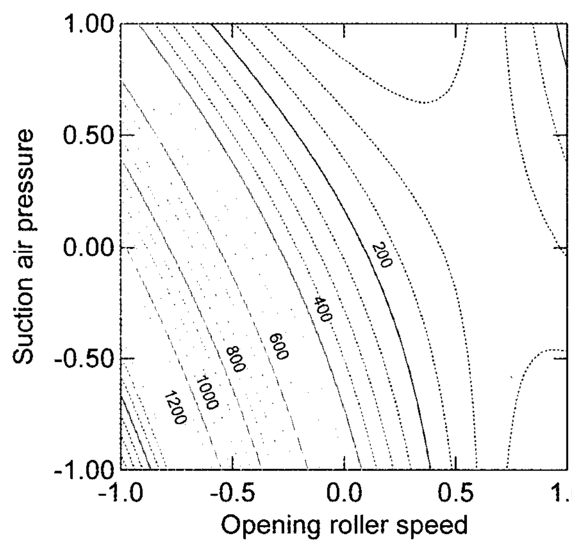

Figure 3. Imperfections of polyester yarns.

yarn unevenness with the increase in opening roller speed upto 14000 rpm. The difference in this behaviour may be due to the fact at high opening roller speed there is increase in fibre breakage in case of DREF-II and PSL Masterspinner, which lead to deterioration in yarn unevenness beyond certain speed range. However for DREF-III machine, due to specially designed opening device, the chances of fibre breakage are less, as there is practically no carding or combing action. It can be observed from Table 3 that opening roller speed does not reduce fibre length significantly. This reduction in unevenness is due to better individualization of fibres. At higher opening roller speed the velocity of fibres inside the transport channel increases and fibres may be transported to the friction drum surface in a much more uniform way and of smaller size tufts. Reduction in yarn unevenness with increase in suction air pressure is in conformity with the findings of Konda *et al.* [5]. The increase in suction air pressure may leads to increase in approaching velocity of fibres onto to the spinning drum, which leads to smaller fibre aggregates onto the drum surface. The decrease in imperfection with the increase in opening roller speed is due to better deposition of individualized fibres at higher suction air pressure.

Contour diagram in Figure 4(a) shows the influence of opening roller speed and suction air pressure on acrylic yarn unevenness at constant 9 % drum speed difference. The contours clearly show that yarn unevenness decreases with

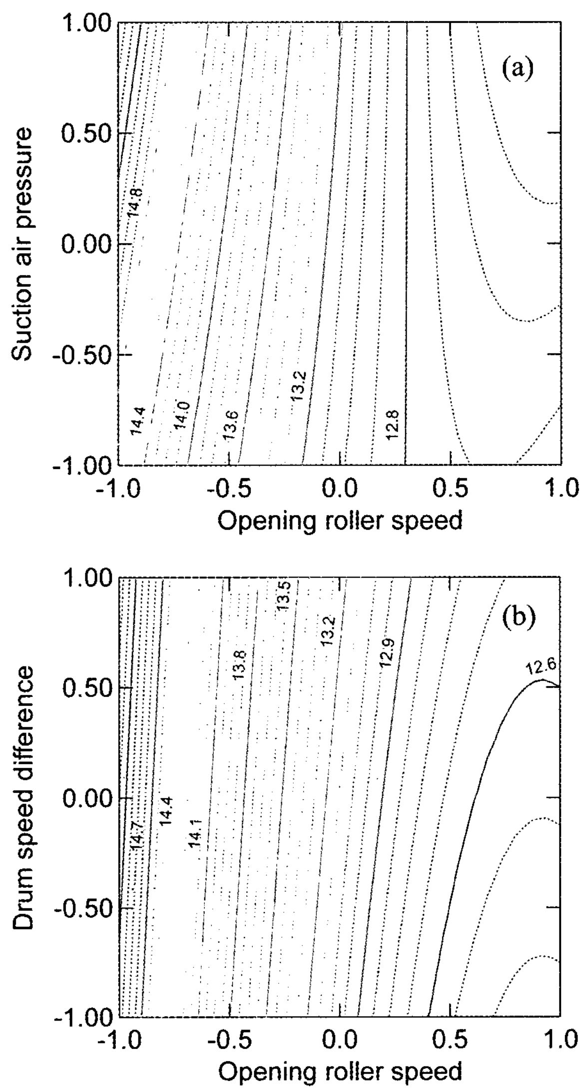

Figure 4. (a) Unevenness (%) of acrylic yarns ($X_2 = 0$), (b) unevenness (%) of acrylic yarns ($X_3 = 0$).

the increase in opening roller speed. The reason of this has been explained above. The contours also show that yarn unevenness increases marginally with the increase in suction air pressure upto 12000 rpm opening roller speed. However yarn unevenness reduces with the increase in suction air pressure at higher opening roller speed. The difference in behaviour for polyester and acrylic yarn is due to different fibre characteristics. The polyester fibres have lower bulk than acrylic fibre due to higher density of polyester fibres. Therefore these fibres tufts after opening are transported in uniform way with increased suction pressure even at low opening roller speed. The acrylic fibres on the other hand have higher bulk than polyester fibres. At lower speed of opening roller the fibres are not sufficiently open; therefore these fibres are fed in the form of clusters of fibres. Since acrylic fibres have higher bulk than polyester fibres, this increases the volume of the clusters inside the duct. Due to increase in suction air pressure these large size clusters are deposited onto the drum surface in more disoriented manner, which is responsible for increase in yarn unevenness with the increase in suction air pressure at lower opening roller speed. However at higher opening roller speed due to better individualization of fibre and subsequent transfer to the drum surface at higher suction air pressure in a much more oriented manner leading to improved uniformity of yarns. Reduction in yarn unevenness with increased suction air pressure is in conformity with the findings of Konda *et al.* [5]. It may be observed from response equation in Table 7 and contour diagram in Figure 4(b) that acrylic yarn unevenness marginally increases with the increase in drum speed difference and significantly decreases with the increase in opening roller speed at constant –20 mbar suction air pressure. The increase in unevenness with the increase in drum speed difference may be attributed to the more rubbing of fibres between two spinning drum surfaces. Contour diagram in

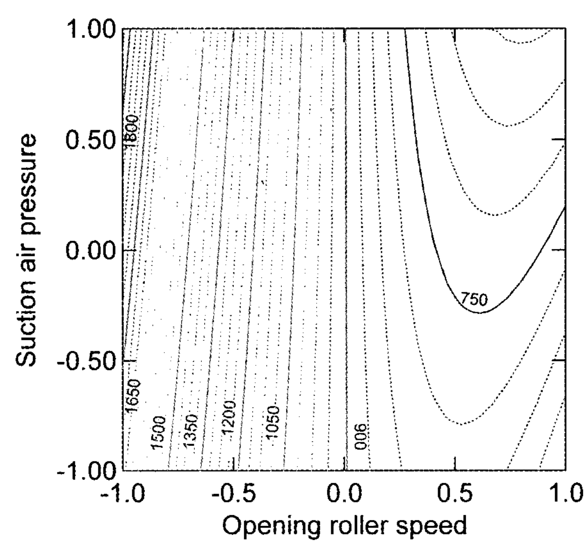

Figure 5. Imperfections of acrylic yarns.

Figure 5 shows that acrylic yarn imperfection continuously decrease with the increase in opening roller speed. The decrease in yarn imperfection, with the increase in opening roller speed, is associated with better opening and individualization of fibres, which is also evident from lower yarn unevenness. It is further observed that with the increase in suction air pressure acrylic yarn imperfections slightly increases upto 12000 rpm opening roller speed and decreases with further increase in opening roller speed. This may be explained in a similar way as explained above.

It is also observed from response surface equations in Table 7 that polyester yarn unevenness and imperfections reduces significantly more than acrylic yarn with the increase in opening roller speed. This may be due to fact that more opening is required for polyester fibres while acrylic fibres are comparatively easy to open.

Yarn Hairiness

Contours in Figure 6 shows that polyester yarn hairiness reduces significantly with the increase in opening roller speed and suction air pressure. It is a well known fact that polyester fibres require more opening due to higher inter-fibre friction. Therefore increase in opening roller speed continuously improves the opening and individualization of fibres. Reduction in the size of the fibre aggregate with the increase in opening roller speed leads to improved fibre deposition onto the spinning drum. These smaller aggregates of fibres are twisted in a better way due to lower bending rigidity of smaller tufts and thus yarn hairiness reduces. Further the increase in suction air pressure increases the frictional torque on the fibres, which reduces slippage between yarn and the friction drum. This increases the twist in the yarn as evident from response surface equation in Table 5. The increase in twist packs the fibres more closely onto the yarn body and results in lower hairiness of yarn.

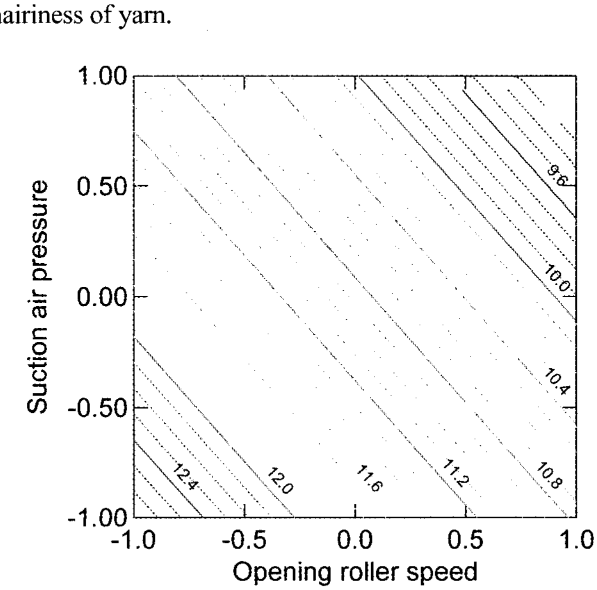

Figure 6. Hairiness index of polyester yarns.

Contour diagram in Figure 7(a) shows that acrylic yarn hairiness also significantly reduces with the increase in suction air pressure due to the reason discussed above. It can also be observed that acrylic yarn hairiness marginally reduces upto 12000 rpm (0 coded level) opening roller speed and then slightly increases with the further increase in opening roller speed. In friction spinning machine fibres after opening are deposited onto the perforated spinning drum surface and get twisted by the frictional torque between fibres and spinning drum. In this process the fibres approach onto the drum at very high speed, and severely crimped and buckled due to relatively slow speed of the spinning drum. This leads to formation of hooks and loops in the yarn and is responsible for higher yarn hairiness. The increase in opening roller speed reduces the size of the clusters of opened fibrous material, which reduces the bending rigidity of clusters. Thus these

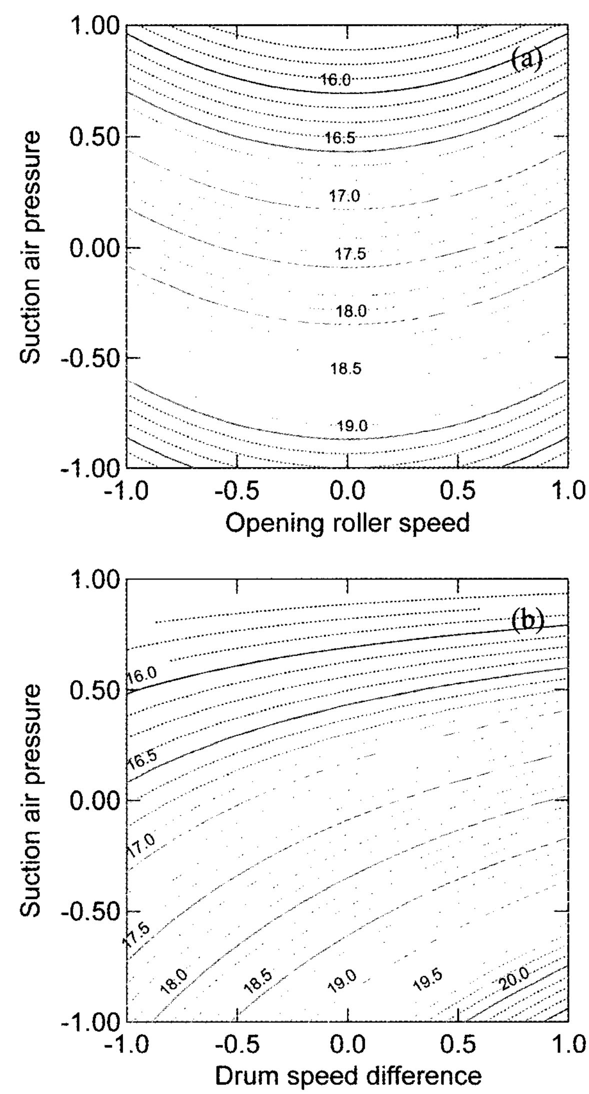

Figure 7. (a) Hairiness index of acrylic yarns ($X_2 = 0$), (b) hairiness index of acrylic yarns ($X_1 = 0$).

small clusters are twisted in a better way. But increase in opening roller speed also increases the speed of approaching fibres onto the spinning drum which increases the folding and buckling of fibres and is responsible for increase in yarn hairiness. This factor is more dominant in case of acrylic fibres as acrylic fibre already have higher bulk and thus have higher bending rigidity. The increase in formation of hooks and loops further increase the bending rigidity of fibre and thus this looped and folded portion of fibres are difficult to twist which is ultimately responsible for increase in yarn hairiness. The results indicate that in case of acrylic fibre the initial reduction in yarn hairiness is dominated by better twisting of small aggregates of fibre and later increase is dominated by increase in fibres hooks and loops during landing due to high speed of the fibres. Contour diagram in Figure 7(b) shows that acrylic yarn hairiness increases with the increase in drum speed difference particularly at lower suction air pressure. As discussed earlier that the increase in drum speed difference may lead to increase in abrasion of surface fibres, which may results in increase in yarn hairiness. It is also observed that the acrylic yarns have significantly higher hairiness than corresponding polyester yarns under similar condition of spinning (Tables 4 and 5). It may be observed from response equations in Tables 6 and 7 that the acrylic yarn have significantly lower level of twist than polyester yarn under similar spinning conditions. The acrylic fibres have higher bulk (due to lower density) and bending rigidity (higher diameter of fibre) than polyester fibres. Due to these factors the acrylic fibres are not closely packed under similar spinning conditions, which lead to higher hairiness.

Yarn Tenacity and Breaking Elongation

The contours in Figure 8 and response equation in Table 6 clearly shows that polyester yarn tenacity increases with the increase in opening roller speed upto 13800 rpm and then start reducing. This is similar to the findings of Ulku *et al.* [2] and Dhamija *et al.* [3], in which there is deterioration in yarn tenacity after a certain range. The increase in tenacity may be due to significant reduction in yarn unevenness and imperfection and better arrangement of fibres in the yarn. The significant lower unevenness and imperfection at higher opening roller speed leads to less number of weak places in the yarns, and consequently higher yarn tenacity. Suction air pressure and drum speed difference do not have significant influence on polyester yarns tenacity. The polyester fibres have smaller diameter, less bulky, lower crimp level, and lower bending rigidity. Therefore these fibres get sufficiently twisted even at lower level of suction air pressure. The increase in suction air pressure increases yarn twist which tends to increase the compactness as well as the tenacity of yarn. But at the same time increase in twist increases the obliquity effect on the

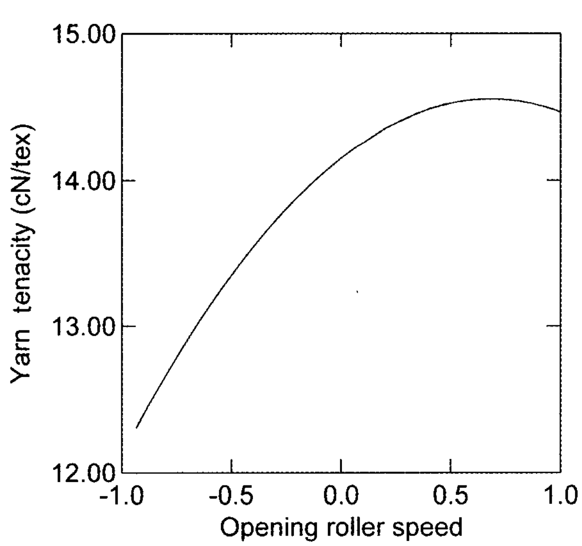

Figure 8. Tenacity of polyester yarns.

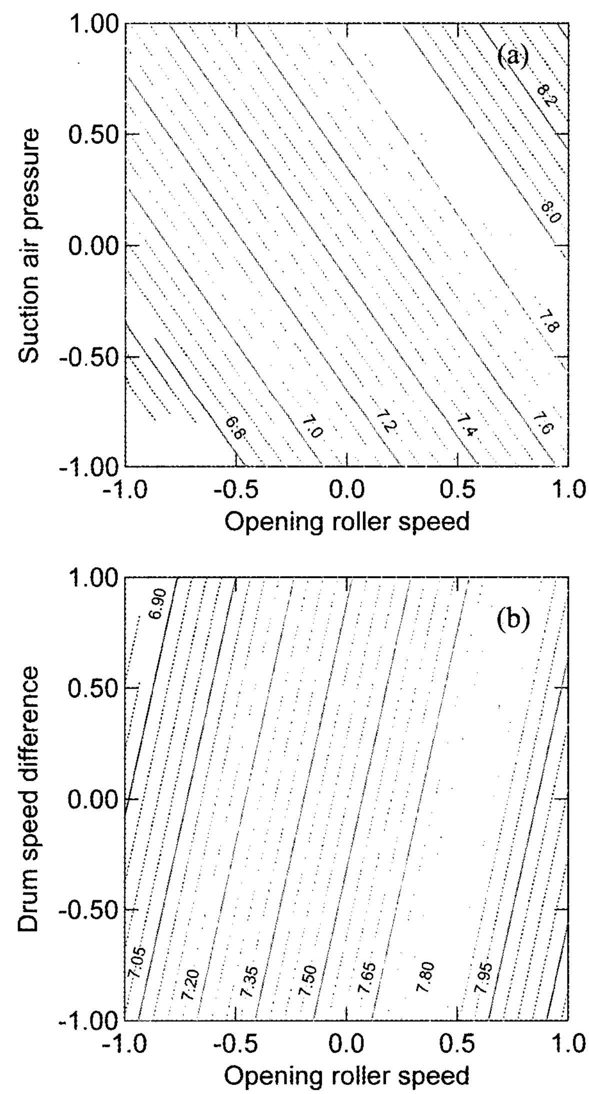

Figure 9. (a) Tenacity of acrylic yarns (X_2 = 0), (b) tenacity of acrylic yarns (X_3 = 0).

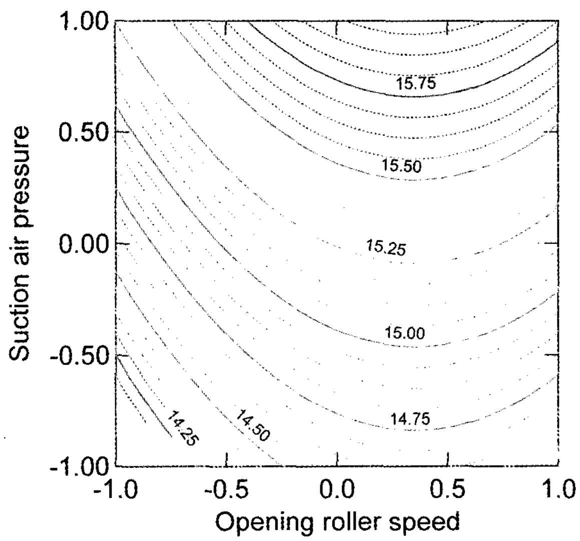

Figure 10. Elongation (%) of polyester yarns.

fibres, which has detrimental effect on yarn tenacity. As both the opposing factors try to contradict each other and thus responsible for no significant influence on polyester yarn tenacity due to increase in suction air pressure.

Contour diagram in Figure 9(a) clearly shows that acrylic yarn tenacity linearly increases with the increase in opening roller speed and suction air pressure. The increase in acrylic yarn tenacity with the increase in opening roller speed may be explained in similar way as discussed above. The increase in acrylic yarn tenacity with the increase in suction air pressure is in agreement with the findings of Konda *et al.* [5] and Ibrahim [7]. This may be due to that the acrylic fibres have more bulk, and higher bending rigidity than polyester fibres. The higher bulk and bending rigidity of fibre is responsible for higher sleeve diameter, which is ultimately responsible for lower level of twist in the yarn as observed in Table 4 and 5 than polyester fibres. The increase in suction air pressure increases the frictional force on the fibre and consequently increase yarn twist. This increase in twist increase yarn compactness, which is responsible for higher yarn tenacity. Since the acrylic fibres have about 30 % less twist than polyester fibres, therefore the influence of obliquity effect is less in this case. Contour diagram in Figure 9(b) clearly shows that acrylic yarn tenacity marginally decreases with the increase in drum speed difference. This slight decrease in yarn tenacity is associated with the increase in yarn unevenness, imperfections. This tends to increase the number of weak places in the yarn, and consequently reduces the yarn tenacity.

Contour diagram in Figure 10 shows that breaking elongation of polyester yarns increases with the increase in suction air pressure. It has been observed from response equation in Table 4 that yarn twist increases with the increase in suction air pressure due to reduced sleeve diameter and increased friction torque. Thus fibres follow longer path in the yarn. Therefore during tensile testing of the yarns the fibres first orient along the yarn axis and then extension in fibres takes place. This is further enhanced by lower unevenness and imperfections at higher suction air pressure, which leads to less number of weak places in the yarn. However for acrylic fibres experimental variables do not show definite trend with yarn breaking elongation which is evident from lower value of R^2 in Table 7.

Conclusion

It is confirmed that for both polyester and acrylic yarn the unevenness and imperfection reduces with the increase in opening roller speed and suction air pressure. The best results are obtained at higher opening roller speed, higher suction air pressure and lower difference in friction drums speed for both fibres. For polyester yarns the hairiness reduces continuously with the increase in opening roller speed and suction air pressure. But for acrylic yarns the hairiness initially decreases and then increases with the increase in opening roller speed and continuously decreases with the increase in suction air pressure. The acrylic yarn hairiness also increases with the increase in difference in drum speed. The yarn tenacity increases with the increase in opening roller speed for both polyester and acrylic yarns. With the increase in suction air pressure the yarn tenacity increases in case of acrylic fibre, while for polyester fibre no significant effect is observed. Increase in spinning drum speed difference has no significant effect on polyester yarn tenacity but marginally increases acrylic yarn unevenness, hairiness and reduces yarn tenacity. For polyester fibres the breaking elongation increases with increase in suction air pressure and increase in opening roller speed, but for acrylic fibres there is no good correlation.

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