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Response to doubling of MJS yarns produced with varying nozzle pressure

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The effects of nozzle pressure and doubling twist on the properties of polyester-viscose two-fold MJS yarn have been investigated and the properties of two-fold MJS yarn have been compared with those of ring-spun yarn. Tensile properties, abrasion resistance, S_3 value, unevenness and imperfections improve after doubling in MJS yarn and the extent of improvement is greater than that in ring-spun yarn. Again, after doubling, increase in flexural rigidity is less than that in ring-spun yarn. Tenacity, breaking elongation and abrasion resistance show optimum values at a particular level of doubling twist, whereas flexural rigidity, hairiness index and S_3 value gradually decrease with the increasing doubling twist. The above parameters are also affected by the characteristics of single yarn produced with different nozzle pressure combinations. Two-fold MJS yarn (with 4.1 tpcm) which are made from single yarns produced under nozzle pressure combination of 2.5 kg cm^{-2} (N_1)/3.5 kg cm^{-2} (N_2) appears to be most suitable for weaving.

Keywords: Abrasion resistance, Breaking elongation, Doubling, Flexural rigidity, Hairiness, Imperfections, MJS yarn, Nozzle pressure, Polyester-viscose yarn, Tenacity, Unevenness

1 Introduction

The worldwide consumption of two-fold staple yarn is second only to single ring-spun yarns, while the advantages of a two-fold yarn are numerous. There have been many attempts to reduce the cost of two-fold staple yarn either by seeking alternatives to a two-fold yarn or by improving the efficiency of the process or by using minimum required folding twist.

Till now scientists have paid little attention on two-fold air-jet spun yarn. Little insight has been given on the extent of improvement after doubling. Again, it is very important to understand the effect of process variables and doubling parameters on the properties of MJS doubled yarn so as to produce better two-fold yarn.

Stahlecker[1] reported that in the folding of jet-spun yarns it is only necessary to use 60-70% of the twist which would be needed for the equivalent ring-spun yarn. Oxenham[2] and Basu *et al.*[3] reported that though the level of folding twist has very little effect on the tenacity of the polyester air-jet spun yarns yet there is an improvement in cotton yarn (air-jet spun) tenacity with increasing folding twist.

Karthikeyan *et al.*[4], in a recent paper, have reported that with the increase in doubling twist in a two-fold MJS yarn, the tenacity decreases but breaking elongation increases. They also reported that strength realization (%) of 2/63s polyester-cotton air-jet spun yarn is more or less equal (30-40%) to that of ring-spun folded yarn. And in coarser counts (30s P/C), the strength realization of air-jet spun folded yarn is twice than that of its ring counterpart. They also reported that the abrasion resistance of air-jet folded yarns is lower by about 15-30% than that of their ring counterparts.

In the present study, an attempt has been made to investigate different aspects of MJS two-fold yarn to optimize the doubling twist for MJS two-fold yarn.

2 Materials and Methods

2.1 Materials

A 14.76 tex (40s) yarn was spun on the Murata air-jet spinning frame (Model MJS 802) using 70:30 P/V blend of polyester fibres (1.26 dtex, 51 mm) and viscose fibres (1.35 dtex, 51 mm). During the production of MJS yarn (single), nozzle pressures (N_1/N_2) were taken as 2 kg cm^{-2}/4 kg cm^{-2}, 2 kg cm^{-2}/3 kg cm^{-2}, 2.5 kg cm^{-2}/3 kg cm^{-2}, 2.5 kg cm^{-2}/3.5 kg cm^{-2} and 2.5 kg cm^{-2}/4 kg cm^{-2}. MJS two-fold yarns were produced on Textool ring doubler machine using doubling twist of 3.1, 4.1, 5.1, 5.9 and 6.7 tpcm. For comparison, a ring-spun yarn of 14.76 tex (40s) was prepared with the same blend and fibres using 7.3 tpcm and than doubled at ring doubler at 5.1 tpcm doubling twist. The properties of MJS single yarns are given in Table 1.

2.2 Methods

Yarn tenacity and breaking elongation were tested in Instron tensile strength tester using 500 mm gauge length and 200 mm/min cross-head speed. Yarn unevenness and imperfections were tested in STAR evenness tester and Uster imperfections counter respectively. Flexural rigidity was tested by ring loop method[5]. Abrasion resistance was tested by flex abrasion (Custom Scientific Instrument INC). Here, the number of strokes to break the specimen is recorded to indicate yarn abrasion resistance[6]. Yarn hairiness was tested in Zwegle G565E instrument.

3 Results and Discussion

3.1 Tensile Properties

It is observed from Table 2 that the tenacity of MJS yarn increases with the increase in doubling twist up to 4.1/5.1 tpcm and then decreases with further increase in doubling twist. The increase in tenacity may be due to the greater cohesiveness among the fibres in the yarn. After that, yarn tenacity decreases due to obliquity of the fibres in the yarn. Breaking elongation (%) of two-fold MJS yarn shows the same trend as yarn tenacity and at 5.1 tpcm doubling twist, the breaking elongation of two-fold MJS yarn is highest. Again, although the CV% of tenacity and breaking elongation decrease after doubling, they do not exhibit any trend with doubling twist.

An examination of the percentage increase in tenacity of the MJS doubled yarn from Table 2 shows that for weaker single yarns (B, C), the improvement in tenacity is more (27.78-46.02%) than that for stronger single yarns (D, E, A) (13.9-30.9%). Also, increase in breaking elongation of MJS two-fold yarns is more for weaker single yarns (B, C) (26.2-37.98%) and less for stronger single yarns (D, E, A) (14.93-33.25%).

It is also observed from Table 2 that in case of MJS two-fold yarn, the increase in tenacity (14-46%) is more than that for ring-spun two-fold yarn (12.14%) over the corresponding single yarns. Increase in breaking elongation of MJS two-fold yarn (15-37%) is also more than that of ring-spun doubled yarn (13.52%) over the corresponding single yarns.

3.2 Unevenness and Imperfections

It is observed from Table 3 that unevenness and imperfections of MJS yarn decrease on doubling. However, increasing or decreasing doubling twist has no significant effect.

A comparison of the unevenness of MJS two-fold yarns with those of corresponding single yarns shows that, in general, the unevenness of

Table 1—Effect of nozzle pressure on properties of polyester-viscose (70:30) MJS single yarn (40s)

Yarn ref. No.	Nozzle pressure kg cm^{-2}		Actual count Ne	Tenacity g/tex	Break. elong. %	U%	Imperfections/1000 m				Flexural rigidity dyn. cm^2	Abrasion resistance No. of strokes	Hairiness/100 m	
	N_1	N_2					Thin places −50%	Thick places +50%	Neps +200%	Total			HI	S_3
A	2	4	14.77	17.32 (7.5)	8.99 (8.6)	11.32	6	2	41	49	2.99	1101.1	10.6	722.3
B	2	3	14.74	16.37 (8.19)	8.82 (10.5)	11.80	5	6	53	64	2.295	1059.3	11.2	918.3
C	2.5	3	14.76	15.49 (8.74)	8.74 (8.9)	12.24	6	8	64	78	2.38	973.2	12.1	1013.6
D	2.5	3.5	14.78	18.53 ((6.83)	9.91 (6.7)	11.54	4	2	57	63	2.61	1233.42	11.5	928.2
E	2.5	4	14.78	17.89 (8.92)	6.69 (6.8)	11.48	3	5	53	61	3.299	1153.4	10.9	878.4
F	Ring-spun yarn		15.31	23.31 (7.17)	11.61 (5.3)	12.88	9	18	112	139	1.62	1494.16	17.2	514.2

HI—Hairiness index; and S_3—Total no. of hairs of length 3 mm and above 3 mm in 100 m yarn length.
Values in parentheses indicate CV%.

Table 2—Effect of doubling on tensile properties of MJS yarn

Yarn ref. No.	Nozzle pressure for single yarn, kg cm^{-2}		Doubling twist tpcm	Tenacity, g/tex			Breaking elongation, %		
	N_1	N_2		Single yarn	Double yarn	% Increase	Single yarn	Double yarn	% Increase
			3.1		22.11 (4.30)	27.65		11.25 (5.16)	25.13
			4.1		22.69 (5.60)	31.00		11.64 (6.64)	29.47
A	2.0	4.0	5.1	17.32 (7.50)	22.24 (5.16)	28.40	8.99 (6.60)	11.98 (3.49)	33.25
			5.9		21.67 (4.09)	25.11		11.63 (3.70)	29.36
			6.7		20.42 (6.60)	17.89		11.45 (7.80)	27.36
			3.1		22.72 (4.60)	33.49		11.13 (5.20)	26.19
			4.1		22.34 (5.04)	37.30		11.25 (8.50)	27.55
B	2.0	3.0	5.1	16.27 (8.19)	22.73 (4.38)	39.70	8.82 (10.55)	12.17 (3.80)	37.98
			5.9		22.17 (5.50)	36.26		11.88 (4.70)	34.69
			6.7		20.79 (4.20)	27.78		11.52 (5.30)	30.61
			3.1		21.29 (3.90)	37.44		10.78 (3.50)	23.34
			4.1		21.86 (5.20)	41.12		11.03 (5.72)	26.20
C	2.5	3.0	5.1	15.49 (8.74)	22.62 (4.76)	46.02	8.74 (8.90)	11.88 (3.86)	35.92
			5.9		22.35 (6.00)	44.28		11.24 (4.45)	28.60
			6.7		21.27 (5.90)	37.31		11.08 (5.80)	26.77
			3.1		22.61 (4.80)	22.01		11.39 (5.38)	14.93
			4.1		23.05 (4.20)	24.39		12.88 (4.79)	29.76
D	2.5	3.5	5.1	18.53 (6.83)	22.92 (5.46)	23.69	9.91 (6.70)	12.92 (9.50)	30.37
			5.9		22.34 (6.30)	20.56		12.74 (4.35)	28.55
			6.7		21.11 (6.30)	13.92		11.61 (4.70)	17.15
			3.1		22.46 (5.40)	25.54		11.32 (4.02)	16.82
			4.1		22.89 (5.06)	27.94		12.02 (6.39)	24.04
E	2.5	4.0	5.1	17.89 (6.92)	22.62 (5.84)	26.43	9.69 (6.80)	12.32 (3.65)	27.14
			5.9		21.73 (3.50)	21.46		12.24 (4.44)	26.31
			6.7		21.03 (5.04)	17.55		11.52 (4.70)	18.88
F	Ring-spun yarn		5.1	23.31 (7.17)	26.14 (6.28)	12.14	11.61 (5.30)	13.18 (5.24)	13.52

Values in parentheses indicate CV%.

Table 3—Effect of doubling on unevenness and imperfections of MJS yarn

Yarn ref. No.	Nozzle pressure for single yarn kg cm^{-2} N$_1$	N$_2$	Doubling twist tpcm	U% Single yarn	U% Double yarn	U% % Change	Imperfections/1000 m Single yarn Thin places −50%	Single yarn Thick places +50%	Single yarn Neps +200%	Single yarn Total	Double yarn Thin places −50%	Double yarn Thick places +50%	Double yarn Neps +200%	Double yarn Total	% Change
			3.1		8.54	−24.55	6	2	41	49	5	0	14	19	−61.22
			4.1		8.7	−23.14					0	0	16	16	−87.34
A	2	4	5.1	11.32	8.42	−25.61					3	0	21	24	−51.02
			5.9		8.55	−24.46					0	0	19	19	−61.22
			6.7		8.43	−25.53					2	0	9	11	−71.55
			3.1		8.7	−26.27	5	6	53	64	3	0	17	20	−68.75
			4.1		9.8	−22.88					0	0	17	17	−73.43
B	2	3	5.1	11.8	8.66	−26.61					3	0	19	22	−65.62
			5.9		8.23	−30.25					0	0	16	16	−75.00
			6.7		8.54	−27.62					2	0	8	10	−84.37
			3.1		9.24	−25.50	8	8	64	78	3	2	51	56	−28.20
			4.1		8.94	−26.96					0	0	17	17	−78.20
C	2.5	3	5.1	12.24	9.03	−26.22					0	2	25	27	−65.38
			5.9		8.64	−29.41					2	0	19	21	−73.07
			6.7		8.80	−28.10					2	0	24	26	−89.23
			3.1		8.7	−24.61	4	2	57	63	2	0	22	24	−61.90
			4.1		8.64	−25.12					3	0	24	27	−57.14
D	2.5	3.5	5.1	11.54	8.42	−27.03					2	0	9	11	−82.53
			5.9		8.62	−25.30					17	0	13	30	−52.38
			6.7		8.55	−25.90					2	0	22	24	−61.90
			3.1		8.65	−24.65	3	5	53	61	3	6	37	48	−24.59
			4.1		8.54	−25.60					0	0	17	17	−72.13
E	2.5	4	5.1	11.48	9.01	−21.51					0	0	11	11	−81.90
			5.9		8.62	−24.91					3	5	55	43	−29.60
			6.7		8.50	−25.95					0	0	16	16	−73.77
F	Ring-spun yarn		5.1	12.88	10.32	−19.87	9	18	112	139	4	6	42	52	−62.58

MJS yarn decreases by 22.87-30.25% after doubling, whereas for ring-spun yarn, the unevenness decreases by 19.87% after doubling. Decrease in imperfections of MJS yarns varies from 24.59% to 84.37%, whereas in case of ring-spun yarn, it is 68.58%.

3.3 Flexural Rigidity

Table 4 shows that as doubling twist increases from 3.1 to 6.7 tpcm, the flexural rigidity of MJS two-fold yarn decreases. This decreasing trend in flexural rigidity may be due to the increase in fibre helix angle, resulting in less stress and strain on the fibres. It is further observed from Table 4 that at 5.9 tpcm doubling twist, the increase in flexural rigidity of MJS yarns varies from 1.3% to 16%, whereas for ring-spun yarn the increase is 41.86% over that for the corresponding single yarn.

3.4 Abrasion Resistance

It is observed from Table 4 that as the doubling twist increases from 3.1 to 6.7 tpcm, the abrasion resistance (the average number of cycles to break the specimen) of the two-fold MJS yarn increases up to 4.1 tpcm and then decreases with further

Table 4—Effect of doubling on flexural rigidity and abrasion resistance of MJS yarns

Yarn ref. No.	Nozzle pressure for single yarn, kg cm^{-2}		Doubling twist tpcm	Flexural rigidity, dyn. cm^{-2}			Abrasion resistance, no. of strokes		
	N_1	N_2		Single yarn	Double yarn	% Change	Single yarn	Double yarn	% change
			3.1		4.264 (18.58)	+42.6		1352.24	+22.81
			4.1		3.588 (17.42)	+20.0		1422.6	+29.20
A	2	4	5.1	2.99 (20.5)	3.2 (14.48)	+7.0	1101.0	1338.32	+22.81
			5.9		3.03 (13.73)	+1.3		1312.53	+19.21
			6.7		3.17 (12.22)	+6.0		1270.42	+15.38
			3.1		3.281 (15.07)	+42.16		1328.32	+25.39
			4.1		3.127 (13.12)	+36.25		1377.91	+30.07
B	2	3	5.1	2.295	2.755 (18.65)	+20.0	1059.3	1345.28	+26.99
			5.9		2.66 (17.72)	+15.9		1285.61	+29.36
			6.7		2.74 (16.21)	+19.38		1243.8	+17.41
			3.1		3.439 (14.3)	+46.1		1325.5	+36.2
			4.1		3.324 (12.38)	+39.66		1389.62	+42.78
C	2.5	3	5.1	2.38 (22.28)	3.282 (16.54)	+37.89	973.2	1372.35	+41.01
			5.9		2.75 (17.32)	+15.54		1262.41	+29.71
			6.7		2.92 (15.41)	+22.68		1233.63	+28.76
			3.1		3.693 (18.83)	+41.44		1502.42	+21.8
			4.1		3.34 (14.52)	+27.92		1554.8	+26.05
D	2.5	3.5	5.1	2.611 (24.23)	3.18 (12.48)	+21.79	1233.42	1505.31	+21.04
			5.9		2.852 (17.33)	+9.2		1432.16	+16.11
			6.7		2.82 (15.9)	+8.0		1319.8	+7.0
			3.1		4.33 (18.45)	+31.25		1452.31	+25.91
			4.1		3.968 (17.62)	+20.27		1468.52	+27.32
E	2.5	4	5.1	3.299 (23.25)	3.753 (17.96)	+13.76	1153.4	1332.4	+15.51
			5.9		3.372 (12.25)	+2.21		1325.2	+14.89
			6.7		3.38 (13.07)	+2.4		1253.61	+8.88
F	Ring-spun yarn		5.1	1.62 (21.01)	2.44 (13.97)	+41.88	1496.18	1832.16	+22.45

Values in parentheses indicate CV%.

increase in doubling twist. Initial increase in abrasion resistance may be due to the increase in yarn tenacity. Decrease in abrasion resistance at higher doubling twist may be due to the cutting effect on the yarns with the increase in twist. Although, in few instances, the yarn tenacity increases up to 5.1 tpcm but the former effect may be predominating in decreasing abrasion resistance. However, it may be noted that after 5.1 tpcm doubling twist, the tenacity of all the samples decreases, which may also contribute to decrease in yarn abrasion resistance with increasing doubling twist.

Again, it is observed that the abrasion resistance of MJS two-fold yarn made with single MJS yarn (D) of very high abrasion resistance is always more than that of MJS two-fold yarn made with single MJS yarn (C) of low abrasion resistance at every doubling twist.

It is also observed from Table 4 that after doubling, the increase in abrasion resistance for MJS yarn varies from 7% to 42.78%, whereas for ring-spun yarn, it is 22.45%.

3.5 Hairiness

Table 5 shows that the hairiness index of MJS two-fold yarn is higher than that of the corresponding single MJS yarn at low doubling twist and lower at higher doubling twist. Also, it is found that the hairiness index of two-fold ring-spun yarn is higher than that of single ring-spun yarn. But after doubling, the S_3 values (the total number of hairs of length 3 mm and above 3 mm in 100 m yarn length) for both types of yarn decrease significnatly and are lower than that of the corresponding single yarns. The above phenomena may be due to the increase in the total number of hairs as the total exposed surface area increases after doubling. Decrease in hairiness index at much higher doubling twist is due to the entrapping of protruded fibres in two-fold MJS

Table 5—Effect of doubling on hairiness of MJS yarn

Yarn ref. No.	Nozzle pressure for single yarn, kg cm^{-2}		Doubling twist tpcm	Single yarn		Double yarn		% Change	
	N_1	N_2		HI	S_3	HI	S_3	HI	S_3
			3.1			14.5	277.0	+36.79	81.65
			4.1			12.8	211.3	+20.75	70.74
A	2	4	5.1	10.6	722.3	11.6	161.2	+9.43	77.68
			5.9			9.6	146.5	−9.43	79.71
			6.7			10.3	136.4	−2.8	81.11
			3.1			16.8	323.2	+50.0	84.8
			4.1			15.2	275.0	+35.71	70.05
B	2	3	5.1	11.2	918.3	12.8	196.1	+12.5	78.64
			5.9			13.4	126.7	−19.64	86.20
			6.7			11.1	99.4	−0.89	89.17
			3.1			17.5	360.0	+44.62	64.48
			4.1			15.2	311.8	+25.81	69.23
C	2.5	3	5.1	12.1	1013.6	12.6	185.4	+4.13	81.70
			5.9			11.4	132.2	−5.78	86.95
			6.7			11.8	114.8	−2.47	88.67
			3.1			17.2	331.6	+49.56	64.27
			4.1			15.8	220.2	+37.39	76.27
D	2.5	3.5	5.1	11.5	928.2	11.2	175.3	−2.6	81.11
			5.9			9.7	146.1	−15.65	84.25
			6.7			10.2	134.7	−11.30	85.48
			3.1			14.9	289.2	+36.69	67.07
			4.1			13.2	266.4	+21.10	89.67
E	2.5	4.0	5.1	10.9	878.4	13.2	266.4	+4.5	76.62
			5.9			11.8	145.6	+8.2	83.42
			6.7			10.3	110.2	−5.5	87.45
F	Ring-spun yarn		5.1	17.2	514.2	20.4	422.3	+18.6	17.87

HI—Hairiness index; and S_3—Total no. of hairs of length 3 mm and above 3 mm in 100 m yarn length.

yarn. Decrease in S_3 value after doubling is due to entrapment of long hairs as revealed from test results.

It is also observed from Table 5 that after doubling, the decrease in S_3 value of MJS yarn (61.65-89.17%) is greater than the decrease in S_3 value of ring-spun yarn (17.87%).

From the above observations it may be concluded that, in general, two-fold MJS yarn with 4.1 tpcm doubling twist can be selected to get optimum process performance and yarn quality. Again, in general, the two-fold MJS yarns made from single yarn produced under nozzle pressure combination of 2.5 kg cm^{-2} (N_1)/3.5 kg cm^{-2} (N_2) appear to be most suitable for weaving. However, for knitting, other nozzle pressure combinations (N_1/N_2) with suitable doubling twist may be selected to get optimum process performance and quality.

4 Conclusions

4.1 MJS two-fold yarn gives maximum tenacity, breaking elongation and abrasion resistance with doubling twist of 4.1/5.1 tpcm. After doubling, the increase in tenacity of MJS yarn is greater (14-46%) than that of ring-spun yarn (12.14%).

4.2 Unevenness and imperfections of MJS yarn decrease by 22.85-30.25% and 24.59-84.37% respectively; the corresponding values for ring-spun yarn are 19.87% and 68.58% respectively.

4.3 At higher doubling twist (5.9-6.7 tpcm), MJS two-fold yarns show minimum flexural rigidity. After doubling, increase in flexural rigidity of MJS yarn (1.3-16%) is much less than that of ring-spun yarn (41.86%).

4.4 Increase in abrasion resistance (after doubling) of MJS yarn (42.78%) is greater than that of ring-spun yarn (22.45%). With increase in doubling twist, the abrasion resistance of two-fold MJS yarn initially increases and then decreases, showing the maximum value at 4.1 tpcm.

4.5 After doubling, the decrease in hairiness ($S_3 \geqslant 3$ mm) of MJS yarn (61.65-89.17%) is greater than that of ring-spun yarn (17.87%). Hairiness index of doubled yarn is higher at low doubling twist but it gradually decreases with increase in doubling twist and at much higher doubling twist, it is lower than that for corresponding single yarns.

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