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Effect of retwisting parameters of splicing on the retained splice strength

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Effect of three crucial parameters of splicing, exclusively related to retwisting operation of splicing, namely air pressure, retwisting time and overlapping length on retained splice strength (RSS) has been studied. During this study, the parameters related to untwisting are kept constant based on the visual untwisting performance. Three-factor three-level Box-Behnken design is employed on three different cotton yarn counts (20s Ne, 40s Ne and 60s Ne), produced by ring spinning. Interactive effects of parameters have also been analyzed through contour plots and optimization conditions are achieved using the statistical software called Minitab. The optimization conditions can be used as a guide to set the splicer parameters. It is observed that average retained splice strength of the yarn increases with the increase in yarn count. Higher RSS can be obtained with the combination of lower compressed air pressure with relatively higher retwisting time.

Keywords: Cotton yarn, Pneumatic splicing, Retained splice strength, Retwisting time, Ring spinning, Splicing air pressure

Though there are many different techniques to splice the textile yarn, the pneumatic splicing is widely used due to its performance and versatility. It has now become the wise choice for the production of knot-free yarn. The pneumatic splicing principles like untwisting and retwisting may look very simple at first sight, but it is quite complex in actual due to more number of variables related to fibre, yarn and device. As this study is mainly focused on the splicing of spun yarns, the weightage is given only to device related parameters, since the cotton yarn is used alone for this study.

The splicing quality is being evaluated by a parameter called retained splice strength (RSS) and retained splice appearance (RSA). RSS is defined as the ratio of breaking strength of the spliced yarn to that of parent yarn. At the same time, the RSA is subjective matter and cannot be measurable with any available scale.

The effect of fibre and yarn related properties on RSS has already been studied by many researchers[1-4]. It was evident in previous research[1] that the longer staple fibres perform better during splicing. Webb *et al*.[3] studied the relationship between splicing performance and yarn count. There were many studies[4-8] reported on the effect of splicing device related parameters on RSS like air pressure, overlapping length and duration of preparation of air blast. Cheng *et al*[4,5] reported that the count of yarn and overlapping length are the crucial parameters which affect splice performance. Splicer parameters were optimized to produce better spliced yarn. It is also found by Das *et al*[2]. that RSS increases initially with the increase in air pressure and after a certain level it deteriorates. Further, the optimization of splice performance has been studied for different types of yarns, like ring spun, open end, airjet, etc. using Box-Behnken method[8]. Splicer parameter optimization through Taguchi method has also been reported by Webb *et al*[7].

It is a known fact that untwisting and retwisting are the principles of pneumatic splicing. Hence, both untwisting and retwisting parameters are equally important. But the untwisting performance can be observed through naked eye when there is no retwisting air pressure applied on the splicer. On the other hand, once the retwisting air supply valve is closed, the performance of untwisting is visible to naked eye and optimization of untwisting parameters can be done accordingly. But there is no visual chance to evaluate the retwisting until otherwise the sample has undergone a tensile testing.

Therefore, the retwisting parameters have also been studied in detail in this investigation. Though there are many studies conducted previously by combining both untwisting and retwisting parameters, it is necessary to understand the role of each retwisting parameters since the retwisting cannot be assessed by naked eye like untwisting.

Experimental

Three different counts of ring spun cotton yarns, namely 20s, 40s and 60s Ne were used to find out the

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effect of retwisting parameters (retwisting time, overlapping length and air pressure) on RSS. Three-factor three-level Box-Behnken response surface design[9] (Table 1), was used. Actual values for different levels of each factor along with coded values are given in Table 2. All the trial runs were randomized to minimize the error. Fifteen different combinations were used on each count to make it 45 different trials for three counts in total. Fifty splice samples per trial were prepared using Mesdan (Model: 498Q) splicer.

Table 1 — Three-factor three-level Box-Behnken design

Sample No.	Coded factor level		
	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 factor values along with coded values

Factor	Level		
	-1	0	+1
Compressed air pressure, Bar	5.5	6	6.5
Retwisting time, ms	200	250	300
Overlapping length, mm	25	30	35

During this study, the other splice parameters which are related to untwisting, namely untwisting air flow and untwisting time, were kept constant at an optimum value of 40 lpm and 450 ms respectively.

Unit of measurement used for the air pressure is Bar, which was measured and controlled with the help of a regulator fitted with gauge on the input line. The retwisting time with respect to the graduation scale of the device was measured by recording the valve opening sound and capturing the duration from wave form using sound analyzer software. Figure 1 shows the time observed from the air release sound wave form analyzing technique for one experiment (it is 200ms in this case). Overlapping length has been measured on a linear scale without applying compressed air during splicing cycle.

Testing and Analysis

Both the parent yarn and spliced yarn samples were tested as per ISO 2062:2009 under standard temperature at 250mm gauge length using a single yarn strength tester working under constant rate of extension (CRE) principle. Statistical software called Minitab (version 15) was used to generate contour plots and for the optimization analysis.

Results and Discussion

Results of this retwisting study with actual factor levels are given in Table 3. Three parameters namely air pressure, retwisting time and overlapping length

Table 3 — Results of retwisting study

Run order	Sample No.	Air pressure Bar	Retwisting time ms	Overlapping length mm	Retained splice strength, %		
					20s Ne	40s Ne	60s Ne
1	13	6	250	30	77.16	97.10	93.24
2	4	6.5	300	30	72.83	88.64	92.82
3	6	6.5	250	25	72.71	85.29	82.27
4	12	6	300	35	74.54	91.31	94.51
5	9	6	200	25	71.46	90.86	86.07
6	8	6.5	250	35	81.96	89.08	84.38
7	2	6.5	200	30	71.11	95.32	84.80
8	5	5.5	250	25	74.20	83.96	99.15
9	11	6	200	35	78.65	97.55	96.20
10	7	5.5	250	35	79.45	89.53	89.02
11	14	6	250	30	78.19	95.54	90.29
12	10	6	300	25	71.00	83.74	91.98
13	3	5.5	300	30	78.08	80.17	95.78
14	15	6	250	30	75.79	92.20	84.38
15	1	5.5	200	30	74.42	92.87	81.42

influence the retained splice strength (RSS) during retwisting process. Contour plots are used to explain the effects of each factor at three different levels on different yarn counts.

Effect of Air Pressure, Time and Overlapping Length on RSS

20s Ne Yarn

Interactions among compressed air pressure, retwisting time and overlapping length on RSS for 20s Ne yarn is given in Figs 2(a)-(c). Figure 2(a) shows that the maximum RSS of 78 % is achieved in case of minimum compressed air pressure of 5.5 Bar at retwisting time of 250 ms. Figure 2(b) shows that maximum RSS of 80% is achieved at air pressure of 5.5 Bar and an overlapping length of 35mm.

As shown in Figs 2(a) and (c), the optimum retwisting time gives maximum RSS. RSS is directly proportional to overlapping length in the experiment region which is clearly illustrated in Figs 2(b) and (c). However, the longer overlapping length produces thicker splice and tail which is not acceptable even though it gives higher RSS. Therefore, it is purely a tradeoff between RSS and RSA (retained splice appearance) when the overlapping length is concern.

Fig 1 — Valve opening time calculation by sound wave

40s Ne Yarn

Figures 3(a)-(c) show the interactions among the splicing air pressure, retwisting time and overlapping length on RSS of 40s yarn. As observed in 20s count, the maximum RSS of above 90 % has been obtained when the retwisting is done at relatively low air pressure (5.5 - 6 Bar) [Figures 3(a) and (b)]. But the requirement of retwisting time and overlapping length has come down when yarn count is increased to 40s. This may be

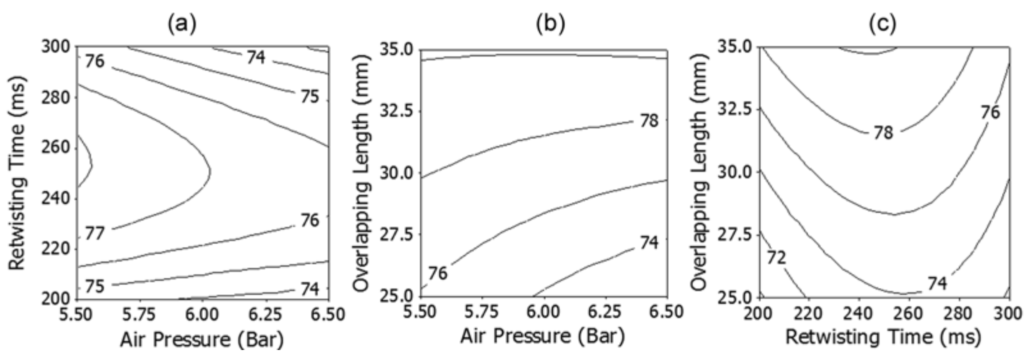

Fig. 2 — (a) Effect of splicing air pressure and twisting air flow on RSS of 20s yarn (overlapping length 5mm), (b) effect of splicing air pressure and overlapping length on RSS of 20s yarn (twisting airflow 3.5ms) and (c) effect of twisting airflow and overlapping length on RSS of 20s yarn (splicing air pressure 6 Bar)

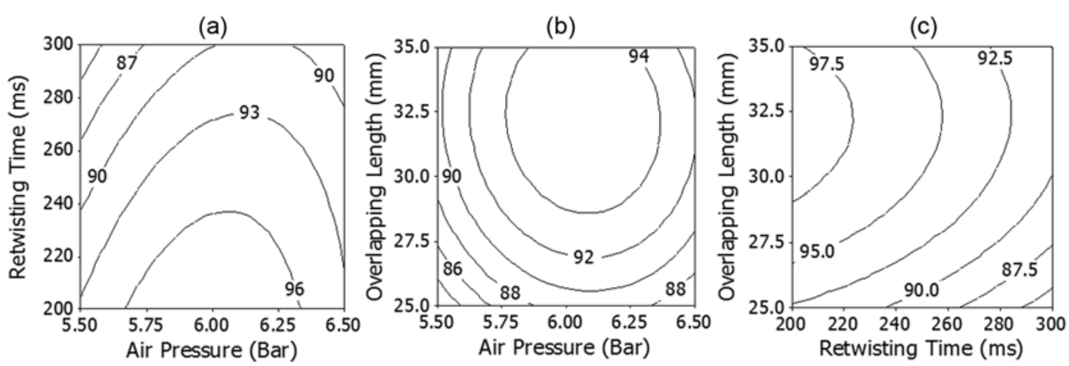

Fig. 3 — (a) Effect of splicing air pressure and twisting air flow on RSS of 40s yarn (overlapping length 30mm), (b) effect of splicing air pressure and overlapping length on RSS of 40s yarn (twisting airflow 250ms) and (c) effect of twisting airflow and overlapping length on RSS of 40s yarn (splicing air pressure 6Bar)

due to the fact that the 40s yarn has got longer fibre length and less number of fibres in cross-section. The maximum RSS is produced with minimum retwisting time of 200ms and medium overlapping length of 30 mm, as shown in Figs 3(a)-(c).

60s Ne Yarn

Figures 4(a)-(c) show the relationship among the splicing air pressure, retwisting time and overlapping length of the 60s yarn on RSS. The same trend as observed in 20s and 40s yarns is also observed in 60s Ne yarn. The higher RSS (>90%) is obtained in lower splicing air pressure (<5.75 Bar) with the combination of higher retwisting time and lesser overlapping length. As shown in Fig. 4(b), maximum RSS has been achieved with minimum overlapping length of 25mm. It has been noticed that the requirement of overlapping length is gradually reduced from 20s to 60s. At the same time, the RSS is found increasing with the increase in retwisting time as shown in Figs 4(a) and (c).

Optimization Analysis

Optimization analysis is necessary to find out the optimum values of the studied parameters. As the maximum achievable RSS significantly varies with respect to linear density, the optimization analysis has been done on individual counts. Also an attempt has been made to find out a common solution for all three counts. This optimization analysis has been carried out using an in-built function of the Minitab software, also called as Global Solution. Achieving target RSS has been fixed as Goal with the desirability of 1. Optimization values for this untwisting study to achieve maximum RSS is given in Table 4. It can be treated as a guide to set the pneumatic splicer for respective cotton yarn counts to obtain maximum splicing performance.

With reference to the optimization analysis on individual counts, the maximum achievable RSS is significantly higher than the target. Air pressure and over lapping length are inversely proportional to the linear density of the yarn. The retwisting time is comparatively lower when applying higher air pressure. On an attempt to find out a common solution for all three counts, the maximum achievable RSS is only little higher than the target. In this case, the target for all three yarn counts can be met by

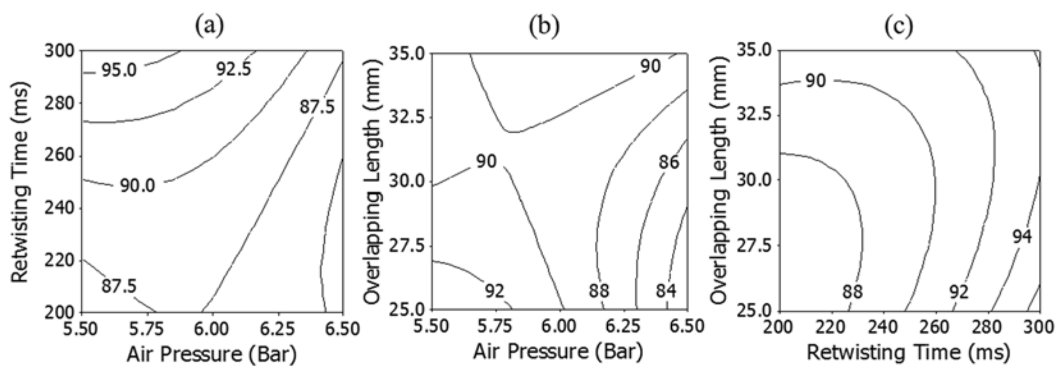

Fig 4 — (a) Effect of splicing air pressure and twisting air flow on RSS of 60s yarn (overlapping length 30mm), (b) effect of splicing air pressure and overlapping length on RSS of 60s yarn (twisting airflow 250ms) and (c) effect of twisting airflow and overlapping length on RSS of 60s yarn (splicing air pressure 6Bar)

Table 4 — Optimized values for the factors to achieve maximum RSS %

Yarn	Response optimization parameters			Optimized parameter				
	Goal	Lower RSS %	Target RSS %	Air pressure Bar	Retwisting time ms	Overlapping length mm	Maximum RSS %	Desirability
				Separate solution for individual counts				
20s Ne	Maximize	75	80	6.5	239.39	35	80.43	1.00
40s Ne	Maximize	80	85	5.98	200	32.17	98.73	1.00
60s Ne	Maximize	85	90	5.5	300	25	102.08	1.00
				Common / global solution for all three counts				
20s Ne	Maximize	75	80	6.48	221.21	35	80.00	1.00
40s Ne	Maximize	80	85	-	-	-	92.39	1.00
60s Ne	Maximize	85	90	-	-	-	90.39	1.00

applying the compressed air at relatively higher pressure with less retwisting time and maximum overlapping length.

The studied parameters namely air pressure, retwisting time and overlapping length are having mixed effect on RSS for different linear densities of yarn. Therefore, these factors have to be set according to the linear density of the yarn or else we can go by the optimized solution.

The average retained splice strength of the yarn increases with the increase in yarn count. This may be due to the fact that the longer fibres have better intermingling during retwisting.

Overlapping length always has the positive effect on RSS, irrespective of the count of yarn and it has to be increased without affecting the splice appearance. Higher RSS can be obtained with the combination of lower compressed air pressure with relatively higher retwisting time.

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