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Effect of Retwisting Parameters of Splicing On the Retained Splice Strength

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Abstract

Knotless yarn joining process called Splicing is done by retwisting of the overlapped untwisted yarn ends. Therefore the level of untwisting, length of overlapping and the amount of retwisting are equally important to produce a better splice. Of course, the air pressure, air flow and time are the key parameters in both untwisting and twisting. As splicing involves more number of parameters, it is relatively difficult to plan an integrated study by involving every parameters related to untwisting and retwisting. At the same time, it is also possible to visually check the level of untwisting before retwisting by closing the retwisting valve of the splicing device. Therefore, due importance is given to find out the effect of three crucial parameters found during retwisting called air pressure, retwisting time and overlapping length on Retained Splice Strength (RSS). The parameters exclusively related to untwisting were kept constant based on the visual untwisting performance during the study. Three-factor three-level Box-Behnken design were employed on three different cotton yarn counts namely 20s Ne, 40s Ne and 60s Ne produced by Ring Spinning. Interactive effects of parameters had been analyzed through contour plots and optimum solution had been arrived using the statistical software called Minitab.

Key words: Overlapping length, pneumatic splicing, retained splice strength, splicing air pressure, retwisting time.

1. Introduction

Though there are many different techniques to splice the textile yearn, the pneumatic splicing is widely used due to its performance and versatility. And it becomes the wise choice for the production of knot-free yarn. The pneumatic splicing principles like untwisting and retwisting may looks very simple at first sight, but it is quite complex in actual due to more number of variables namely related to fibre, yarn and device. As this study is mainly focusing on the splicing of spun yarns, weightage given only to device related parameters since the cotton yarn is alone used 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 expressed as the percentage of the breaking strength of parent yarn. At the same time, the RSA is subjective matter and cannot be measurable with any available scale. It is not new, but the effect of fibre and yarn related properties affecting the Retained Splice Strength (RSS) had been studied by different researchers[1-4]. It was evident in previous research made by Kaushik R.C.C et al[1] that the longer staple fibres are performing better during splicing. Webb C.J. 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, over lapping length and duration of preparation of air blast etc. Cheng K.P.S. et al[4, 5], reported that the count of yarn and overlapping length are the crucial parameters which affects splice performance. Splicer parameters had been optimized in this study to produce better spliced yarn. It is also found by A. Das et al[2] that RSS increases first with the increase in air pressure and after certain level it deteriorates. Further, the optimization of splice performance had been done for different types of yarns like Ring Spun, Open End, Airjet etc. using Box-Behnken method[8]. Splicer parameter optimization through Taguchi method had been done by Webb C.J.et al[7]. It is known fact that untwisting and the 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 had been undergone a tensile testing. Therefore, the retwisting parameters had been studied in detail in this study. 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.

2. Experimental

2.1. <u>Materials and Method:</u>

Three different counts of Ring Spun Cotton yarns namely 20s, 40s and 60s Ne was chosen for this study to find out the effect of retwisting parameters namely retwisting time and overlapping length and air pressure on RSS. Three-factor three-level Box-Behnken response surface design[9] given in Table 1 was used. Actual values for the different levels of each factor along with coded values are given in Table 2. All the trial runs were randomized to minimize the error. 15 different combinations were used on each count to make it 45 different trials for three counts in total. 50 splice samples per trial had been prepared using a Testing Unit under laboratory condition. Splice samples 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	-	-	0
2	+	-	0
3	-	+	0
4	+	+	0
5	-	0	-
6	+	0	-
7	-	0	+
8	+	0	+
9	0	-	-
10	0	+	-
11	0	-	+
12	0	+	+
13	0	0	0
14	0	0	0
15	0	0	0

Table 2. Actual factor values along with coded values

Factors	Levels		
	-1	0	+1
Compressed Air Pressure (Bar)	5.5	6	6.5
Retwisting time (millisecond),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 maintained constant at an optimum value of 40 lpm and 450 ms respectively. Air pressure (in Bar) was measured and controlled with the help of a regulator fitted with gauge. The unit of measurement for untwisting and retwisting time is second. It has been found out using sound analyzer software by recording the valve opening sound and capturing the duration from wave form in the software. Figure 1 shows the time found from the air release sound wave form analyzing technique for one experiment(it is 200ms in this case). Untwisting airflow has been theoretically calculated since the other parameters like air pressure, orifice opening diameter and valve opening duration are known. The orifice opening area had been calculated with the help of CAD model. Overlapping length has been measured in scale without applying compressed air during splicing.

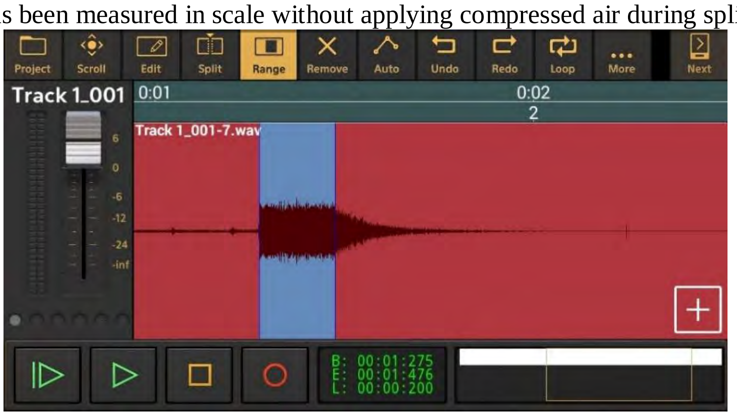

Figure 1. Valve opening time calculation by sound wave method

2.2. Testing and analysis:

Both the parent yarn and spliced yarn samples were tested 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) has been used to generate contour plots and to do the optimization analysis.

3. 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 influences 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.

Table 3. Results of retwisting study

Run Order	Standard Order	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

3.1. Effect of air pressure, time and overlapping length on RSS of 20s yarn:

Interactions between compressed air pressure, retwisting time and overlapping length on RSS for 20s Ne is given in figures 2(a)-2(c) as contour plots. Figures 2(a) shows that the maximum RSS of 78% is achieved in minimum compressed air pressure of 5.5Bar at retwisting time of 250ms. In figures 2(b) it is observed that maximum RSS of 80% is achieved an air pressure of 5.5 bar and with an overlapping length of 35mm.

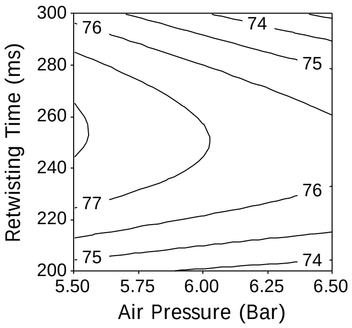

Figure 2(a)

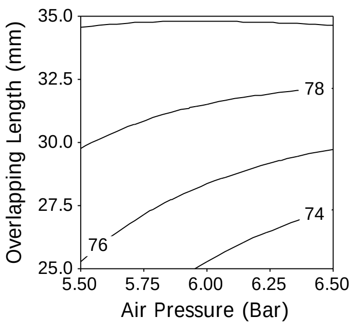

Figure 2(b)

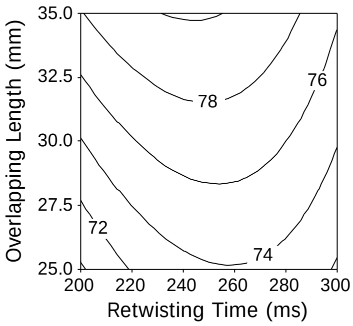

Figure 2(c)

Figure 2(a) Effect of splicing air pressure and twisting air flow on RSS of 20s yarn (overlapping length= 5)
Figure 2(b) Effect of splicing air pressure and overlapping length on RSS of 20s yarn (twisting airflow= 3.5)
Figure 2(c) Effect of twisting airflow and overlapping length on RSS of 20s yarn (splicing air pressure= 6Bar)

As shown in figures 2(a) and 2(c), optimum retwisting time gives maximum RSS. RSS is directly proportional to overlapping length in the experiment region which is clearly illustrated in figures 2(b) & 2(c). But longer the 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.

3.2. Effect of air pressure, time and overlapping length on RSS of 40s yarn:

Figures 3(a)-3(c) shows the interactions between 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 to 6 Bar) as shown in figure 3(a) and 3(b). But the requirement of retwisting time and overlapping length has come down when compared to 20s due to the fact that the 40s 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 figures 3(a)-3(c).

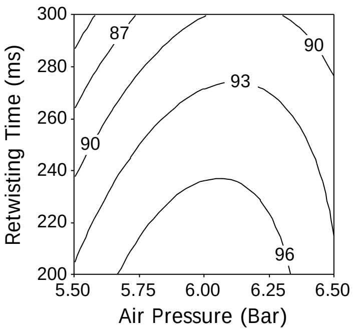

Figure 3(a)

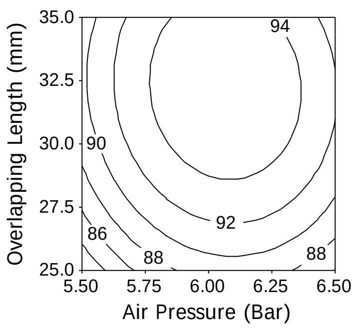

Figure 3(b)

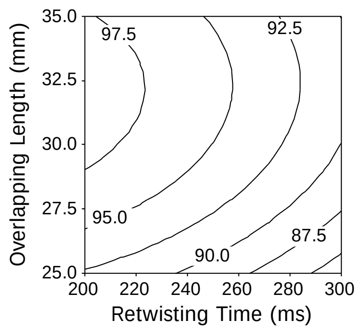

Figure 3(c)

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

3.3. Effect of air pressure, time and overlapping length on RSS of 60s yarn:

Contour Plots 4(a)-4(c) shows the relationship between the splicing air pressure, retwisting time and overlapping length of the 60s yarn on RSS. Same trend as found in 20s and 40s was observed in 60s Ne. The higher RSS greater than 90% had been obtained in lower splicing air pressure less than 5.75 Bar with the combination of higher retwisting time and lesser overlapping length. As shown in the figure 4(b), maximum RSS has been achieved with minimum overlapping length of 25mm. It has been noticed that the requirement of overlapping length got gradually reduced from 20s to 60s. At the same time, the RSS is found increasing with the increase in retwisting time as shown in the figures 4(a) & 4(c).

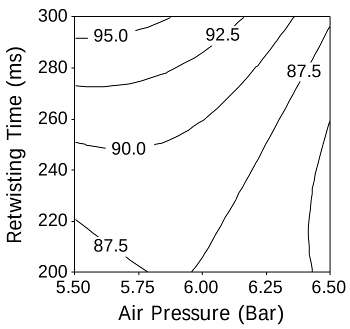

Figure 4(a)

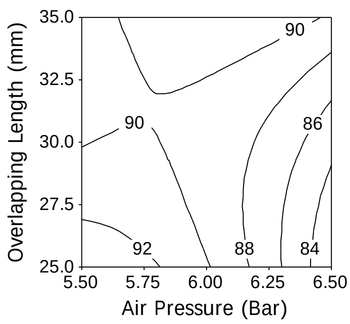

Figure 4(b)

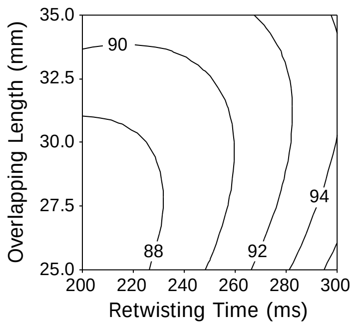

Figure 4(c)

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

3.4. Optimized solution

Optimized values for the studied parameters had been predicted using Minitab software and which are given below in Table 4. These are also called as Global Solution. It can be treated as a guide to set the pneumatic splicer for respective cotton yarn counts to obtain maximum splicing performance.

Table 4. Optimized values for the factors to achieve maximum RSS

Type of Yarn	Response Optimization Parameters			Optimized parameter values for maximum RSS%				
	Goal	Lower RSS%	Target RSS%	Air Pressure (Bar)	Retwisting Time (ms)	Overlapping Length (mm)	Maximum RSS%	Desirability
a) 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
b) 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

4. Conclusion

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 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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