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Influence of splicing parameters on retained splice strength, elongation and appearance of spliced cotton/flax blended yarn

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The present study aims at investigating the effect of different yarn splicing parameters on the strength, elongation and appearance of the spliced cotton/flax yarn of 74 tex linear density. Splice length, twisting time, yarn holding lever type, front plate type, untwisting pipe type and splicing nozzle profile have been taken as independent variables. A ½ fractional factorial experimental design is employed using two levels of each variable. The design and analysis of experiments are accomplished using MINITAB® software. The results indicate that the retained splice strength of yarn is mainly affected by the splicing nozzle profile. Retained splice elongation is mainly affected by the type of untwisting pipe while the appearance of the spliced yarn is mainly affected by the splicer lever type. Furthermore, due to significant interactions, an optimal combination of splicing variables is necessary for best retained spliced yarn strength, elongation and appearance.

Keywords: Blended yarn, Cotton/flax yarn, Retained splice elongation, Retained splice strength, Splice scanner

1 Introduction

In the yarn winding process, ring yarn bobbins are converted into yarn packages which are more practical in the subsequent processes of warping, weaving and knitting. This process not only ensures the continuity of the yarn by joining yarn ends together from the short-length bobbins but also results in clearing of several yarn faults. Manual knotting has been a traditional practice for joining yarn ends together, but it can seriously deteriorate the resultant yarn and fabric appearance. Pneumatic splicing is a modern approach to do the task, which, if appropriately accomplished, gives much better results in terms of the spliced yarn strength as well as appearance[1].

Pneumatic splicing is a relatively complex phenomenon as compared to manual knotting and is the most widely used technique for acceptable knot-free joint. Previous studies[2-3b] reveal that a splice consists of three distinct zones, viz. twisting, wrapping and tucking or intermingling. In a pneumatic splicing chamber, yarn ends to be spliced are overlapped, surplus yarn ends (as per specified splice length) are removed and a turbulent (Reynolds number up to 10^5) compressed air blast is released to perform the simultaneous splicing action. Due to process complexity, instability and lack of knowledge, the process outputs are often unpredictable.

A couple of studies have been reported on how splicing and yarn parameters affect the strength, abrasion, bending and appearance of the spliced cotton and polyester/cotton blended yarns[4a, 4b]. A statistical model has been developed to observe the effect of fibre friction, yarn twist and splicing air pressure on spliced cotton yarn performance[5]. Comparison of splicing performance of viscose staple fibre yarns made from ring, rotor, friction and air-jet spinning technologies has been reported[6] along with the splicing performance of synthetic filament yarns[7]. Some researchers have illustrated the effect of splicing parameters (splice length, duration of splice air blast and splice air pressure) on the tensile and structural characteristics of spliced yarn of different spinning technologies[8a, 8b]. They found that the difference in yarn structure, due to varied spinning technologies, and yarn splicing parameters influence the performance of splice.

Although the concept of pneumatic splicing is not new, there have so far been little published works available on the study of factors affecting the mechanical properties of spliced yarns, particularly no work has been reported on the cotton/flax blended yarns. The aim of this study is to investigate the effect of different splicing parameters on strength, elongation and appearance of the spliced cotton/flax blended yarns.

2 Materials and Methods

A cotton/flax blended yarn of 74 tex was prepared with 75 % cotton and 25 % flax fibres. Properties of

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cotton and flax fibres used for the preparation of yarn are given in Table 1. A scutcher lap weighing 496 g/m (16 oz/yd) was produced in the blow room of spinning mills by mixing 75 % cotton and 25 % flax fibres. The lap was processed on Howa CMK-3 card to produce sliver of 4.6 g/m (65 grains/yd). Carded sliver was further processed on Toyoda (DYH 500C) breaker draw frame and Reiter (RSB-1) finisher draw frame for making 0.844 ktex roving on Toyota (FL-16) speed frame. Yarn of 74 tex was produced from this roving on Toyota RY ring frame at a spindle speed of 9000 rpm. This yarn has the specifications 73.55 tex with 16.46 % mass variation, 5.0 thin places, 414 thick places, 447 neps, 9.88 % hairiness index, 1039.39 g single yarn strength and 6.18 % yarn elongation. A pneumatic splicer, Murata 21C Mach splicer, was used to splice the yarn ends. The untwisting and splicing pressure values were kept at 6.0 and 6.5 bar respectively. Splicing factors and their levels used in the experiments are given in Table 2.

A ½ fractional factorial experimental design was employed and each experiment was performed with three replications. Mesdan Splice Scanner-2 was used to test the breaking strength of parent and spliced yarn with a gauge length of 250 mm and traverse speed of 500 mm/min. Breaking strength of spliced yarn was measured in terms of retained splice strength (RSS %), which is a ratio of breaking strength of the spliced yarn to parent yarn expressed in percentage, as shown below:

$$\text{RSS\%} = \frac{\text{Breaking strength of spliced yarn}}{\text{Breaking strength of parent yarn}} \times 100$$

Breaking elongation of spliced yarn was also measured in terms of retained breaking elongation (RSE %), which is the ratio of breaking elongation of spliced yarn to the breaking elongation of the parent yarn expressed in percentage, as shown below:

$$\text{RSE\%} = \frac{\text{Breaking elongation of spliced yarn}}{\text{Breaking elongation of parent yarn}} \times 100$$

The visual appearance ratings of the spliced portion of yarn were averaged from the subjective ratings of each sample by ten skilled individuals on a scale[5], 1 – totally unacceptable, 2 – marginally acceptable, 3 – acceptable, 4 – good and 5 – identical to parent yarn. A brief description of splicing factors is given below.

Splice Length Control

The splice length is controlled by adjusting the position of a lever to get maximum strength and best appearance of splice. The adjustment can be done from position 1 to 8 on a scale. At position 1 the splice length will be longer and vice versa (Fig. 1). For coarse counts, shorter splice length and for fine counts longer splice length is mostly preferred.

Twisting Time

Twisting time is the duration of compressed air blast in seconds for splicing the yarn ends in the twisting/splicing nozzle. This time affects the splice shape, appearance and strength. For coarse counts, more twisting time is usually preferred while less time is preferred for fine counts.

Untwisting Pipe

The untwisting performance can be controlled by changing the type of untwisting pipe as well as the position of a particular untwisting pipe in untwisting nozzle. To obtain good splice shape and strength, untwisting performance must be at the optimum level. Insufficient untwisting of yarn ends to be spliced, will result in lower splice strength/elongation retention rates. Untwisting pipes with different diameter and length are available which are selected depending on twist level, count of yarn and fibre type. N0 and N2 type untwisting pipes are used in this study. N0 pipe is the standard

Table 1— Properties of cotton and flax fibres

Parameter	Cotton	Flax
2.5 % Span length, mm	27.05	27.96
50 % Span length, mm	13.23	10.41
Floating fibre, %	19.20	64.49
Uniformity ratio, %	49.10	37.25
Fineness, µg/inch	04.75	06.77
Strength, g/tex	41.84	51.04

Table 2— Splicing factors and their levels

Factors	Levels	
	-1	+1
Splice length control lever, position	1	3
Twisting time, s	0.12	0.2
Yarn holding lever, type	H	J1
Front plate, type	FB0	8FB1
Untwisting pipe, type	N0	N2
Splicing nozzle profile	G2Z	G8Z

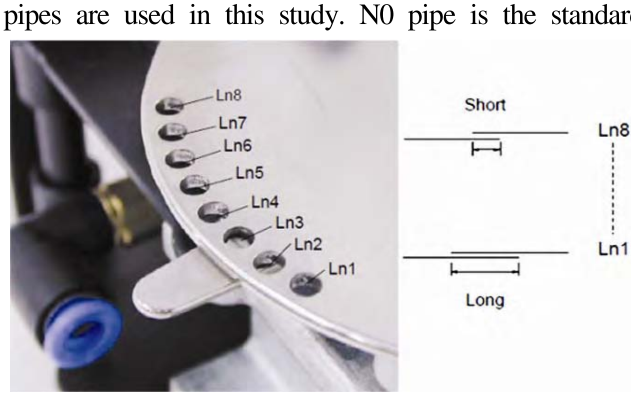

Fig. 1— Splice length control lever

untwisting pipe and can be used for coarse as well as fine counts. It has a length of 48mm and diameter of 6 mm. It is mainly used for untwisting short fibres. N2 pipe is used for untwisting coarse yarns and the yarns with more stiffness. It has a length of 30 mm and diameter of 6 mm.

Twisting Nozzle

Twisting nozzle, also known as splicing nozzle, is used to splice the untwisted yarn ends with the help of compressed air blast. Different nozzle types are available and a particular type of nozzle is selected depending on fibre type, fibre length, yarn count and direction of twist. G2Z and G8Z type twisting nozzles are selected in this study. G2Z nozzle can be used for all counts ranging from 6 tex to 84 tex. It has 1.4 mm diameter of splicing/twisting chamber. G8Z nozzle is mostly preferred for coarse counts ranging from 60 tex to 120 tex. The twisting chamber of that nozzle has a diameter of 1.3 mm.

Front Plate

It is a plate on which the twisting nozzle is mounted in the splicing unit. It is used for proper guidance of untwisted yarn ends into the twisting nozzle. It has two profiles at upper and lower sides which are slightly offset relative to each other for proper guidance of yarn ends and holes for entry of yarn ends into untwisting pipes.

Yarn Holding Lever

It holds the yarn ends after untwisting and keeps them in place during twisting in the twisting nozzle. It has two arms for holding the upper and lower yarn ends during twisting/splicing. Different types of yarn holding lever are available. H and J1 type levers are used in this study.

3 Results and Discussion

3.1 Effect of Yarn Splicing Parameters on Retained Splice Strength

Average values of RSS % at different splicing parameters are given in Table 3. The results are analyzed by using MINITAB®- 16 software. The effect of splicing nozzle and the interaction between the holding lever and the front plate is found to be statistically significant with 95 % confidence

Table 3— Effect of yarn splicing parameters on retained splice strength and appearance

Splice length control lever (Ln)	Twisting time s	Yarn holding lever	Front plate	Un-twisting pipe	Splicing nozzle	Mean RSS %	Mean RSE %	Appearance rating
1	0.12	H	8FB1	N2	G8Z	90.7	92.6	5
3	0.12	H	8FB1	N2	G2Z	88.1	86.7	1
1	0.2	H	8FB1	N2	G2Z	62.2	77.3	5
3	0.2	H	8FB1	N2	G8Z	91.2	88.4	4
1	0.12	J1	8FB1	N2	G2Z	62.1	78.9	4
3	0.12	J1	8FB1	N2	G8Z	63.4	72.6	1
1	0.2	J1	8FB1	N2	G8Z	81.5	85.5	4
3	0.2	J1	8FB1	N2	G2Z	70.4	76.0	1
1	0.12	H	FB0	N2	G2Z	72.3	87.5	4
3	0.12	H	FB0	N2	G8Z	72.6	88.4	2
1	0.2	H	FB0	N2	G8Z	58.1	76.4	2
3	0.2	H	FB0	N2	G2Z	78.6	92.1	5
1	0.12	J1	FB0	N2	G8Z	90.1	93.3	4
3	0.12	J1	FB0	N2	G2Z	83.8	79.8	1
1	0.2	J1	FB0	N2	G2Z	82.4	86.8	4
3	0.2	J1	FB0	N2	G8Z	89.2	90.9	3
1	0.12	H	8FB1	N0	G2Z	90.0	117.0	5
3	0.12	H	8FB1	N0	G8Z	85.1	100.3	4
1	0.2	H	8FB1	N0	G8Z	88.5	89.5	3
3	0.2	H	8FB1	N0	G2Z	87.2	105.7	4
1	0.12	J1	8FB1	N0	G8Z	78.4	82.3	3
3	0.12	J1	8FB1	N0	G2Z	68.9	81.1	1
1	0.2	J1	8FB1	N0	G2Z	67.5	86.8	1
3	0.2	J1	8FB1	N0	G8Z	81.1	89.8	2
1	0.12	H	FB0	N0	G8Z	63.9	90.4	4
3	0.12	H	FB0	N0	G2Z	60.6	81.3	3
1	0.2	H	FB0	N0	G2Z	49.2	76.7	1
3	0.2	H	FB0	N0	G8Z	68.9	85.3	1
1	0.12	J1	FB0	N0	G2Z	69.1	103.8	1
3	0.12	J1	FB0	N0	G8Z	91.6	86.9	1
1	0.2	J1	FB0	N0	G8Z	98.0	101.6	1
3	0.2	J1	FB0	N0	G2Z	78.6	89.8	3

(p-values 0.018 and 0.000 respectively), while the interactions, such as twisting time×holding lever and front plate×untwisting pipe are found to be statistically significant at 90 % confidence level (p-values 0. 091 and 0.079 respectively). The main effect plot given in Fig. 2 depicts the effect of each splicing variable on the retained splice strength (RSS %). It is clear that the effect of twisting time and type of untwisting pipe is not significant on the retained splice strength. RSS % is better for G8Z nozzle, J1 lever, 8FB1 plate and setting of splice length control lever at position 3. This can be explained by comparatively larger twisting chamber of G8Z nozzle (favorable for coarser counts) than G2Z nozzle, proper guidance of J1lever in combination with 8FB1 plate and suitable splice length at Ln3 position for this particular yarn count. The probable reason for this may be good fibre entanglement in the splice portion and compact splices which results in better RSS%. The interaction plot given in Fig. 3(a) shows that the plate 8FB1 gives better RSS % with H lever, while the plate FB0 gives better RSS % with J1 lever. Similarly, according to Fig. 3(b), lever J1 results in better RSS% when twisting time is 0.2 seconds while lever H gives higher RSS% when the twisting time is 0.12s. Furthermore, as given in Fig. 3(c), RSS% is better when plate 8FB1 is used along with N0 untwisting pipe and plate FB0 is used along with N2 untwisting pipe. This is possibly due to well suitability of combined interaction of these factors for proper guidance of yarn ends during untwisting and twisting process, thus resulting in a better intermingling and compact packing of fibres during splicing.

3.2 Effect of Yarn Splicing Parameters on Retained Splice Elongation

Average values of RSE % at different yarn splicing parameters are given in Table 3. These results are

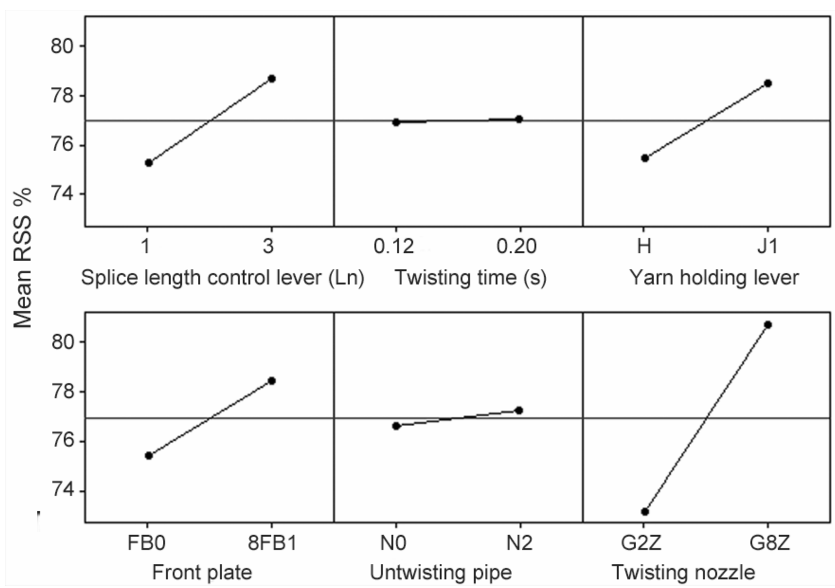

Fig. 2— Effect of different splicing parameters on retained splice strength (RSS %)

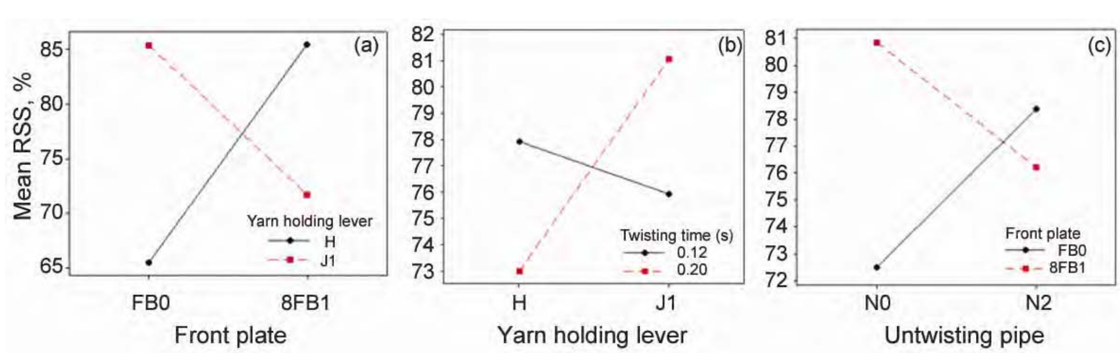

Fig. 3— Effect of (a) front plate and lever type, (b) lever type and twisting time and (c) front plate type and untwisting pipe on RSS %

analyzed through MINITAB®-16 software. The effect of untwisting pipe is found to be statistically significant at 95 % confidence level (p-value 0.016). Figure 4 gives the main effect plot of different splicing parameters. It is clear from the figure that the type of untwisting pipe has significant effect on RSE %, while the effect of other splicing parameters is not significant. This is perhaps due to proper untwisting of yarn ends before splicing and proper intermingling of fibres during twisting, thus increasing the packing density of yarn at spliced portion which results in more RSE %. Interactions of splice length control lever setting with twisting time and yarn holding lever with front plate are also found to be statistically significant at 95 % confidence level (p-value 0.024 and 0.003 respectively).

The effect of splice length control lever setting and twisting time is given in Fig. 5(a). It is clear that RSE% is better if less twisting time is used for longer splice length and more twisting time is used for shorter splice length. This may be due to the fact that at shorter splice length, the fibre overlap is slightly insufficient but longer twisting time results in better fibre consolidation. However, at longer splice length and shorter twisting time, the proper binding of fibres takes place, resulting in higher RSE %.

Figure 5(b) gives the effect of type of yarn holding lever and front plate on yarn RSE %. It is evident that RSE % is better when H lever is used in combination with 8FB1 plate and J1 lever is used in combination with FB0 plate. This may be due to combined interaction of these factors which resulted in better intermingling of fibres.

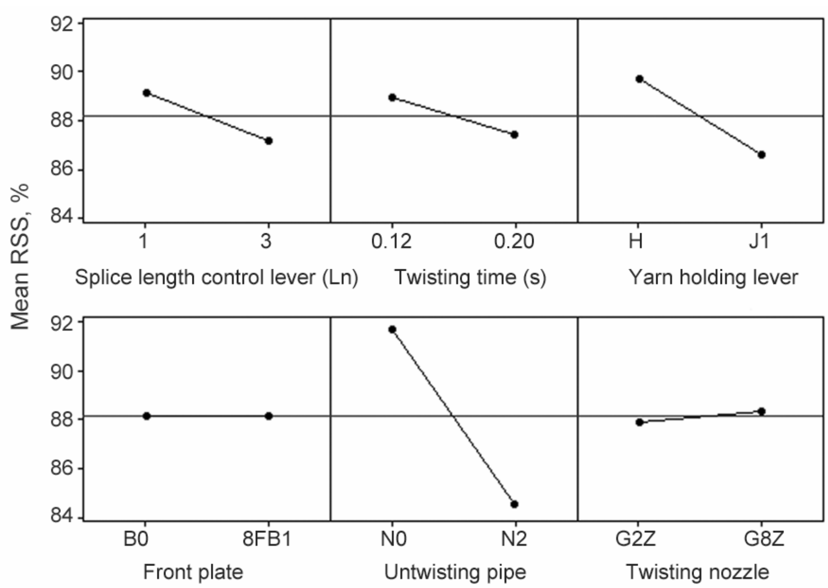

Fig. 4— Effect of different splicing parameters on retained splice elongation (RSE %)

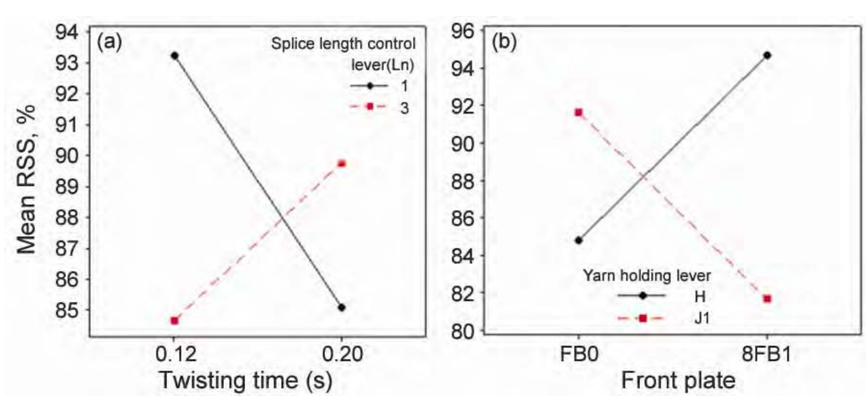

Fig. 5— Effect of (a) splice length and twisting time, and (b) yarn holding lever type and front plate on RSE %

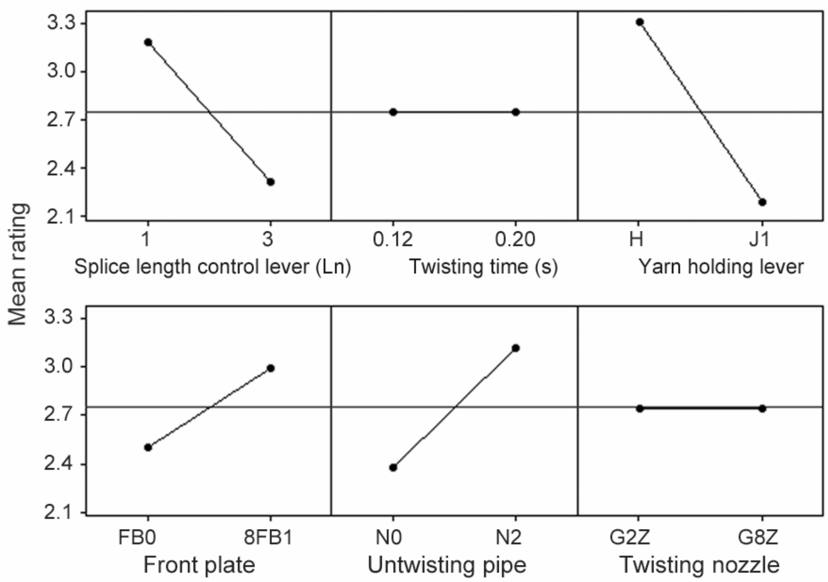

Fig. 6— Effect of different splicing parameters on appearance rating of the spliced yarn

3.3 Effect of Yarn Splicing Parameters on Appearance of Spliced Yarn

Average results of spliced yarn appearance at different yarn splicing parameters are given in Table 3. Statistical analysis shows that setting of splice length control lever and yarn holding lever type have significant effect (p-value 0.035 and 0.010 respectively) on the appearance of spliced yarn with 95 % confidence, while untwisting pipe type has statistically significant effect (p-value 0.063) at 90 % confidence level. Moreover, significant interactions are found between setting of splice length control lever and twisting time (p-value 0.010), setting of splice length control lever and untwisting pipe type (p-value 0.035). Main effects plot given in Fig. 6 depicts that the appearance of the spliced yarn is better for position 1 of control lever and holding lever H. At position 1 of length control lever, splice is longer than at other positions. So, better appearance of splice is achieved at longer splice when H-type yarn holding lever is used. These findings may be attributed to decrease in splice diameter and good wrapping of fibres, which results in compact structure of splice.

Twisting time, splicing nozzle, front plate and untwisting pipe do not appear to have any significant effect. Figure 7 depicts the effect of control lever and twisting time on the spliced yarn appearance. It is clear that the appearance is better when shorter twisting time is used for position 1 of control lever and longer twisting time is used for position 3 of control lever. This may be due to the fact that lower twisting time with long overlapped yarn ends and more twisting time with shorter overlapped yarn ends give good entanglement of fibres during splicing and compact structure, resulting in better splice appearance.

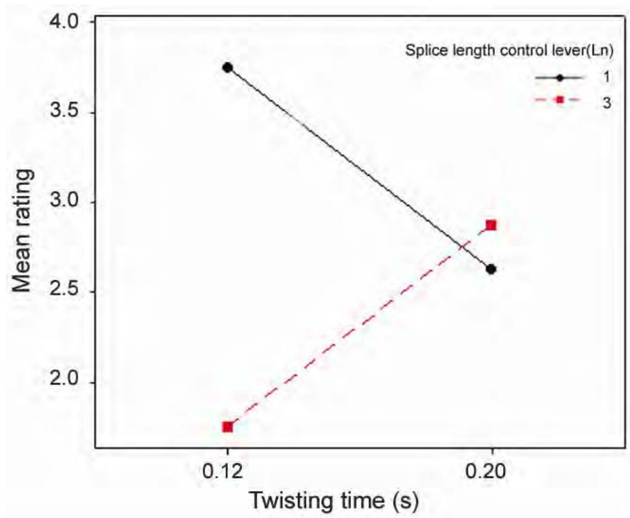

Fig. 7— Effect of splice length and twisting time on splice appearance

4 Conclusion

Different splicing parameters affect the characteristics of spliced portion of yarn in different manner. Retained splice strength (RSS %) of yarn is mainly affected by the splicer nozzle type. Retained splice elongation (RSE %) is mainly affected by the type of untwisting pipe while the appearance of the spliced yarn is mainly affected by the splicer lever type. The 8FB1 plate has better compatibility with H lever and N0 untwisting pipe, while FB0 plate has better compatibility with J1 lever and N2 untwisting pipe for achieving better RSS % and RSE %. The combination of J1 lever with more twisting time and H lever with less twisting time give better RSS %. Similarly, the combination of less twisting time with shorter splice length and more twisting time with longer splice length give better RSE %. Furthermore, the appearance of spliced portion of yarn is better if shorter twisting time is used for Ln1 position of control lever and longer twisting time is used for Ln3 position of control lever.

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