Strength of cotton dual-core elastane yarn splice

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ABSTRACT – REZUMAT

Strength of cotton dual-core elastane yarn splice

Cotton/elastane yarns are composite yarns composed of a blend of elastane core covered with cotton fibres. An increase in the demand for sports and leisure garments with high comfort and elasticity has led to more significant usage of elastane filaments. New yarn using two elastane filaments with a high ratio of elastane are introduced.
An experimental study was established to define the most appropriate parameters for spliced cotton dual-core elastane yarn strength. The splice strength was enhanced when binding air pressure, joining air duration, and preparation duration were raised. Increased preparation air pressure does not affect the strength of the splice.

Keywords: *splice strength, dual-core elastane yarn, splicing conditions, experimental design*

Rezistența îmbinării firului de elastan cu miez dublu acoperit cu bumbac

Firele din bumbac/elastan sunt fire compozite compuse dintr-un amestec de miez de elastan acoperit cu fibre de bumbac. O creștere a cererii de articole de îmbrăcăminte sport și pentru agrement cu confort și elasticitate ridicate a condus la o utilizare mai intensă a filamentelor de elastan. Recent, au fost introduse fire noi care utilizează două filamente de elastan cu un raport ridicat de elastan.
A fost stabilit un studiu experimental pentru a defini cei mai adecvați parametri pentru rezistența firului din elastan cu miez dublu îmbinat cu bumbac. Rezistența îmbinării a fost îmbunătățită atunci când presiunea aerului de legare, durata aplicării aerului de legare și durata pregătirii au crescut. Creșterea presiunii aerului de preparare nu a afectat rezistența îmbinării.

Cuvinte-cheie: *rezistența îmbinării, fire din elastan cu miez dublu, condiții de îmbinare, design experimental*

INTRODUCTION

Cotton/elastane yarns are composite yarns composed of a blend of elastane core covered with cotton fibres. An increase in the demand for sports and leisure garments with high comfort and elasticity has led to greater use of elastane filaments [1, 2].

Recently New yarn using two elastane filaments with a high ratio of elastane are introduced. Winding aims to obtain a large package and eliminate undesirable faults.

Splicing is the most used method to joint yarn together. Different splicing methods, pneumatic, mechanical, and electrostatic, were developed [3].

Most of the research papers conducted in splicing concentrated on pneumatic splicing. The principle of pneumatic splicing consists of untwisting and later retwisting two yarn ends using an air blast. First, the yarn is opened, then fibres are intermingled and finally twisted in the same direction as that of the parent yarn.

The most important parameter that characterizes pneumatic splicing is appearance and mechanical properties.

Retained Splice Strength RSS is the most relevant factor in evaluating the splice's mechanical properties. RSS is expressed by dividing the strength of the spliced yarn by the strength of the parent Yarn [4]:

$$RSS\ (\%)\ 100 \times \frac{SYS}{PYS} \qquad (1)$$

where *SYS* is the Strength of Spliced Yarn and *PYS* is the Strength of Parent Yarn.

A value of *RSS* more than 80% is considered acceptable properties [5–10].

Retained Splice Elongation *RSE* is expressed by dividing the elongation of the spliced yarn by the elongation of the parent Yarn.

Except for wool yarns, it was found that a good relationship exists between *RSS* and *RSE* [9]. This means that analysing one property is sufficient to evaluate the mechanical properties of the splice. There is a lack of research in the field of splicing. The reason is that the structure of the splice is very complex and that the velocity of the winding machine is essential (more than 1500 m/min).

Some numerical models were proposed for the analysis of the splice device (parameters and geometry) and the splice morphology (case of multi-filament yarns) where the splice operation is realized using different simulations software [11].

The experimental study was conducted to study the effect of yarn characteristics and splicing parameters on *RSS* and the appearance of the splice [12].

Most of the studies mentioned above have been elaborated on classical yarns, and some research concerns elastic yarns.
The primary purpose of this work is to optimize the splice parameters of cotton dual-core yarn with a high ratio of elastane. Taguchi's experimental design was investigated to analyse the effect of splicing process parameters on the strength of the splice of the obtained yarn.
The elastomeric yarn utilized in our study is a cotton/elastane denim yarn with 42 tex linear density and an elastane percentage of 24%.
The splices were equipped on the Autoconer Schlafhorst splicer X5 (Prism LC5), employing a direct blast of compressed air.
The assortments of the regulation points are organized according to a fractional set (six parameters, each one with two levels of values, integrated into 12 configurations).
We varied six regulation points for adapting the splicing conditions, two for "end preparation air volume" (Preparation pressure Pp and Preparation duration Pd) and four for "joining yarn ends" (Joining air pressure Jap, joining air duration 1 Jad1 (first impulsion), joining air duration 2 Jad2 (second impulsion) and joining air duration 3 Jad3 (third impulsion).
The response measured is the strength of the splice expressed by the Retained Splice Strength RSS (%)

MATERIALS AND METHODS

In our investigations, we utilized a cotton/elastane denim yarn with 42 tex linear density and an elastane percentage of 24% (for the two filaments, 5% for the first one E1 (Lycra ®) and 19% for the second one E2 (T400®). The elastomeric yarns were assembled according to the double core-spinning method (figure 1), introducing two extended elastane filament cores to the front drafting roller of a spinning frame where it infiltrates with staple fibres resulting in a core-spun yarn. The elastane exploited is constructed by Dupont. Moreover, the elastane counts are 78 dtex for E1 and 83 dtex for E2.

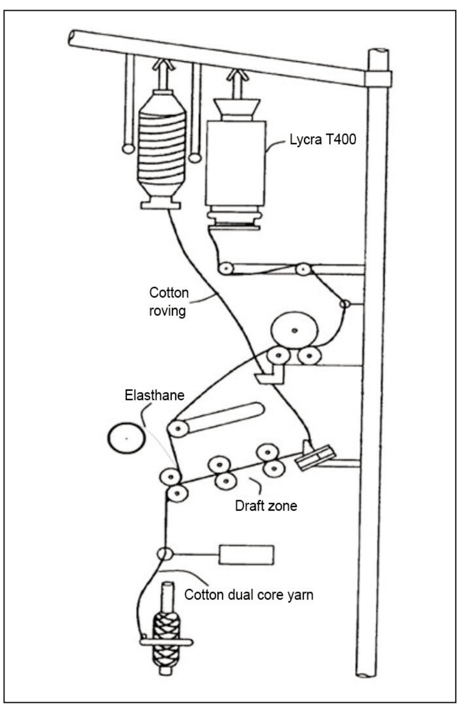

Fig. 1. The principle of the dual-core spinning method

The splices were trained on the Autoconer Schlafhorst splicer X5 (Prism LC5), utilizing a direct blast of compressed air. For The Schlafhorst splicer (figure 2), we varied six regulation points for altering the splicing conditions, two for "end preparation air volume" (Preparation pressure **Pp** and Preparation duration **Pd**) and four for "joining yarn ends" (Joining air pressure **Jap**, joining air duration 1 **Jad1** (first impulsion), joining air duration 2 **Jad2** (second impulsion) and joining air duration 3 **Jad3** (third impulsion). The assortments of the regulation points are placed according to a fractional set (six parameters, each one with two levels of values, integrated in 12 configurations). The factors and levels employed in the orthogonal analysis are displayed in table 1.

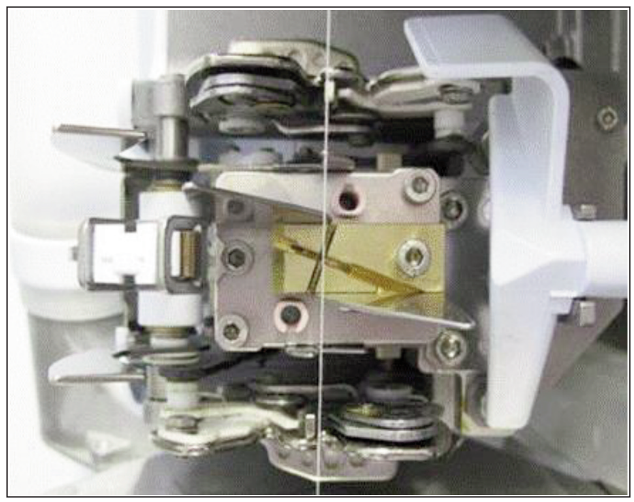

Fig. 2. The Schlafhort pneumatic splicer

Table 1

PARAMETER VALUES		
Parameters	**Low level 1**	**High level 2**
Preparation pressure Pp	4 bars	5 bars
Preparation duration Pd	400 ms	500 ms
Joining air pressure Jap	5 bars	6 bars
Joining air duration Jad1	60 ms	100 ms
Joining air duration Jad2	60 ms	100 ms
Joining air duration Jad 3	60 ms	100 ms

RESULTS AND DISCUSSIONS

The breaking strength is described in terms of Retained Spliced Strength (**RSS**). The RSS is the strength of the spliced yarn represented as the percentage of the parent yarn in which the splice is inserted.

The breaking strength of the splice yarn RSS was tested on the LLOYD tensile tester, and sample sizes for the core spun yarns were 40 ends. Results are resumed in table 2.

Table 2

RESULTS OF EXPERIMENTS						
Pp	**Pd**	**Jap**	**Jad1**	**Jad2**	**Jad3**	**RSS**
1	1	1	2	2	2	25.18
2	2	1	2	2	1	39.72
2	2	1	2	1	1	47.70
2	1	2	1	2	1	40.66
1	2	2	2	1	2	72.25
1	2	1	1	2	2	61.30
2	1	1	1	1	2	44.88
1	2	2	1	1	1	47.34
2	1	2	2	1	2	71.00
1	1	1	1	1	1	40.50
1	1	2	2	2	1	64.43
2	2	2	1	2	2	60.83

The analysis of variance is resumed in table 3, we accept the Hypothesis H_0 if Pvalue is less than 0.05. H_0: the factor has an effective influence on the response with a probability P.

The main effect plots for means are given in figure 3. To check the adequacy of our model, we check the normality assumption.

Table 3

ANALYSIS OF VARIANCE			
Factor	**DF**	**F**	**P**
Pp	1	1.555	0.213
Pd	1	72.787	<0.001
Jap	1	381.132	<0.001
Jad1	1	24.731	<0.001
Jad2	1	40.131	<0.001
Jad3	1	122.351	<0.001

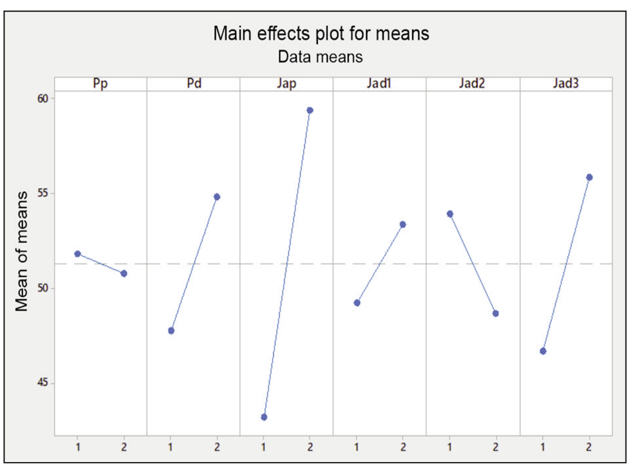

Fig. 3. Main effect plots for means

Figure 4, illustrates the normal probability plot of residuals (error between estimated value and measured values)

The figure shows that this plot will resemble a straight line. This confirms the hypothesis that error distribution is normal.

According to practical design techniques, the effects of the parameters were computed. Results are shown in table 4 where the impact of a parameter – for example, the value of preparation pressure Pp – on the breaking strength of the splice, – such as RSS is calculated as:

$$\overline{RSS}_{HIGH\,Pp} - \overline{RSS}_{total} = 0.5 \cdot (\overline{RSS}_{HIGH\,Pp} - \overline{RSS}_{LOW\,Pp}) \quad (2)$$

Regarding table 3, it is evident that the Joining air pressure **Jap**, the Join air duration 3 **Jad3**, and the Preparation duration **Pd** influence the mechanical splice properties. Figure 5 illustrates the **RSS** variations in terms of $\overline{\boldsymbol{RSS}}_{\boldsymbol{HIGH}}$ and $\overline{\boldsymbol{RSS}}_{\boldsymbol{LOW}}$.

Table 4

PARAMETER EFFECTS						
Parameter	**Pp**	**Pd**	**Jap**	**Jad1**	**Jad2**	**Jad3**
RSS	–1	**7.08**	**16.2**	4.13	–5.26	**9.18**

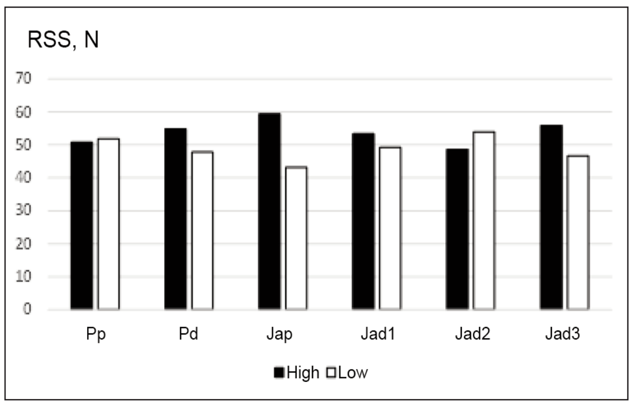

Fig. 5. RSS variation

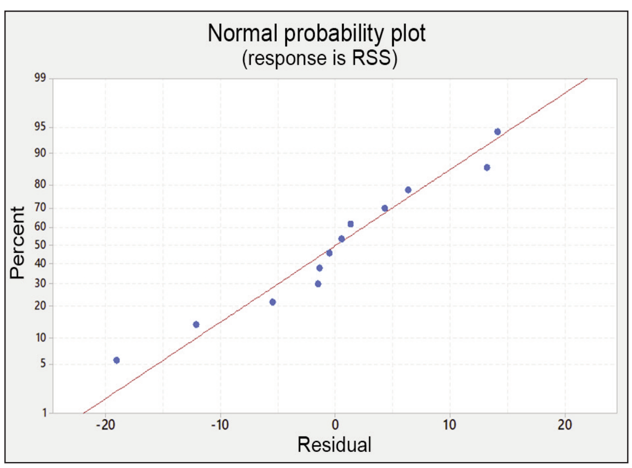

Fig. 4. Normal probability plot of residuals

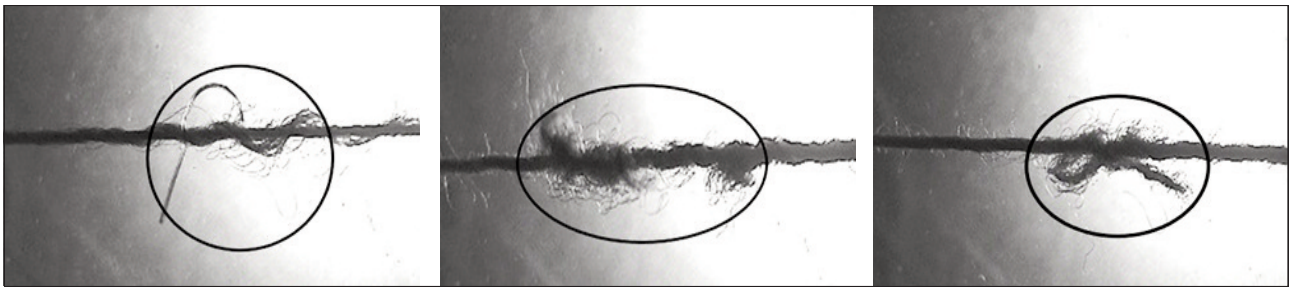

Fig. 6. Appearance of dual-core elastane yarn splice (low RSS)

The results demonstrate that the increase in the join air pressure of 20% (from 5 to 6 bars) leads to a rise in RSS of about 37%. On the other hand, the variation of preparation pressure from 4 to 5 bars does not affect the splice strength.

This result is different from that found by Ben Hassen for a splice of elastomeric yarn with a low amount of elastane. It was found that the effect of preparation pressure is equivalent to that of joining pressure [13]. The principle of pneumatic splicing consists of untwisting and later retwisting two yarn ends using an air blast. A pressure of 4 bars seems sufficient to untwist the two core-spun yarns to be joined together. An increase in this preparation pressure has no other positive effect on yarns' tail opening. We can then adjust the preparation pressure on a fixed value. On the other hand, the phenomena are more complex for the retwisting part.

Das [14] and Webb [15] demonstrated a minimum pressure P0 needed to force the intermingling of both yarns together to obtain the splice. Increasing splicing air pressure enhances the torque, which causes more intermingling and binding of fibres in the overlapped region until a specific limit. In our case, 6 bars do not exceed the limit and are more adequate to adjust for the core-spun yarns.

According to figure 6, when we change the joining air preparation from 400 to 500 ms, the RSS of the splice increases by about 15%. The RSS rise more than 18% when a total join air duration of 300 ms is adjusted in comparison to an initial value of 180 ms (possibility to add effects on the orthogonal design of experiment tables). These results agree with numerical models proposed for the analysis of the splice device using different simulation software which demonstrated that the quality of the yarn preparation will be affected by the speed and pressure of the compressed air, the volume and the length of the air injection time. Also improving of the duration of joining implicates an expansion of the aerodynamic acting forces and guides to further twisting and intermingling of the yarn ends.

Table 2 shows that the maximum RSS obtained is 72% (experiment 5). In practice, a value of RSS of more than 80% is considered an acceptable property. For pneumatically wet spliced cotton/elastane yarns with a low ratio of elastane (5%), Ben Hassen proved that in optimal conditions, an RSS of 90% can be obtained [13, 16, 17]. The design of the chamber used to produce our splice seems to be not adapted to the new double-covered yarn with a high level of elastane ratio.

The difference in structure between classic can also explain the difference in results, elastic yarn with a low rate of elastane and yarns with double-covered yarn with a high rate of elastane (our case). To illustrate this phenomenon, several images were taken to show the dual-core elastic yarns' appearance for some combinations with low RSS.

Kaushik [18, 19] proved that the splice portion is composed of two zones, splicing zone Z1 and transition zone Z2; he demonstrated that most breaks occur in Z1. In our case of low RSS (figure 6), we remark that the splicing zone is irregular, and the joining between the two yarn ends is not effectively done. This phenomenon causes a stress concentration and consequently breaking in the splicing zone

With a high rate of elastane, fibres-elastane cohesion will be reduced. This increases the migration of the elastane filament during splicing outside the yarn and minimizes the chance that elastane will be placed at the centre of the yarn after the joining operation.

CONCLUSIONS

The paper presents an experimental study of the mechanical properties of a dual-core elastane yarn splice. Results show that joining parameters have more effect than preparation parameters. In particular, the mechanical properties of the splice are susceptible to the variation of the joining pressure. The results demonstrated that the increase in the join air pressure of 20% (from 5 to 6 bars) leads to an increase of RSS of about 37%. The rise in splicing air pressure increases the torque, which causes more intermingling and binding of fibres in the overlapped region. According to our study, the maximum RSS obtained is 72%, less important than the value obtained in literature for classical and elastic yarn with a low elastane ratio. The difference in structure between yarns can explain the difference in results, elastic yarn with a low rate of elastane and yarns with double-covered yarn with a high rate of elastane (our case). More efforts should be made by the manufacturer of the splicing device to design a chamber adequate for new complex yarn structures such as dual-core spun yarn with a high ratio of elastane. Further research can also be continued to study the appearance of the splice of this new yarn.

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