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Sizing Effect on Wet-Pneumatic Spliced Denim Yarn Performance

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Abstract
In this study, the mechanical behaviour of parent as well as wet spliced cotton denim yarns were compared before and after sizing in order to evaluate the sizing contribution and to predict the effectiveness of sized splices during weaving. The sizes used were natural (CarboxyMethylCellulose size) and synthetic (Acrylic size).It is found that splicing improves the breaking strength of both parent and spliced yarns, while sizing improves the elongation at break of only wet pneumatic spliced yarns. The same results were obtained under cyclical tensioning.

Key words: *wet pneumatic splicing, sizing, breaking strength, elongation at break, cyclical tensioning, denim yarn.*

Introduction

The wet pneumatic splicing of warp and weft yarns is a recent technique based on the addition of water at the moment of the junction to improve splice resistance and appearance. Both ends of yarns were overlapped and held in a suitably shaped chamber: a prism. A turbulent blast of air was used to intermesh and entangle both fibres and water.

Spliced yarn mechanical properties such as breaking strength, elongation at break and the cyclical tensioning lifetime are the most important parameters influencing not only spliced yarn appearance and performance of the end-product but also the cost of the yarn-to-fabric process.

In the last thirty years, studies have been carried out by Cheng [1] and Kaushik [2 - 4] in order to analyse the effect of parent yarn structure and splicer parameters on the appearance and mechanical properties of the pneumatic splice. Kaushik [2] studied the performances of splices during warping and weaving. Recently, in our earlier study [5] we proposed to optimise the properties of wet pneumatic splicing using statistical and experimental design methods.

During weaving, both spliced and parent yarns need high mechanical performance in order to decrease the rate of break, which is why warp yarns are protected from destruction and their mechanical properties improved by sizing before the weaving process, as defined by Exbrayat [6] and Sherilyn [7].

As splice is the weakest zone in the yarn, it will be interesting to examine the effect of sizing on the mechanical properties of both parent and spliced yarns.

In this paper, the mechanical behaviour of both parent and wet spliced denim yarns were compared before and after sizing using natural and synthetic sizes.

Materials and methods

Splicing and sizing conditions

Three cotton denim yarns were used in the experiment, as shown in ***Table 1***. A pneumatic splicer, a Shlafhorst Autoconer 338 (***Figure 1,*** see page 130), produced all the spliced yarn joints in optimal conditions according to the results of our earlier work [5]. The size formulations used in this investigation are shown in ***Table 3***. ***Table 2*** presents the factors and levels used in the orthogonal analysis.

Before sizing, the breaking strength, elongation at break and cyclical tensioning (repetitive stresses applied to the specimen during the cycles) of the splices were tested. Wet pneumatic splice samples were sized in the form of leas at a speed of 1.41 m/min on sizing laboratory apparatus, a standard scarf Mathis (***Figure 2***), under constant conditions, simulating a sizing machine.

Directly before entering the size box, a thermostat built into the box, controlling the temperature of the sizing bath, and the squeezing pressure rollers are regulated to 90 °C and 0.4 MPa, respectively, in order to correspond in terms of the industrial sizing process, as affirmed by Kovacevic [8]. The box was equipped with an immersing roller and a pair of squeezing rollers with possible regulation of the squeezing pressure.

Table 1. *Yarn parameters.*

Tex	t.p.m.
29.4	746
64.7	503
100.0	404

Table 2. *Levels of input parameters.*

Levels	Yarn count Y_C, tex	Size recipe
1	29.4	Natural
2	64.7	Synthetic
3	100	-

It was important to maintain the size at a relatively constant temperature so that the viscosity and, hence, the degree of penetration would remain uniform over the length of the treated yarn, as recommended by Sherilyn [9].

The splices were dried in a heating chamber, with the stream of air adjusted to 100 °C for 10 minutes, and then wound on a reel. The samples were impregnated in a sizing bath after separating them by means of a comb. All the samples were equally exposed to the same sizing conditions.

Test conditions

After sizing, the breaking strength, elongation at break and cyclical tensioning of the wet pneumatic spliced yarns were tested. The maximum yarn breaking load was established using a Lloyd universal tensile tester. We tested 50 specimens, and the mean value was calculated.

Table 3. *Agents used for preparing the two sizes;* T^*_{break} *- time of break to cook size;* $R^*_{1\ size\ cover}$ *and* $R^*_{2\ size\ covers}$ *- refraction percentages for one size and two size covers;* V^*_{final} *- final volume.*

Natural size - Carboxymethylcellulose			Synthetic size - Acrylic		
Components	**Quantity**	**Condition of use**	**Components**	**Quantity**	**Condition of use**
Water	7.01 dcm^3	θ = 93 °C	Water	8.04 dcm^3	θ = 93 °C
Ethylex	670 g	T^*_{break} = 10 s	Ethylex	1.03 kg	T^*_{break} = 10 s
Native starch	154.6 g	-	Native starch	0 g	-
Fibrosint M77	103 g	$R^*_{1\ size\ cover}$ = 12.9%	Fibrosint M77	206.18 g	$R^*_{1\ size\ cover}$ = 12.9%
Molvenin CG 70V		$R^*_{2\ size\ cover}$ = 11.5%	Molvenin CG70V		$R^*_{2\ size\ cover}$ = 11.5%
Avirol GPW	92.78 g	T^*_{break} = 10 dcm^3	Avirol NW 81	61.85 g	T^*_{break} = 10 dcm^3
Urea	77.31 g		Urea		

The length of the specimens was 100 mm, as recommended by Cheng and Lam [1], and Kaushik [3, 4]. The average test speed was regulated according to the duration of the test, which was 20 ± 3 seconds, according to the standard norm: NFG 07-003 [9]. This French standard (December 1971) is a textile standard detailing tests on individual yarns, reviewed since 31 December 1987 and published since 1988, and presents a method of determining the breaking load and extension at break of a yarn.

The specimen is subjected to traction until rupture by means of a suitable testing device (dynamometer) which indicates the tensile properties (breaking strength and elongation at break) within 20 ± 3 second. The machine, at a constant speed of the displacement of the grip, contains a pair of grips to hold the yarn by each of its ends. After breaking, the most important yarn tensile characteristics are saved.

The preliminary tension of the test yarn was 0.5 cN/tex [9]. The spliced and original test yarns after sizing were wound manually, and the method of testing was identical to that of spliced and parent yarns before sizing.

Spliced yarn tensile fatigue is important for the determination of spliced yarn quality before and after weaving, according to the study results of Friedman [10]. By testing cyclical tensioning resistance, the sizing effect can be found, and the quality and uniformity of sizing can be tested. We would like to note that, in general, sized samples of parent and spliced denim yarns are woven using a Sülzer HP 7200 projectile loom (as in our case). The speed of the repeated cyclical tensioning of a Sülzer loom is about 400 cycles/min, representing the upper limit which could be used on our laboratory apparatus. To simulate the progressive degradation of spliced and parent yarns in the reality of dynamic tests during weaving on a projectile loom machine, we used the level of cyclical tensioning given above as the highest speed in our experiments. As our laboratory apparatus had been designed for traditional materials, mechanically it cannot simulate a higher number without risking damage to it. There is no doubt that for defects (weakest zones as splices, irregularity zone in yarns as thickness, etc...) a few hundred cycles can be sufficient to cause breakage. The testing of yarn fatigue was carried out on a Lloyd dynamometer tester. The specimens were mounted and fixed at their initial length (100 mm), and we randomly imposed an elongation at break of 60% to 80% [11]. The breaking strength after the imposed cycles was registered. Cyclical tensioning was carried out by cyclic stresses and variable forces arising at shedding, leading to cumulative damage forces during the weaving process. The test speed on the Lloyd tensile tester was 100 mm/min. The Lloyd tensile tester speed needed to be regulated after trying ten specimens of each combination of our experimental design. As mentioned previously, the regulation of the tester was made according to the AFNOR norm NFG 07-003 [9], taking into consideration the time of spliced yarn breaking (20 ± 3 second). The apparatus stopped automatically when the extension cycles of the parent and spliced yarn were reached. After that we exposed the same sample to a tensile test in or-

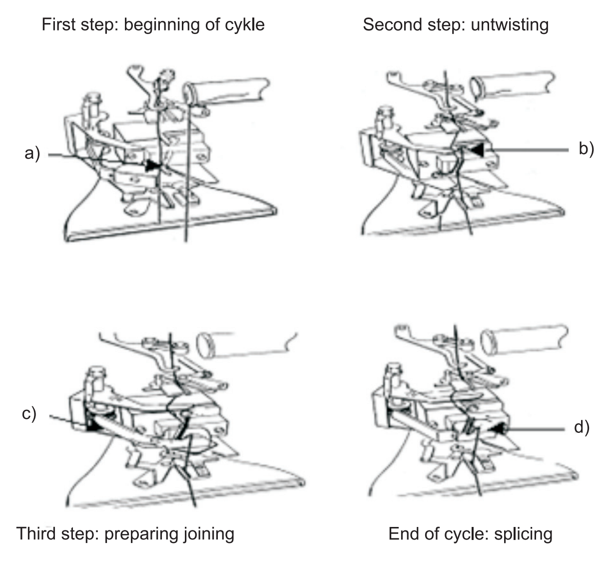

Figure 1. *Wet pneumatic splicing process; a) prism (canal for joining), b) end opening, c) adjustment length of spice (SL), adjustment air and water joining.*

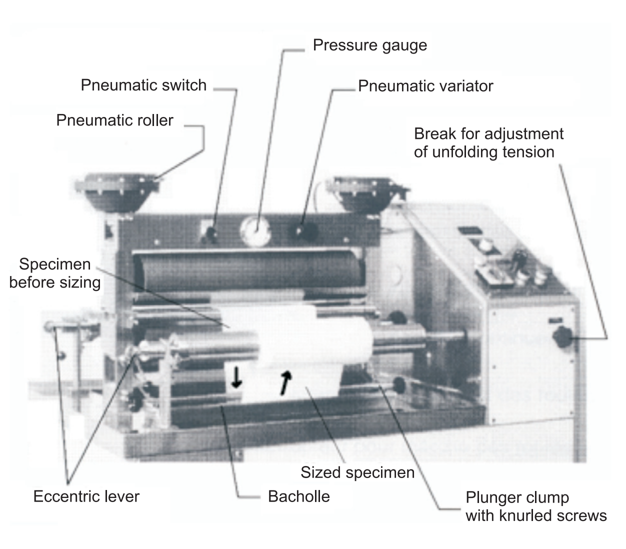

Figure 2. *Sizing process using laboratory apparatus, a standard scarf Mathis.*

der to record the loss of both breaking strength and elongation at break. The test results, appropriately elaborated, are presented in ***Figures 3 - 6***.

__Table 4.__ Mean tensile properties of samples before and after sizing.

Yarn count, tex	Spliced yarn tensile properties						Parent yarn tensile properties					
	Breaking strength, B_s, N			Elongation at break, E_b, %			Breaking strength, B_s, N			Elongation at break, E_b, %		
	B_{ss}	B_{ss1}	B_{ss2}	E_{bs}	E_{bss1}	E_{bss2}	B_{spy}	B_{spys1}	B_{spys2}	E_{bpy}	E_{bpys1}	E_{byps2}
29.4	3.31	4.68	4.62	5.25	5.28	5.35	4.02	5.18	5.5	6.44	6.06	5.54
64.7	6.48	9.29	12.22	5.10	6.45	7.47	8.59	11.97	14.09	6.28	7.30	6.28
100	7.06	10.63	13.42	5.28	6.33	7.18	11.49	18.54	20.96	7.43	9.59	7.43

__Table 5.__ Contributions of sizing to the tensile properties of the samples tested.

Yarn count, tex	Contribution of sizing to wet spliced yarn properties, %				Contribution of sizing to parent yarn properties, %			
	B_{ss1} - B_s	B_{ss2} - Bs	E_{bss1} - E_b	E_{bs2} - E_b	B_{ss1} - B_s	B_{ss2} - B_s	E_{bs1} - E_b	E_{bs2} - E_b
29.4	41.23	28.29	0.52	1.88	28.85	36.81	-5.90	-13.97
64.7	43.39	47.01	26.56	46.50	39.34	64.02	-7.71	-20.60
100	50.56	47.38	19.77	35.96	43.60	82.41	-10.12	-30.36

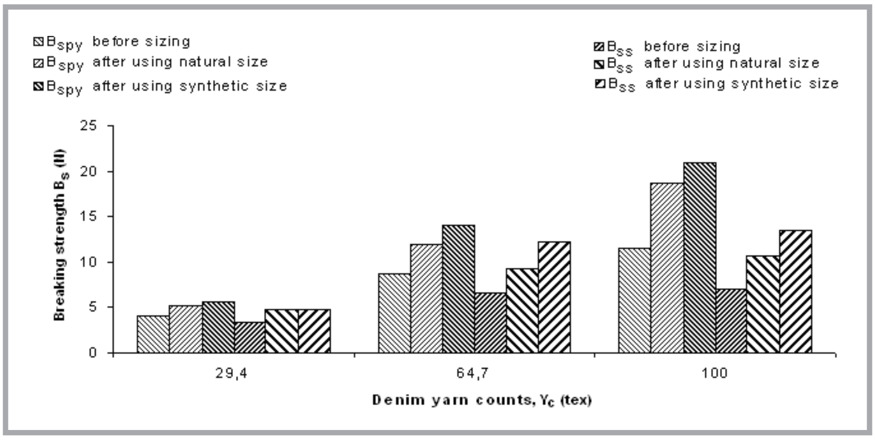

***Figure 3.** Variation in the breaking strength of both parent and spliced denim yarns (B_{spy} and B_{ss}) as a function of yarn counts (Y_c) before and after sizing.*

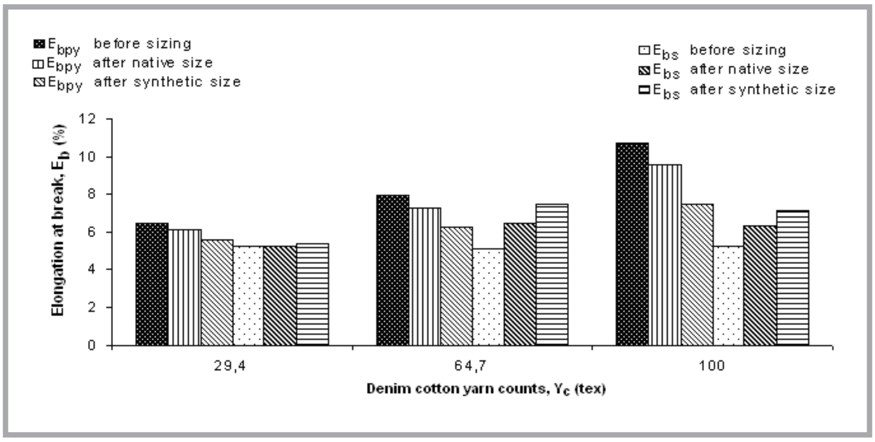

***Figure 4.** Variation in the elongation at break of both parent and spliced denim yarns (E_{bpy} and E_{bs}) as a function of yarn counts before and after sizing.*

Results and discussion

Size effect on spliced and parent yarn breaking strength (B_s) and elongation at break (E_b)

The mean tensile test results of both parent and spliced yarns before (B_s, E_b, B_{spy}, E_{bpy}) and after sizing ($B_{ss}1$, $B_{ss}2$, $E_{bs}1$, $E_{bs}2$, $B_{spys}1$, $B_{spys}2$, $E_{bpys}1$, $E_{byps}2$) using natural (indexed by s1 in ***Tables 4*** and ***5***) and synthetic size (indexed by s2 in ***Tables 4*** and ***5***) were investigated, respectively, and saved in ***Table 5***. The results shown in ***Table 4*** help to evaluate easily the effect of sizing on the tensile properties of the samples tested.

Figures 3 and ***4*** show, respectively, variation values of the breaking strength and elongation at break of both parent and spliced yarns (breaking strength of spliced yarn: B_{ss}, breaking strength of parent yarn: B_{spy}, elongation at break of spliced yarn: E_{bs} and elongation at break of parent yarn: E_{bpy}) before and after sizing using two sizes.

The tensile tests on sized and unsized cotton spliced and parent yarns show that sizing increases yarn strength (***Figure 3***), which is due to an increase in yarn count (the mean increase in the value of the yarn count after sizing is 9.7%), yarn cohesiveness and prevention of fibre slippage, as explained by Sherilyn [7]. Thick spliced yarns have better synthetic size affinity than thin yarns, according to the results of Kaushik [3, 4] .

On the other hand, from ***Figure 4*** we can conclude that synthetic size gives better mechanical behaviour of spliced and parent yarns. This finding corresponds to those presented by Kovacevic [8].

Figure 4 indicates that splicing decreases parent yarn extensibility, which is proved by the latest studies of Slausson [7]. Moreover, ***Table 5*** shows differences between the overall properties of both spliced and parent yarn before (B_s, E_b, B_{spy}, E_{bpy}) and after sizing ($B_{ss}1$, $B_{ss}2$, $E_{bs}1$, $E_{bs}2$, $B_{spys}1$, $B_{spys}2$, $E_{bpys}1$, $E_{byps}2$).

On the other hand, it is interesting to note that sizing increases spliced yarn extensibility, which can be due to the splice complex structure, which encourages size penetration, as demonstrated by Kaushik [2].

In addition, our statistical findings show that the coefficient of variation (CV%) of the elongation at break ranges from 10.02% to 19.64% before sizing. After sizing, the coefficient of variation of the elongation at break decreases, becoming between 6.89% and 16.4% and between 7.12% and 14.75% for natural and synthetic size, respectively. Hence, the extensibility of sized spliced yarn is statistically significant. Moreover, the decrease in the coefficient of variation of the breaking strength of the sized samples proves that sizing contributes positively

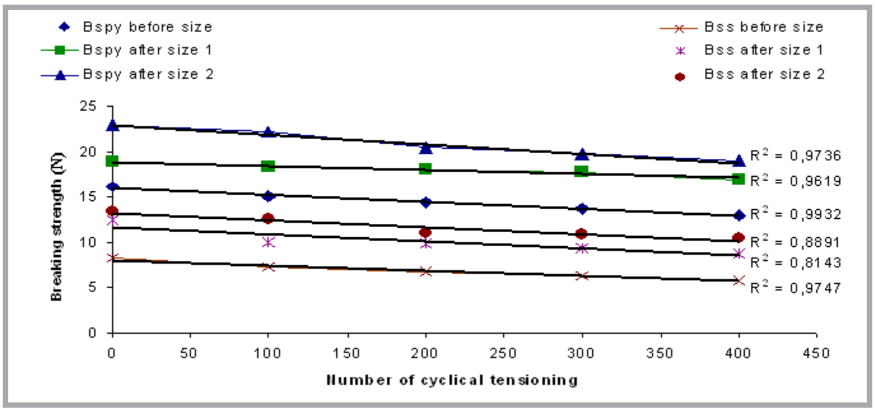

Figure 5. *Breaking strength variation of both parent and spliced yarns after cyclical tensioning.*

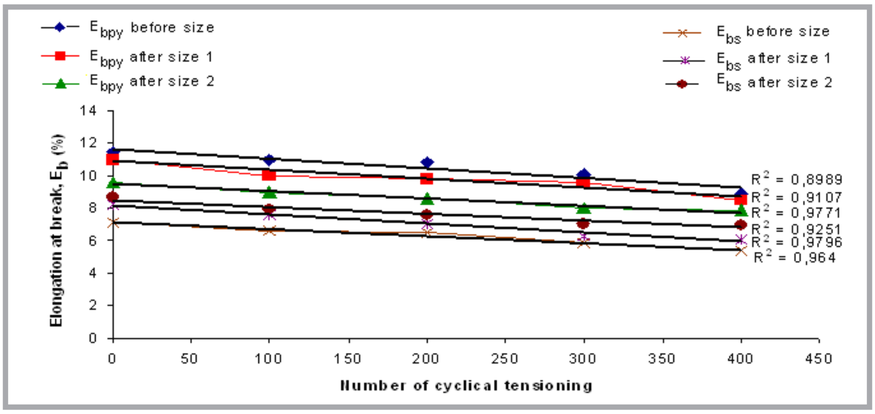

Figure 6. *Elongation at break variation of both parent and spliced yarns after cyclical tensioning.*

in the consolidation of spliced structures. Hence, we recorded the CV% in the case of the breaking strength before sizing, ranging from 16.59% to 33.25%. However, after sizing, the coefficient of variation of the breaking strength ranges from 7.27% to 32.25% (in the case of natural size) and from 11.61% to 20% (in the case of synthetic size).

Size effect on spliced and parent yarn breaking strength (B_s) and elongation at break (E_b) after cyclical tensioning

Figures 5 and ***6*** show, respectively, variation values of the breaking strength and elongation at break of both parent and spliced yarns after cyclical tensioning.

The average lifetimes, which are represented by fatigue data, of sized parent and spliced denim yarns show that splice and original yarn performance decrease when the number of fatigue cycles increases. Consequently, spliced and parent yarn breakages increase during the weaving process.

Figures show that the range of the linear regression coefficient of determination (R^2) is from 0.8143 to 0.9932 for the breaking strength, as shown on ***Figure 5***, and from 0.8989 to 0.9796 for the elongation at break (see ***Figure 6***).

These high regression coefficient values prove that the evolution of the breaking strength and elongation at break can be fitted by the linear regression method.

Using experimental equations of regression, fitting models can be used to predict the number of lifetimes of a sized sample. Cyclical tensioning confirms that splicing improves the breaking strength of both parent and spliced yarns. However, contrary to parent yarns, sizing improves the elongation at break of wet pneumatic spliced yarns.

Conclusion

This study has shown that splicing improves the breaking strength of both parent and spliced yarns. On the other hand, contrary to parent yarns, sizing improves the elongation at break of pneumatic wet spliced yarns. The same results were obtained under cyclical tensioning for both natural and synthetic sizes.

From these results, we can state two objectives:

- First, the need to control splices before and after sizing
- Second, to ensure that splice breakages (the weakest zone in the yarn) are not caused by cyclical stresses during weaving but by rubbing and abrasion.

Hence, a rigorous choice of recipe agents and sizing conditions will solve this problem.

Further detailed studies will follow.

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