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STRENGTH OF WET SPLICED DENIM YARNS AFTER SIZING USING A CENTRAL COMPOSITE DESIGN

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Abstract

The retained strength of wet spliced yarns can be controlled to some extent by suitable choices of certain factors related to the process. In order to understand how these variables influence the breaking force of wet spliced yarns, a central composite design was formulated and three variables – yarn count, the duration of air joining and the duration of water joining – were considered. Analysis of the results indicates that yarn count and length of splice contribute significantly to this mechanical property of wet sized spliced yarns. The duration of water joining, the duration of air joining of splice and the recipe size have a considerable effects.

Key words:

Spliced yarns, sizing, recipe, breaking strength, pneumatic splicer system, denim yarn

Introduction

The mechanical properties of spliced yarns which affects the quality of the denim yarn are influenced by variations in parameters such as raw materials and process & machine variables. Increasing some of these variable results can increase or decrease the performance of mechanical properties. Splicing is a technique which was especially developed to meet requirements in weaving where demands are severe. This is the manner of joining two ends after preparation by air under pressure **[4, 11]**. Cheng **[1, 5]** studied abrasion and the tensile strength & elongation of the splices. He showed by linear regression and neural networks that the linear density of yarn is the most influential parameter on these physical properties. Sharma & Kaushik **[2, 3, 7]** treated the various zones which participate in traction by defining the total mechanism of splices. They showed especially that splice remains a failing technique in weaving, and it is essential to optimise it in order to improve certain input parameters. In 1985 Haagege **[10]** used the technique of image analysis of morphology of splices to prove that splicing is not reliable compared to the parent yarn. In general, it is important that mechanical properties of wet spliced yarn after sizing should have the highest values. For this reason, the levels of the variables that affect the performance of the splice should be selected so that maximum properties are achieved.

We have studied the effect of four parameters with the help of a central composite design for the experiments. Our statistical analysis of the results obtained from these experiments establishes a relationship of retained strength and retained elongation at break with these variables. The details of the experiments and the subsequent analysis are reported in this paper.

Experimental design

We chose a central composite design (rotatable, second-order) for the experiments because of its obvious advantages of rotatability **[5]** and the ability to analyse all the quadratic and interaction effects **[5]**. The design is shown in Table I. it was supplemented by ten central observation points, which helped in estimating the experimental (pure) error variance.

The various levels chosen for the different parameters were 29,4 tex, 64,7 tex and 100 tex yarn count, 1, 2.5 and 4 lengths of splice were expressed by position in an Schlafhorst autoconer splicer system, with 60 ms, 410 ms, and 800 ms duration of water joining and 60 ms, 240 ms, and 420 ms duration of air joining. These levels adequately cover the factor space available for each parameter.

The general relation between the response Y (in this case, Y= RSS1 or RSS2 after sizing within the first or second recipe size) and different parameters (xi and xj in this case are coded values of the four input parameters defined earlier) will be expressed as shown below:

$$Y = a_0 + \sum_{i=1}^{n} a_i x_i + \sum_{i=1}^{n} a_{ii} x_i^2 + \sum_{i=1}^{n-1} \sum_{j=2}^{n} a_{ij} x_{ij} ,$$

where a_0 = the constant term, a_i = the coefficients of main factor effects, a_{ii} = the coefficient of quadratic effects, a_{ij} = the coefficients of interaction effects, and n = the number of factors chosen (four in this case).

Materials and methods

Spliced yarns specimens were prepared on a Schlafhorst 338 autoconer **[9]**. Splices were produced at the levels prescribed by the central composite design, and six others were central points. In this way, we could consider variations in the central observation point as being due to variations in the setting of the process and the machine variables. The spliced yarns were sized according to two different recipes. The following agents were used for preparing the sizes which were mixed at a temperature of 93°C:

Ethylex: 65kg, native starch, Fibrosint M77, Molvenin CG 70V, Ariol GPW and urea. The size preparation recipe, the size parameters, and the sizing conditions were the same for all the samples:
Composition size 1: 65 kg (Ethylex) +15 kg (native starch) +10 kg (Fibrosint M77) + 10 kg (Molvenin CG70V) + 9kg (Avirol GPW) + 7,5kg (urea) + 680 l water.

Composition size 2: 100 kg (Ethylex) + 20 kg (Fibrosint M77) + 20 kg (Molvenin CG70V) + 6 kg (Avirol GPW) + 6 kg (urea) + 780 l water.

Wet spliced yarns were impregnated with the MATHIS system (Figure 1) for sizing, at a speed of 1.41m/min and a bath temperature of 93°C on average. We made it possible to exert constant experimental conditions (drying conditions).

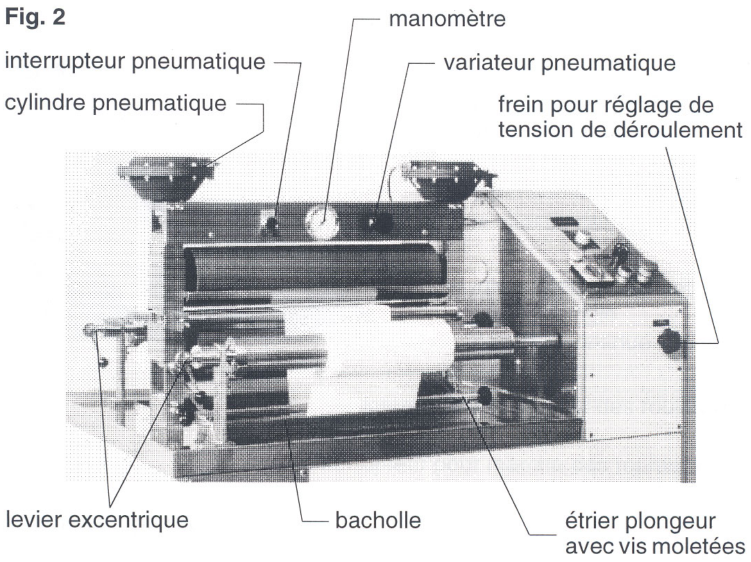


Figure 1. Sizing standard scarf MATHIS system

The splices were then tested on a Lloyd tensile tester to determinate mechanical properties. The length of each specimen is 100 mm, following Sharma & Kaushik's method **[2, 3, 7]**. We tested 50 samples in each test of our experimental design.

Results and discussion

Table 1 shows the mechanical properties of spliced yarns produced with different levels of variables according to the central composite design. To estimate the coefficients in the general relation between the response Y and different parameters, we followed the forward selection regression procedure. For the analysis of variance, with Minitab 14 software we calculated the total sum of squares, the sum of squares due to regression, the sum of squares due to total error, the sum of squares due to pure error, and the sum of squares due to lack of fit according to the method given by Droesbeke, Fine **[8]** and Goupy **[9]**.

We prepared Table 1 by taking the entire main, quadratic, and interaction effects into account. We obtained the t value for each parameter, showing in consequence the different significant input parameters. We found that the parameters Yc, and SL were significant, while the parameters Daj, Dwj and recipe size had little influence.

Table 1. The central composite design used for investigating variation in retained strength of spliced denim yarns as function of variations in input parameters

Yc	SL	Daj	Dwj	RSS1	RSS2
29.4	1	60	20	91.1197	80.3636
100	1	60	20	44.4984	70.8969
29.4	4	60	20	85.9073	64.3636
100	4	60	20	49.7303	61.1164
29.4	1	420	20	94.4015	88.9091
100	1	420	20	21.2513	63.2634
29.4	4	420	20	91.8919	92.1818
100	4	420	20	71.3053	66.8893
29.4	1	60	800	90.1544	84.7273
100	1	60	800	59.0076	64.2653
29.4	4	60	800	75.4826	77.8182
100	4	60	800	55.6634	38.3111
29.4	1	420	800	94.2085	93.8182
100	1	420	800	80.3128	86.7366
29.4	4	420	800	92.8571	77.6364
100	4	420	800	55.178	56.6794
29.4	2.5	240	410	98.4556	97.6364
100	2.5	240	410	79.2341	68.2252
64.7	1	240	410	91.4787	95.0319
64.7	4	240	410	61.8212	59.2619
64.7	2.5	60	410	74.4361	74.0951
64.7	2.5	420	410	95.9064	89.78
64.7	2.5	240	20	76.1069	84.8829
64.7	2.5	240	800	75.8563	82.115
64.7	2.5	240	410	76.4411	93.9674
64.7	2.5	240	410	78.4461	93.8254
64.7	2.5	240	410	76.8588	92.8318
64.7	2.5	240	410	74.6032	91.9092
64.7	2.5	240	410	78.0284	88.9993
64.7	2.5	240	410	75.3551	90.3478
64.7	2.5	240	410	73.35	90.7026

A second regression analysis used shows that those parameters that were significant; the results of this analysis are shown in Table 2. This regression analysis yielded coefficients of each parameter as well as the constant term, from which we obtained the response surface equation (in uncoded form):

$$RSS1 = 113{,}654 - 1{,}294Y_c + 12{,}021SL - 3{,}001SL^2 \tag{1}$$

$$RSS2 = 61{,}45 + 0{,}11Y_c + 17{,}08SL - 3{,}69SL^2 \tag{2}$$

where RSS1 and RSS2 are the retained strength of spliced yarns sized with first and second glue and expressed in percentage of parent yarns.

The sign of any coefficient for a main effect indicates the direction in which the response moves when the concerned variable changes from a lower to a higher level. The amount by which the response changes for a certain amount of change in the controlled variable is given by the amount of change in the controlled variable multiplied by the value of the coefficient. We see from Equations 1 and 2 that all the main effects present there make positive and negative contributions to mechanical properties of wet spliced yarns.

We calculated the values of R^2 (R = overall correlation coefficient) by dividing the sum of squares due to regression by the sum of squares. An R^2 value of RSS1 and RSS2 of 0.823 and 0.83 respectively indicates that these models can explain 82.3% and 83% of the total variation in the response. The quadratic terms (D_{aj}^2 *and* D_{wj}^2) indicate that neither has any effect because of their null values. We tested the applicability of the model in representing the response by testing the mean square of the regression against that of the total error.I In the case of RSS1, we found that the regression was significant because the F-ratio of regression was 4.57, which was well above the table F-ratio of 0.002 (at a 95% significance level).

Table 2. Tests of hypotheses concerning the individual parameters in the model given by MINITAB14 software

Input parameters	RSS1 (%)				RSS2 (%)			
	Coeff.	Standard Error	T	P	Coeff.	Standard Error	T	P
Constant	113,65	22,0263	5,16	0,000	61,455	16,699	3,68	0,002
Yc	-1,294	0,7088	-1,826	0,087	0,1147	0,537	0,213	0,834
SL	12,02	15,34	0,783	0,445	17,089	11,632	1,469	0,161
Daj	-0,032	0,106	-0,304	0,765	0,07	0,08	0,873	0,395
Dwj	0,043	0,0407	1,053	0,308	0,029	0,03	0,939	0,362
Yc*Yc	0,004	0,00053	0,828	0,42	0,002	0,004	-0,506	0,62
SL*SL	-3,001	2,9203	-1,028	0,319	-3,693	2,214	-1,668	0,115
Daj*Daj	0	0,0002	0,27	0,791	-0,0001	0,0002	-0,706	0,491
Dwj*Dwj	0	0	-1,129	0,276	0	0	-0,392	0,7
Yc*SL	0,06	0,05	1,194	0,25	-0,031	0,037	-0,821	0,424
Yc*Daj	0	0,0004	-0,273	0,789	-0,0001	0,0003	-0,197	0,847
Yc*Dwj	0	0,0002	1,748	0,1	-0,0001	0,0001	-0,759	0,459
SL*Daj	0,009	0,0098	0,923	0,37	0,0045	0,0074	0,602	0,556
SL*Dwj	-0,01	0,0045	-2,175	0,045	-0,0064	0,0034	-1,876	0,079
Daj*Dwj	0	0	0,819	0,425	0	0	0,475	0,641

We also tested the ‘lack of fit’ (i.e., the mean square representing the failure of the experimental points to fall exactly on the surface represented by the function) against the mean square of the pure error. We found that the F-ratio of lack of fit was 52.44, which was higher than the table F-ratio of 3.38 (at a 95% significance level). This indicates that the lack of fit was significant, which means that terms higher by an order of one were present.

In the case of RSS2, we found that the regression was significant because the F-ratio of regression was 5.97, which was well above the table F-ratio of 0.001 (at a 95% significance level).We also tested the ‘lack of fit’ (i.e. the mean square representing the failure of the experimental points to fall exactly on the surface represented by the function) against the mean square of the pure error. We found that the F-ratio of lack of fit was 28.76, which was higher than the table F-ratio of 3.509 (at a 95% significance level). This indicates that the lack of fit was significant, which means that terms higher by an order of one were present.

Figures 2 and 3 shows two-dimensional contour plots. We see the zones whose responses were maximum (100%). There are zones indicating that the strength is better, the more the long durations (Dwj and Daj) are used for splices average starting from thin spliced yarn. It is readily apparent that the in a structure where the number of fibres to the section is considerable under our experimental conditions. Splicing a thick yarn after sizing does not cause significant tensile strengths.

Figure 4 shows the parameters which are most influential on the breaking strength of wet pneumatic splices. The recipe of size 2 decreases the strength values of splice by approximately 5%. It must therefore be concluded that size (recipe size 2) deprived of starch does not encourage the breaking strength. The type of recipe must be considered during sizing because in the long run it affects the efficacy of splices, especially during weaving, where the constraints are enormous.

In descending order, we classify the effect of the parameters on RSS after sizing as follows: Yc>SL>Daj>Dwj>C.

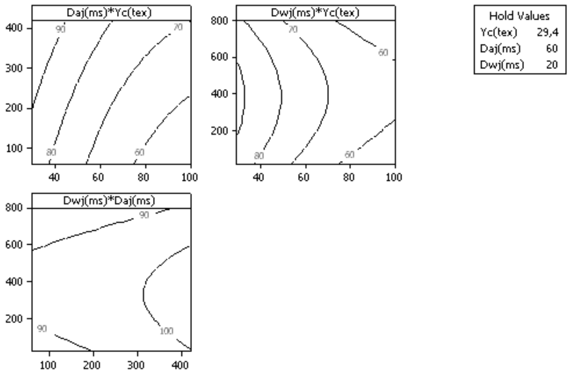


Figure 2 :Contour Plots of RSS1(%)

a

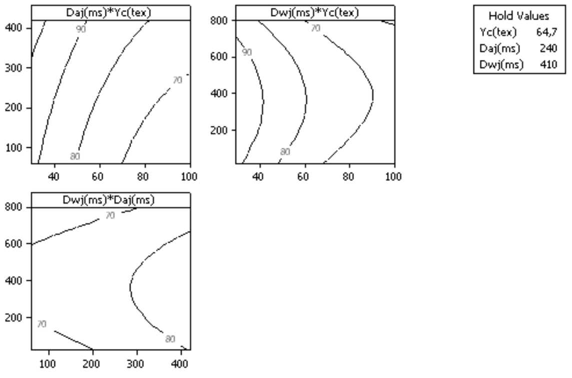


Figure 3: Contour Plots of RSS1(%)

b

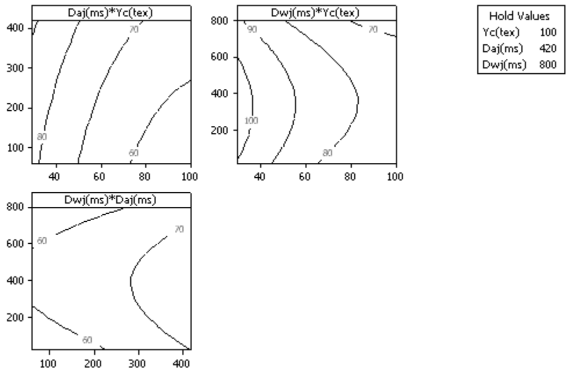
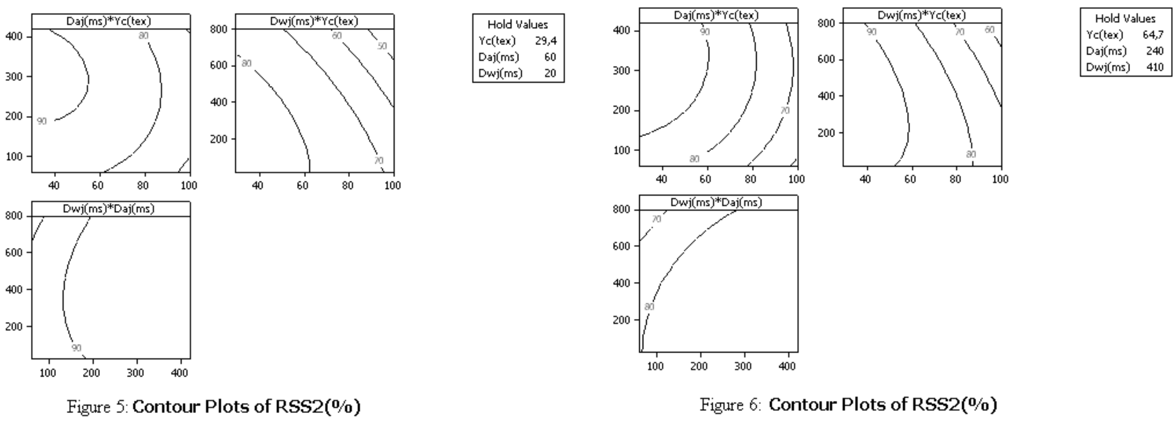


Figure 4: Contour Plots of RSS1(%)

c

Figure 2. Two-dimensional contour plot of RSS1 showing the contours as function of overall input parameters: (a) Strength after sizing with recipe 1 as function of low levels of input parameters, (b) as function of input parameters chosen at medium levels, (c) as function of input parameters fixed at high levels



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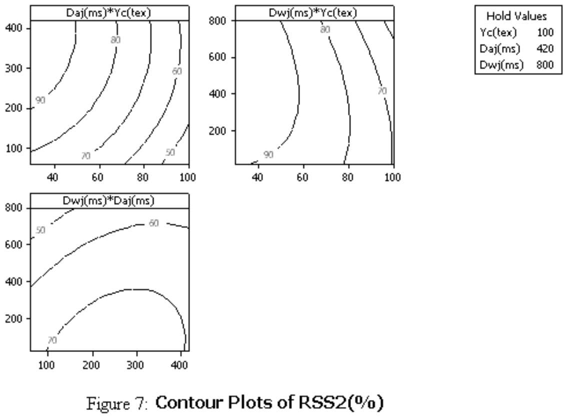

f

Figure 3. Two-dimensional contour plot of RSS2 showing the contours as function of overall input parameters: (d) Strength after sizing with recipe 2 as function of low levels of input parameters, (e) as function of input parameters chosen at medium levels, (f) as function of input parameters fixed at high levels

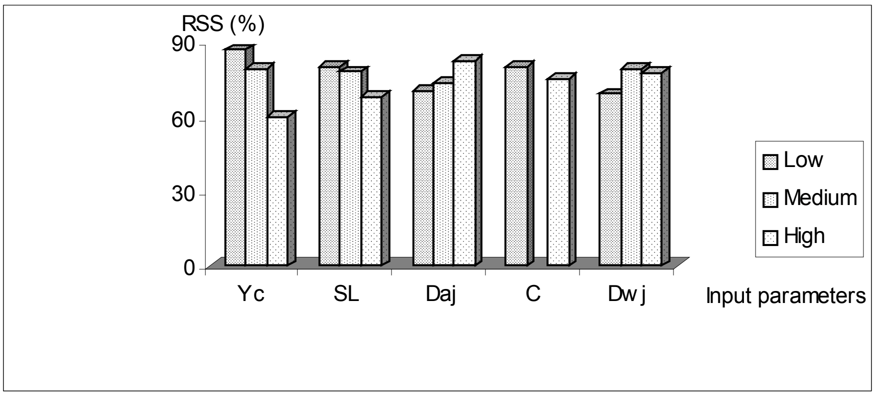

Figure 4. Variation of RSS as function of input parameters

Conclusion

Detailed regression analysis shows that while the factors of yarn count, Yc, length of splice, SL and quadratic effect, SL^2 are highly significant, their interactions with the other factors are not significant regarding the strength of spliced yarn. Although a sizable lack of fit sum of squares is present, the response surface equation describes the experimental system reasonably well for our purpose, since regression accounts for 80% and 83.4% of the total variation of the data. The model can thus be used to predict the response within reasonable limits.

Sizing encourages the resistance of wet pneumatic-spliced denim yarns, and this was justified for the two recipes used. With this type of experimental design, we optimised the basis of input parameters and their impacts on the breaking strength of splice after sizing.

This study shows that the two most influential parameters on breaking strength of wet pneumatic splices are yarn count and length of splice, which can be optimised to limit the strength value at high levels.

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