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Research Article

DESIGN OF MECHANICAL PROPERTIES OF WIND FABRIC

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ABSTRACT

In the article, among the main properties of the fabric, the fiber composition of the hemlock thread, the thickness of the hemlock thread, and changes in the density of the hemlock thread in the fabric are analyzed as factors affecting it. Using mathematical modeling methods, regression equations were obtained to calculate the tensile strength of the tissue. The coefficients of the regression equation were tested by Student's and the equation by Fisher's test. Cotton and polyester fibers were used as the fiber content of the hemp yarns used in weaving. 100 percent polyester yarn used as a yarn of 3 different linear densities has been found to have little effect on strength and elongation at break, and strength compared to cotton yarn.

KEYWORDS

Fabric, mechanical indicators, warp density, polyester, mathematical model, regression, tensile strength, elongation at break, Student's criterion, adequacy.

INTRODUCTION

Weave is created as a result of weaving two systems of threads perpendicular to each other in a certain order on a loom. Threads located along the length of the fabric had called warp threads,

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and threads located transversely had called warp threads. The structure of the fabric refers to the arrangement and interconnection of warp and weft threads in a certain order. The structure of the tissue determines its surface appearance (decoration) and physical-mechanical properties. The structure of the tissue depends on a number of factors:

— type of warp and weft thread, linear density and their proportions;

— the density of the tissue on the body and the back and their proportions;

— to the type of interweaving of threads in the fabric;

— to the conditions of weaving and technological plaiting of fabric on a loom.

The fabric is formed as a result of the interaction of warp and weft threads on the loom. During this period, the straight-line shape of the threads changes to a wavy shape. The degree of bending of the threads in this process depends on the factors that determine the tissue structure. If the linear density of the yarns in a system changes, then their warp in the fabric will also change. As the linear density of the warp yarn increases and the linear density of the weft yarn decreases, the warp of the warp yarn decreases, that is, the location of the warp yarn is closer to a straight line in the fabric, and in the case of warp yarn, it is more bent. As a result, the structure of the tissue changes, as well as its physical and mechanical properties. In addition, the type of thread (type of fiber, size of cooking, method of preparation) also affects the structure of the fabric [1-4].

It is desirable to effectively use the properties of woven fabric in mathematical modeling of the influence of the fabric on mechanical parameters.

METHODOLOGY AND EMPIRICAL ANALYSIS

Factors included as influencing factors are x1- density of jute yarn (yarn/10 cm), x2- thickness of metric number (Nm), x3- change of percentage of cotton and polyester in jute yarn (%) indicators are taken. The choice of the levels and ranges of changes of the researched factors is presented in Table 1 below.

Selection of levels and ranges of changes of the researched factors

Table 1

Name of factors and measurement	Changing levels			Change interval
	-1	0	1	
x_1 – warp density (yarn/10 cm)	230	250	270	20
x_2 – thickness of rope thread (Nm- metric number)	40	50	60	10

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x_3- change of percentage of cotton and polyester in jute yarn (%)	100	50	0	50

In order to check whether the mathematical model is adequate or not, Fisher's criteria and Student's criterion were used to determine regression coefficients. As an output factor, Y1-tissue breaking strength (strength) (N) in the direction of warp thread was selected.

The main purpose of mathematical modeling of this research work is to determine the breaking force of the spilled fabric with the help of factors affecting the spill. Using a program written in the Pascal programming language, an isoline deviation plot was obtained based on computational models. With these isolines, we can determine the breaking strength and breaking elongation curves based on the factors affecting the flow [5-10].

Table 2. Central non-composite experience matrix

№	Factors			x_1x_2	x_1x_3	x_2x_3	x_1^2	x_2^2	x_3^2	Y1	$S_u^2(Y_1)$
	x_1	x_2	x_3								
1	+	+	0	+	0	0	+	+	0	359	25
2	+	-	0	-	0	0	+	+	0	331	25,3
3	-	+	0	-	0	0	+	+	0	374	17
4	-	-	0	+	0	0	+	+	0	368	14
5	+	0	+	0	+	0	+	0	+	365	36
6	+	0	-	0	-	0	+	0	+	349	64
7	-	0	+	0	-	0	+	0	+	360	36,4
8	-	0	-	0	+	0	+	0	+	371	4,9
9	0	+	+	0	0	+	0	+	+	360	23
10	0	+	-	0	0	-	0	+	+	358	17
11	0	-	+	0	0	-	0	+	+	352	7,2
12	0	-	-	0	0	+	0	+	+	331	6,2
13	0	0	0	0	0	0	0	0	0	351	6,1
14	0	0	0	0	0	0	0	0	0	350	7,4
15	0	0	0	0	0	0	0	0	0	353	7,5

Based on the experience, we are looking for a hierarchical regression multifactorial mathematical model. Three general regression models can be obtain:

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$$Y_R = b_0 + \sum_{i=1}^{M} b_i x_i + \sum_{\substack{i=j=1 \\ j \neq 1}}^{n} b_{ij} x_i x_j + \sum_{i=1}^{M} b_{ii} x_i^2$$

or since three factors are involved in our experience, the above expression takes the following form:

$$Y_R = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_{12}x_1x_2 + b_{13}x_1x_3 + b_{23}x_2x_3 + b_{11}x_1^2 + b_{22}x_2^2 + b_{33}x_3^2$$

$b_0 \ldots b_1 \ldots$ – are regression coefficient in the equation,

x_1, x_2, x_3– coded value of coefficients.

Regression models for optimization of tissue breaking strength, strength (Y_1).

Let's calculate the regression coefficients:

$$b_0 = \frac{1}{N_s}\sum_{u=1}^{N_s} \overline{Y}_{\overline{u}} = \frac{1}{3}(351 + 350 + 353) = 351{,}33$$

$$b_i = g_3 \sum_{u=1}^{N} x_{iu}\overline{Y}_u$$

$g_2 = 0{,}166$ $g_5 = 0{,}125$

$g_3 = 0{,}125$ $g_6 = 0{,}0625$

$g_4 = 0{,}25$ $g_7 = 0{,}3125$

b_1 =0,125(359+331+(-374)+(-368)+365+349+(-360)+(-371))=-8,63

b_2 =0,125(359+(-331)+374+(-368)+360+358+(-352)+(-331))=8,63

b_3 =0,125(365+(-349)+360+(-371)+360+(-358)+352+(-331))= 3,50

$$b_{ij} = g_4 \sum_{u=1}^{N} x_{iu}x_{ju}\overline{Y}_u$$

b_{12} =0,25(359+(-331)+(-374)+368)= 5,50

b_{13} =0,25(365+(-349)+(-360)+371)= 6,75

b_{23} =0,25(360+(-358)+(-352)+331)=-4,75

$$b_{ii} = g_5 \sum_{u=1}^{N} x_{iu}^2\overline{Y}_u + g_6 \sum_{i=1}^{M}\sum_{u=1}^{N} x_{iu}^2\overline{Y}_u - g_2 \sum_{u=1}^{N} \overline{Y}_u$$

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$$\sum x_1^2\overline{Y_u} = 359 + 331 + 374 + 368 + 365 + 349 + 360 + 371 = 2877$$

$$\sum x_2^2\overline{Y_u} = 359 + 331 + 374 + 368 + 360 + 358 + 352 + 331 = 2833$$

$$\sum x_3^2\overline{Y_u} = 365 + 349 + 360 + 371 + 360 + 358 + 352 + 331 = 2846$$

$$\sum \overline{Y_u} = 359 + 331 + 374 + 368 + 365 + 349 + 360 + 371 + 360 + 358 + 352 + 331 + 351 + 350 + 353 = 5332$$

$$\sum_{i=1}^{M}\sum x_i^2\overline{Y_u} = 2877 + 2833 + 2846 = 8556$$

b_{11}=0,125*2877+0,0625*8556-0,166*5332=9,26

b_{22}=0,125*2833+0,0625*8556-0,166*5332=3,76

b_{33}=0,125*2846+0,0625*8556-0,166*5332=5,39

Let's write the equation taking into account the found regression coefficient:

$$Y_1 = 351{,}33 - 8{,}63x_1 + 8{,}63x_2 + 3{,}5x_3 + 5{,}5x_1x_2 + 6{,}75x_1x_3 - 4{,}75x_2x_3 + 9{,}26x_1^2 + 3{,}76x_2^2 + 5{,}39x_3^2$$

To determine the significance of the regression coefficients of tissue breaking strength, strength (Y1), the variance of the output parameter is determined, and on this basis, the variance in determining the regression coefficients is calculated:

$$S^2\{Y\} = S_m^2\{Y\} = \frac{1}{N_s - 1}\sum_{u=1}^{N_s} S^2\{\overline{Y}\}$$

$$S^2\{\overline{Y}\} = \frac{1}{3-1}\cdot 21 = 10{,}5$$

and on this basis, the variance in determining the regression coefficients is calculated:

$$S^2\{b_0\} = g_1 S^2\{\overline{Y}\} = 0{,}2 \cdot 10{,}5 = 2{,}1$$

$$S^2\{b_i\} = g_3 S^2\{\overline{Y}\} = 0{,}125 \cdot 10{,}5 = 1{,}31$$

$$S^2\{b_{ij}\} = g_4 S^2\{\overline{Y}\} = 0{,}25 \cdot 10{,}5 = 2{,}625$$

$$S^2\{b_{ii}\} = g_7 S^2\{\overline{Y}\} = 0{,}3125 \cdot 10{,}5 = 3{,}281$$

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The mean square deviation in determining the regression coefficients is find:

$$S\{b_0\} = 1{,}45, \quad S\{b_i\} = 1{,}15, \quad S\{b_{ij}\} = 1{,}62, \quad S\{b_{ii}\} = 1{,}81$$

After that, the calculation value of the Student criterion is determined using the following equation:

$$t_R\{b_i\} = \frac{|b_i|}{S\{b_i\}}$$

$$t_R\{b_0\} = \frac{|351{,}33|}{1{,}45} = 242{,}3 \qquad t_R\{b_{12}\} = \frac{|5{,}5|}{1{,}62} = 3{,}4$$

$$t_R\{b_1\} = \frac{|8{,}63|}{1{,}15} = 7{,}5 \qquad t_R\{b_{13}\} = \frac{|6{,}75|}{1{,}62} = 4{,}17$$

$$t_R\{b_2\} = \frac{|8{,}63|}{1{,}15} = 7{,}5 \qquad t_R\{b_{23}\} = \frac{|4{,}75|}{1{,}62} = 2{,}93$$

$$t_R\{b_3\} = \frac{|3{,}5|}{1{,}15} = 3{,}04 \qquad t_R\{b_{11}\} = \frac{|9{,}26|}{1{,}81} = 5{,}12$$

$$t_R\{b_{22}\} = \frac{|3{,}76|}{1{,}81} = 2{,}08 \qquad t_R\{b_{33}\} = \frac{|5{,}39|}{1{,}81} = 2{,}98$$

$$\mathrm{t_j}[\mathrm{P_D} = 0{,}95; \mathrm{f}\{\mathrm{S}_s^2\} = 3 - 1 = 2] = 2{,}77$$

In the studies, it was found that the coefficient b_22 is insignificant for the studied parameters:

The equation is rewritten with significant coefficients:

$$Y_1 = 351{,}33 - 8{,}63x_1 + 8{,}63x_2 + 3{,}5x_3 + 5{,}5x_1x_2 + 6{,}75x_1x_3 - 4{,}75x_2x_3 + 9{,}26x_1^2 + 5{,}39x_3^2$$

The resulting equation for stretching up to Y-discontinuity is checked for adequacy. The test is performed using Fisher's test. Then the estimated value of Fisher's criterion is determined. The calculated value of the optimized factor Y1 is calculated by putting the coded values of all the columns of the 2-table in the matrix (−1, 0 and +1) of equation. Values are taken row-wise, not column-wise. In order to check whether the above-mentioned regression mathematical model is adequate or not, we determine using the calculated value of Fisher's criterion:

$$F_R = \frac{S_{nad}^2\{Y\}}{S^2\{\overline{Y}\}}$$

Here:

$$S^2\{\overline{Y_1}\} = \frac{\sum_{u=1}^{N} S^2\{Y\}}{N_s - 1}$$

$$S_{nad}^2\{Y\} = \frac{\sum_{u=1}^{N-N_s+1}(Y_{Ru} - \overline{Y}_u)^2}{N - N_{k.en} - (N_s - 1)^2};$$

$$N - N_{k.en} - (N_s - 1)^2 = 15 - 7 - (3 - 1)^2 = 4$$

$$N - N_s + 1 = 15 - 3 + 1 = 13$$

Y_1- calculation by inserting the coded values into the regression equation for the elongation at break of the tissue:

$$S^2\{\overline{Y_1}\} = \frac{\sum_{u=1}^{N} S^2\{Y\}}{N_s - 1} = \frac{21}{3 - 1} = 10{,}5$$

$$Y_1 = 351{,}33 - 8{,}63x_1 + 8{,}63x_2 + 3{,}5x_3 + 5{,}5x_1x_2 + 6{,}75x_1x_3 - 4{,}75x_2x_3 + 9{,}26x_1^2 + 5{,}39x_3^2$$

Table 3. Calculation results of values coded into the equation for adequate dispersion

№	Y_1– to’qima uzilish kuchi, mustahkamlik			
	Y_{1i}	Y_{1i}	$(Y_{1i}-Y_{R1i})$	$(Y_{1i}-Y_{R1i})^2$
1	359	366,09	7,1	50,27
2	331	337,8	6,8	46,65
3	374	372,35	-1,7	2,72
4	368	366,09	-1,9	3,65
5	365	367,6	2,6	6,76
6	349	347,1	-1,9	3,61
7	360	371,36	11,4	129,05
8	371	377,86	6,9	47,06
9	360	364,1	4,1	16,81
10	358	366,6	8,6	73,96
11	352	356,34	4,3	18,84
12	331	339,84	8,8	78,15

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$$\sum_{u=1}^{N-N_S+1}(Y_{R1.u}-\overline{Y}_{1u})^2=477{,}518$$

$$S_{nad}^2\{Y_1\}=\frac{477{,}52}{5}=95{,}5$$

It is known that if the calculated value of the criterion is smaller than the table value, that coefficient proves that the calculations were made correctly

$$F_{R1}=\frac{S_{nad}^2\{Y\}}{S^2\{\overline{Y}\}}=\frac{95{,}5}{10{,}5}=9{,}1$$

$$F_j\left[P_D=0{,}95;\ f\left\{S_{nad}^2\{Y\}\right\}=15-7-(3-1)=6;f\{S_u^2\}=3-1=2\right]=19{,}25$$

$$F_{R1}=9{,}1<19{,}25=F_j$$

Therefore, the obtained regression mathematical models represent the researched process with sufficient accuracy.

RESULTS

Since the equation created to determine the characteristics of the output parameter for the study is three-dimensional, one of the input factors in the analysis is assumed to be Xi=0 (the central state), and we use the two-dimensional graph by transforming the models into 2 equations let's make

$$Y_1=351{,}33-8{,}63x_1+8{,}63x_2+3{,}5x_3+5{,}5x_1x_2+6{,}75x_1x_3-4{,}75x_2x_3+9{,}26x_1^2+5{,}39x_3^2$$

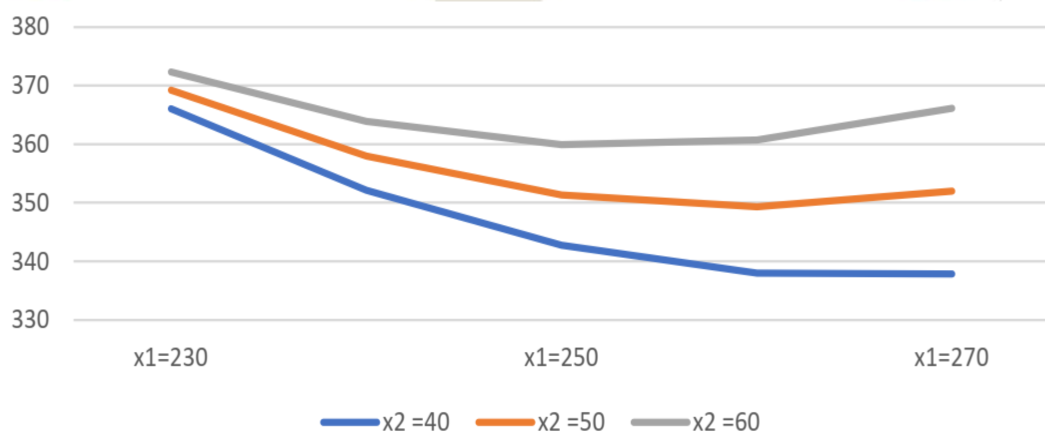

Figure 1.

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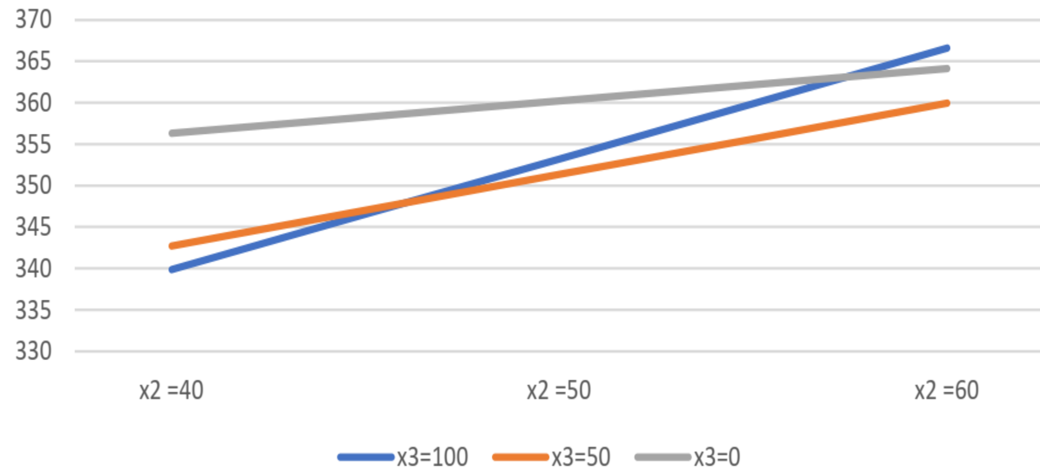

Figure 2

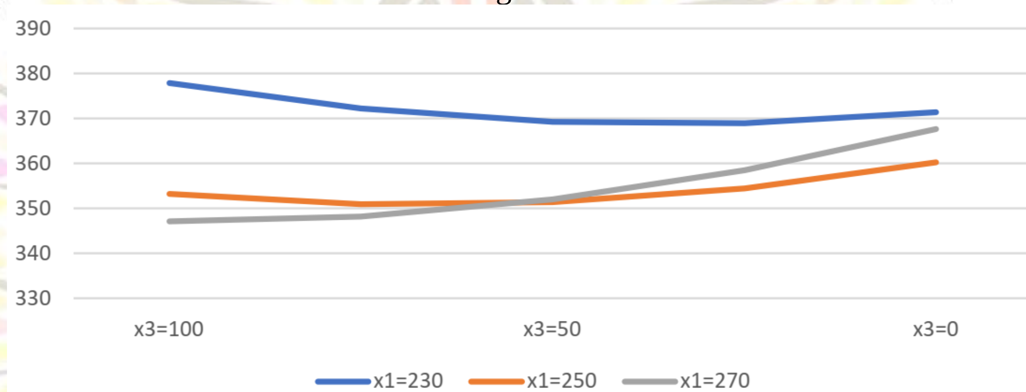

Figure 3

Graph of the regression equation for the design of the mechanical properties of the fabric through yarn

In Figure 1 above, x1 and x2 are the input factors, i.e. the factor x1 is the density of the warp thread in the fabric, and the input factor x2 is the tensile strength of the fabric and the thickness of the warp thread. effect on strength is expressed. Tensile strength, (strength) of the fabric - along with the increase in the density of the fabric, the tensile strength, (strength) of the fabric also changes. When the density of argoq is equal to 270, the thickness of argoq thread is equal to 60.

Figure 2 shows a graph of changes in the x2 and x3 input factors, i.e. the thickness of the rope x2 and the percentage of cotton and polyester in the rope, where the thickness of the rope is equal to 60 100% cotton yarn shows high strength, while 100% polyester has no significant change.

Figure 3 shows the effect of changing the percentage of cotton and polyester fibers in the yarn on the strength of the yarn density on the basis of x3 and x1 input factors, i.e. x3, where 100% polyester is stronger than cotton 'lyatti.

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