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DESIGN OF THE MECHANICAL PROPERTIES OF THE FABRIC USED BY WIND YARN SPINNING FROM COTTON AND POLYESTER FIBERS

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Abstract: In this article, the elongation at break, which is one of the main properties of the fabric, was studied. The fiber content of jute yarn, the thickness of jute yarn, and the change in density of jute yarn in the fabric were analyzed as the factors affecting the elongation at break of the fabric. Also, using mathematical modeling methods, regression equations were obtained to calculate the elongation at break of the tissue. The coefficients of this regression equation were tested based on Student's and Fisher's tests. Cotton and polyester yarns had used for weaving. At the same time, 100 percent polyester fiber yarns of 3 different linear densities were taken as a weft yarn, and their effects on the elongation at break of the fabric were studied.

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

Introduction. It is formed as a result of weaving two systems perpendicular to each other on the loom. Threads located along the length of the fabric had called warp threads, and threads located transversely had called warp threads. The structure of gauze 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.

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 threads in this process depends on the factors that determine the fabric structure. If the linear density of the threads 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.

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 present in table 1 below.

Table 1. Selection of levels and ranges of changes of the researched factors.

Name of factors and measurement	Changing levels			Change interval
	-1	0	1	
x1 – warp density (yarn/10 cm)	230	250	270	20
x2 – thickness of rope thread (Nm- metric number)	40	50	60	10
x3- 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. Y1 - Tissue elongation at break (in the direction of the rope) (%) was chosen as the output factor.

The main goal of mathematical modeling of this research work is to determine the tensile strength of woven fabric using the factors affecting the fabric. Using a program created in the Pascal programming language, an isoline deviation plot was obtained based on computational models. Through these isolines, we can determine the tensile strength and elongation at break based on the factors affecting the tissue.

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	23,8	0,090
2	+	-	0	-	0	0	+	+	0	21,4	0,084
3	-	+	0	-	0	0	+	+	0	22,4	0,092
4	-	-	0	+	0	0	+	+	0	20,8	0,091
5	+	0	+	0	+	0	+	0	+	24,1	0,137
6	+	0	-	0	-	0	+	0	+	20,9	0,004
7	-	0	+	0	-	0	+	0	+	21,7	0,270
8	-	0	-	0	+	0	+	0	+	17,1	0,008
9	0	+	+	0	0	+	0	+	+	23,6	0,006
10	0	+	-	0	0	-	0	+	+	21,1	0,941
11	0	-	+	0	0	-	0	+	+	22,3	0,048
12	0	-	-	0	0	+	0	+	+	15,7	0,007
13	0	0	0	0	0	0	0	0	0	22,5	0,008
14	0	0	0	0	0	0	0	0	0	22,3	0,462
15	0	0	0	0	0	0	0	0	0	23,3	0,096

Based on the results of the experiment, we are looking for a second-order regression multifactor mathematical model. As a result of this experiment, the following general regression model can be obtained:

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

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

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

$b_0...b_1...$ – 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 (Y1).
Let's calculate the regression coefficients:

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

$g_2 = 0{,}166$ $g_5 = 0{,}125$
$g_3 = 0{,}125$ $g_6 = 0{,}0625$
$g_4 = 0{,}25$ $g_7 = 0{,}3125$

$$b_0 = \frac{1}{N_s} \sum_{u=1}^{N_s} \overline{Y_{\overline{u}}} = \frac{1}{3}(22{,}5 + 22{,}3 + 23{,}3) = 22{,}7$$

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

b1 =0,125(23,8+21,4+(-22,4)+(-20,8)+24,1+20,9+(-21,7)+(-17,1))=1,03
b2 =0,125(23,8+(-21,4)+22,4+(-20,8)+23,6+21,1+(-22,3)+(-15,7))=1,34
b3 =0,125(24,1+(-20,9)+21,7+(-17,1)+23,6+(-21,1)+22,3+(-15,7))= 2,11

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

b12 =0,25(23,8+(-21,4)+(-22,4)+20,8)= 0,20
b13 =0,25(24,1+(-20,9)+(-21,7)+17,1)= -0,35
b23 =0,25(23,6+(-21,1)+(-22,3)+15,7)= -1,03

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

$$\sum x_1^2 \overline{Y_u} = 23{,}8 + 21{,}4 + 22{,}4 + 20{,}8 + 24{,}1 + 20{,}9 + 21{,}7 + 17{,}1 = 172{,}2$$

$$\sum x_2^2 \overline{Y_u} = 23{,}8 + 21{,}4 + 22{,}4 + 20{,}8 + 23{,}6 + 21{,}1 + 22{,}3 + 15{,}7 = 171{,}1$$

$$\sum x_3^2 \overline{Y_u} = 24{,}1 + 20{,}9 + 21{,}7 + 17{,}1 + 23{,}6 + 21{,}1 + 22{,}3 + 15{,}7 = 166{,}5$$

$$\sum \overline{Y_u} = 23{,}8 + 21{,}4 + 22{,}4 + 20{,}8 + 24{,}1 + 20{,}9 + 21{,}7 + 17{,}1 + 23{,}6 + 21{,}1 + 22{,}3 + 15{,}7 + 22{,}5 + 22{,}3 + 23{,}3 = 323$$

$$\sum_{i=1}^{M} \sum x_i^2 \overline{Y_u} = 172{,}2 + 171{,}1 + 166{,}5 = 509{,}8$$

b11=0,125*172,2+0,0625*509,8+0,166*323=-0,23
b22=0,125*171,1+0,0625*509,8+0,166*323=-0,37
b33=0,125*166,5+0,0625*509,8+0,166*323=-0.94

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

$$Y_{R1} = 22{,}7 + 1{,}03x_1 + 1{,}34x_2 + 2{,}11x_3 + 0{,}2x_1x_2 - 0{,}35x_1x_3 - 1{,}03x_2x_3 - 0{,}23x_1^2 - 0{,}37x_2^2 - 0{,}94x_3^2$$

To determine the significance of the regression coefficients of the elongation at break of the tissue (Y1), the variance of the output parameter is determined, and on this basis, the variance in the determination of the regression coefficients is calculated:

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

$S^2\{\overline{Y}\} = \frac{1}{3-1} \cdot 0{,}57 = 0{,}3$

$S^2\{b_0\} = g_1 S^2\{\overline{Y}\} = 0{,}2 \cdot 0{,}3 = 0{,}06$

$S^2\{b_i\} = g_3 S^2\{\overline{Y}\} = 0{,}125 \cdot 0{,}3 = 0{,}04$

$S^2\{b_{ij}\} = g_4 S^2\{\overline{Y}\} = 0{,}25 \cdot 0{,}3 = 0{,}07$

$S^2\{b_{ii}\} = g_7 S^2\{\overline{Y}\} = 0{,}3125 \cdot 0{,}3 = 0{,}09$

When determining the regression coefficients, the mean square deviation is found:

$S\{b_0\} = 0{,}24;$ $S\{b_i\} = 0{,}19;$ $S\{b_{ij}\} = 0{,}27;$ $S\{b_{ii}\} = 0{,}3$

After this, we determine the calculated value of the Student's test using the following equation:

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

$t_R\{b_0\} = \frac{|22{,}7|}{0{,}24} = 94{,}58$ $t_R\{b_{12}\} = \frac{|0{,}2|}{0{,}27} = 0{,}74$

$t_R\{b_1\} = \frac{|1{,}03|}{0{,}19} = 5{,}42$ $t_R\{b_{13}\} = \frac{|0{,}35|}{0{,}27} = 1{,}30$

$t_R\{b_2\} = \frac{|1{,}34|}{0{,}19} = 7{,}05$ $t_R\{b_{23}\} = \frac{|1{,}03|}{0{,}27} = 3{,}81$

$t_R\{b_3\} = \frac{|2{,}11|}{0{,}19} = 11{,}11$ $t_R\{b_{11}\} = \frac{|0{,}23|}{0{,}3} = 0{,}77$

$t_R\{b_{22}\} = \frac{|0{,}37|}{0{,}3} = 1{,}23$ $t_R\{b_{33}\} = \frac{|0{,}94|}{0{,}3} = 3{,}13$

In the studies, it was found that the coefficient b_{12}, b_{13} b_{11} b_{22} is insignificant for the studied parameters:

The equation is rewritten with significant coefficients:

$$Y_{R1} = 22{,}7 + 1{,}03x_1 + 1{,}34x_2 + 2{,}11x_3 - 1{,}03x_2x_3 - 0{,}94x_3^2$$

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:

$$S^2\{\overline{Y_1}\} = \frac{\sum_{u=1}^{N} S^2\{Y\}}{N_s-1} \qquad S^2_{nad}\{Y\} = \frac{\sum_{u=1}^{N-N_s+1}(Y_{Ru}-\overline{Y}_u)^2}{N-N_{k.en}-(N_s-1)^2};$$

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

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

Y1- calculation by inserting the coded values into the regression equation for the elongation at break of the tissue:

$$S^2\{\overline{Y_2}\} = \frac{\sum_{u=1}^{N} S^2\{Y\}}{N_s-1} = \frac{0,57}{3-1} = 0,28$$

$$Y_{R2} = 22,7 + 1,03x_1 + 1,34x_2 + 2,11x_3 - 1,03x_2x_3 - 0,94x_3^2$$

$Y_{R1.1} = 22,7 + 1,03 + 1,34 = 25,1$

$Y_{R1.2} = 22,7 + 1,03 + (-1,34) = 22,4$

$Y_{R1.3} = 22,7 + (-1,03) + 1,34 = 23,0$

$Y_{R1.4} = 22,7 + (-1,03) + (-1,34) = 20,3$

$Y_{R1.5} = 22,7 + 1,03 + 2,11 + (-0,94) = 24,9$

$Y_{R1.6} = 22,7 + 1,03 + (-2,11) + (-0,94) = 20,7$

$Y_{R1.7} = 22,7 + (-1,03) + 2,11 + (-0,94) = 22,8$

$Y_{R1.8} = 22,7 + (-1,03) + (-2,11) + (-0,94) = 18,6$

$Y_{R1.9} = 22,7 + 1,34 + 2,11 + (-1,03) + (-0,94) = 24,2$

$Y_{R1.10} = 22,7 + 1,34 + (-2,11) + 1,03 + (-0,94) = 22,0$

$Y_{R1.11} = 22,7 + (-1,34) + 2,11 + 1,03 + (-0,94) = 23,6$

$Y_{R1.12} = 22,7 + (-1,34) + (-2,11) + (-1,03) + (-0,94) = 17,28$

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

№	Y1- elongation of tissue at break			
	Y1i	Y1i	(Y1i-YR1i)	(Y1i-YR1i)2
1	23,8	25,07	1,3	1,613
2	21,4	22,39	1,0	0,980
3	22,4	23,01	0,6	0,372
4	20,8	20,33	-0,5	0,221
5	24,1	24,9	0,8	0,640
6	20,9	20,68	-0,2	0,048
7	21,7	22,84	1,1	1,300
8	17,1	18,62	1,5	2,310
9	23,6	24,18	0,6	0,336
10	21,1	22,02	0,9	0,846
11	22,3	23,56	1,3	1,588
12	15,7	17,28	1,6	2,496

$$\sum_{u=1}^{N-N_s+1} (Y_{R2.u} - \overline{Y}_{2u})^2 = 12,75$$

$$S_{nad}^2\{Y_2\} = \frac{12,75}{5} = 3,19$$

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.

$$F_{R1} = \frac{S_{nad}^2\{Y\}}{S^2\{\overline{Y}\}} = \frac{3,19}{0,28} = 11,3$$

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

$$F_{R1} = 11,3 < 19,25 = F_j$$

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.

$$Y_{R2} = 22,7 + 1,03x_1 + 1,34x_2 + 2,11x_3 - 1,03x_2x_3 - 0,94x_3^2$$

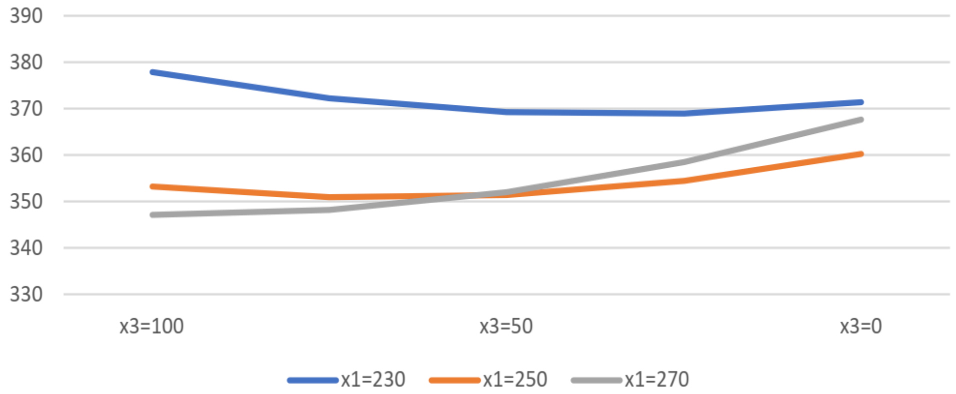

Figure 1.

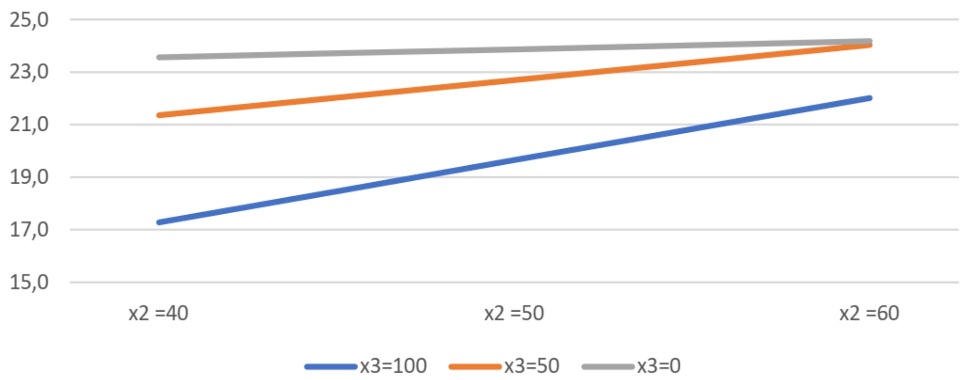

Figure 2.

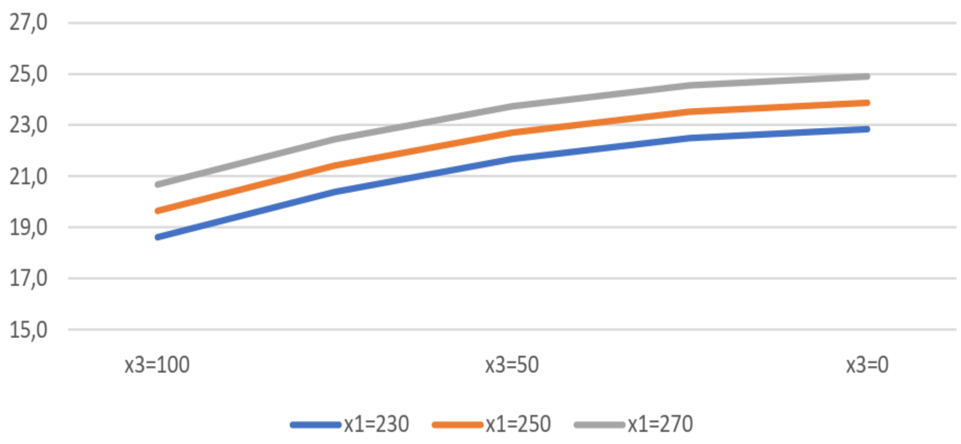

Figure 3.

The graph of the regression equation for the design of the mechanical properties of the fabric through the yarn had presented.

Conclusion. Figure 1 above shows the influence of the x1 and x3 factors, that is, the x1 factor on the density of the weft thread in the fabric, and the x2 factor on the tensile elongation of the fabric according to the composition of the weft thread. Elongation of the tissue at break - along with the increase in the density of the fabric, the elongation at break of the tissue also changes. When the density of the yarn is equal to 270, the elongation at break in the composition of the yarn is 100% polyester, compared to cotton.

Figure 2 shows a graph of changes in the x2 and x3 input factors, i.e. the thickness of the hemp yarn x2 and the percentage of cotton and polyester in the hemp yarn, where the thickness of the hemp yarn is equal to 60 100% cotton yarn has longer elongation at break compared to 100% polyester.

Figure 3 shows the effect of changing the percentage of cotton and polyester fibers in the yarn on the elongation at break according to the yarn density by the input factors x3 and x1, i.e. x3. When the yarn density is 270, three types of yarn change is changing in the same way.

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