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A THEORETICAL STUDY OF THE PERFORMANCE OF THE TANDA THREAD WETTING DEVICE BASED ON A MATHEMATICAL MODEL

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Abstract

In this article, the results of the device for wetting the tanda threads are studied on the basis of a mathematical model, in which the influencing factors are x_1- the volume of air supplied to the device in mm^3, x_2 - the distance between the wetting device and the tanda threads, mm, x_3 - the air temperature during moistening, indicators are obtained. As an output factor, Y_1 is the number of yarn breaks on the weaving loom (units). Selected and mathematical model results are presented.

Keywords: Input Factor, Air Volume, Humidification Device, Air Temperature, Levels Of Change, Mathematical Model, Regression, Fisher's Test, Number Of Thread Breaks, Dispersion, Student's Test.

Factors included as influencing factors x_1 **-** the volume of air supplied to the device in mm ^{3} x_2 **-** the distance between the threads of the body with the moistening device, mm , x_3 – air temperature in humidification °C, the indicators are obtained. The choice of levels and intervals of the studied factors is presented in Table 1.

Table 1: Choice of levels and intervals of change of factors under investigation

Name and designation of factors	Change levels			Change interval
	-1	0	1	
x_1 - volume of air supplied to the device, mm ^{3}	2·10-2	7.5·0-2	13·10-2	5.5·10-2
x_2 - the distance between the threads of the body with the moistening device, mm	20	40	60	20
x_3 – air temperature during humidification, °C .	10	15	20	5

In order to determine the regression coefficients, Student and Fisher's criteria were used to check whether the mathematical model was suitable or not.[1] Y_1 as an output factor – number of yarn breaks on the weaving loom (pieces).

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Table 2: Central non-composite experience matrix

No	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	68	3.4
2	+	-	0	-	0	0	+	+	0	67	2.6
3	-	+	0	-	0	0	+	+	0	66	3.4
4	-	-	0	+	0	0	+	+	0	60	2.6
5	+	0	+	0	+	0	+	0	+	69	3.1
6	+	0	-	0	-	0	+	0	+	64	2.4
7	-	0	+	0	-	0	+	0	+	62	3.4
8	-	0	-	0	+	0	+	0	+	59	2.6
9	0	+	+	0	0	+	0	+	+	61	2.7
10	0	+	-	0	0	-	0	+	+	60	3.7
11	0	-	+	0	0	-	0	+	+	58	3.4
12	0	-	-	0	0	+	0	+	+	50	4.2
13	0	0	0	0	0	0	0	0	0	52	2.6
14	0	0	0	0	0	0	0	0	0	55	3.1
15	0	0	0	0	0	0	0	0	0	50	2.3

From the results of TOT, it became clear that the studied process is represented by a higher order equation. Therefore, in order to obtain a second-order regression mathematical model, the central non-composite experiment (MNKT), which is somewhat simpler and convenient compared to other methods, and widely used in the research of technological processes of the cotton industry, was selected and implemented [2].

Based on the results of the experiment, we are looking for a second-order regression multifactor mathematical model [3]. As a result of this experiment, the regression model of the following general form can be obtained:

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

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

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

In Eq

b_0 ....b_1...– regression coefficients,

x_1, x_2,x_3– coded value of the factors.

- Y_1 - Calculation of regression models for the optimization of the number of threads breaking on the weaving loom:

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Regression coefficients are determined:

$$b_0 = \frac{1}{N_s}\sum_{u=1}^{N_s}\overline{Y_{\overline{u}}} = \frac{1}{3}(52 + 55 + 50) = 52{,}3$$

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

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

b_1 =0,125(68+67+(-66)+(-60)+69+64+(-62)+(-59))=2,63

b_2 =0,125(68+(-67)+66+(-60)+61+60+(-58)+(-50))=2,50

b_3 =0,125(69+(-64)+62+(-59)+61+(-60)+58+(-50))=2,13

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

b_{12} =0,25(68+(-67+(-66)+60)=-1,25

b_{13} =0,25(69+(-64)+(-62)+59)=0,50

b_{23} =0,25(61+(-60)+(-58)+50)=-1,75

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

$\sum x_1^2\overline{Y_u} = 68 + 67 + 66 + 60 + 69 + 64 + 62 + 59 = 515$

$\sum x_2^2\overline{Y_u} = 68 + 67 + 66 + 60 + 61 + 60 + 58 + 50 = 490$

$\sum x_3^2\overline{Y_u} = 69 + 64 + 62 + 59 + 61 + 60 + 58 + 50 = 483$

$\sum \overline{Y_u} = 68 + 67 + 66 + 60 + 69 + 64 + 62 + 59 + 61 + 60 + 58 + 50 + 52 + 55 + 50 = 901$

$\sum_{i=1}^{M}\sum x_i^2\overline{Y_u} = 515 + 490 + 483 = 1488$

b_{11}=0,125*515+0,0625*1488-0,166*901=7,81

b_{22}=0,125*490+0,0625*1488-0,166*901=4,68

b_{33}=0,125*483+0,0625*1488-0,166*901=3,81

Taking into account the determined regression coefficients, the equation is written:

$Y_{R1} = 52{,}3 + 2{,}63x_1 + 2{,}50x_2 + 2{,}13x_3 - 1{,}25x_1x_2 + 0{,}50x_1x_3 - 1{,}75x_2x_3 + 7{,}81x_1^2 + 4{,}68x_2^2 + 3{,}81x_3^2$

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Y 1 - The number of threads breaks on the weaving loom optimization determines the significance of the regression coefficients, for this, the variance of the output parameter is determined and, on this basis, the variance in the determination of the regression coefficients is calculated:

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

$S^2\{\overline{Y}\} = \frac{1}{3-1} \cdot 8 = 4$

$S^2\{b_0\} = g_1 S^2\{\overline{Y}\} = 0{,}2 \cdot 4 = 0{,}8$

$S^2\{b_i\} = g_3 S^2\{\overline{Y}\} = 0{,}125 \cdot 4 = 0{,}5$

$S^2\{b_{ij}\} = g_4 S^2\{\overline{Y}\} = 0{,}25 \cdot 4 = 1$

$S^2\{b_{ii}\} = g_7 S^2\{\overline{Y}\} = 0{,}3125 \cdot 4 = 1{,}25$

The mean squared deviation in determining the regression coefficients is found:

$S\{b_0\} = 0{,}89; \quad S\{b_i\} = 0{,}70; \quad S\{b_{ij}\} = 1; \quad S\{b_{ii}\} = 1{,}11$

After that, the calculated value of Student's criterion is determined using the following equation:

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

$t_R\{b_0\} = \frac{|52{,}3|}{0{,}89} = 58{,}7 \qquad t_R\{b_{12}\} = \frac{|-1{,}25|}{1} = 1{,}25$

$t_R\{b_1\} = \frac{|2{,}63|}{0{,}70} = 3{,}71 \qquad t_R\{b_{13}\} = \frac{|0{,}50|}{1} = 0{,}50$

$t_R\{b_2\} = \frac{|2{,}50|}{0{,}70} = 3{,}54 \qquad t_R\{b_{23}\} = \frac{|1{,}75|}{1} = 1{,}75$

$t_R\{b_3\} = \frac{|2{,}13|}{0{,}70} = 3{,}01 \qquad t_R\{b_{11}\} = \frac{|7{,}81|}{1{,}11} = 6{,}98$

$t_R\{b_{22}\} = \frac{|4{,}68|}{1{,}11} = 4{,}19 \qquad t_R\{b_{33}\} = \frac{|3{,}81|}{1{,}11} = 3{,}41$

The table value of the student criterion is obtained from Appendix 3:

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

It is known that if the calculated value of the criterion is smaller than the table value, then that coefficient is not significant and it is removed from the equation. In the studies b_{12}, it was found b_{13} that the insignificant for the studied parameters: b_{23} .The equation with significant coefficients is rewritten: coefficient is

$$Y_{R1} = 52{,}3 + 2{,}63x_1 + 2{,}50x_2 + 2{,}13x_3 + 7{,}81x_1^2 + 4{,}68x_2^2 + 3{,}81x_3^2$$

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Obtained Y 1 - checking the adequacy of the equations of the number of threads breaking on the weaving loom. The test is performed using Fisher's test. The estimated value of Fisher's criterion is determined. The estimated value of the optimized factor Y 1 is calculated by putting the coded values of all the columns of the table in the matrix (–1, 0 and +1) of equation 2.3. Values are taken row-wise, not column-wise. Y The calculations for the formula are as follows, and the calculation results are included in table 3.4: Y 1 is the calculation of the number of threads in the body by the number of interruptions (pieces) by putting their coded values into the equation: In order to check whether the above-mentioned regret mathematical model is adequate or not, we determine using the calculation value of Fisher's criterion.

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

here

$S^2\{\overline{Y_1}\} = \frac{\sum_{u=1}^{N} S^2\{Y\}}{N_S - 1} = \frac{45,5}{3-1} = 22,75$

$$Y_{R1} = 52,3 + 2,63x_1 + 2,50x_2 + 2,13x_3 + 7,81x_1^2 + 4,68x_2^2 + 3,81x_3^2$$

$Y_{R1.1} = 52,3 + 2,63 + 2,50 + 7,81 + 4,68 = 69,92$

$Y_{R1.2} = 52,3 + 2,63 - 2,50 + 7,81 + 4,68 = 64,92$

$Y_{R1.3} = 52,3 - 2,63 + 2,50 + 7,81 + 4,68 = 64,66$

$Y_{R1.4} = 52,3 - 2,63 - 2,50 + 7,81 + 4,68 = 59,66$

$Y_{R1.5} = 52,3 + 2,63 + 2,13 + 7,81 + 3,81 = 68,68$

$Y_{R1.6} = 52,3 + 2,63 - 2,13 + 7,81 + 3,81 = 64,42$

$Y_{R1.7} = 52,3 - 2,63 + 2,13 + 7,81 + 3,81 = 63,42$

$Y_{R1.8} = 52,3 - 2,63 - 2,13 + 7,81 + 3,81 = 59,16$

$Y_{R1.9} = 52,3 + 2,50 + 2,13 + 4,68 + 3,81 = 65,42$

$Y_{R1.10} = 52,3 + 2,50 - 2,13 + 4,68 + 3,81 = 61,16$

$Y_{R1.11} = 52,3 - 2,50 + 2,13 + 4,68 + 3,81 = 60,42$

$Y_{R1.12} = 52,3 - 2,50 - 2,13 + 4,68 + 3,81 = 56,16$

Table 3

№	Y_i	Y_{Ri}	$(Y_{Ri}-Y_i)$	$(Y_i-Y_{Ri})^2$
1	68	64.92	3.08	9,486
2	67	64.92	2.08	4,326
3	66	64,66	1.34	1,796
4	60	59.66	0.34	0.116
5	69	68,68	0.32	0.102
6	64	64.42	-0.42	0.176
7	62	63.42	-1.42	2,016
8	59	59.16	-0.16	0.026
9	61	65.42	-4.42	19,536

10	60	61.16	-1.16	1,346
11	58	60.42	-2.42	5,856
12	50	56.16	-6.16	37,946

$$\sum_{u=1}^{N-N_S+1}(Y_{R1.u}-\overline{Y}_{1u})^2 = 82{,}729$$

$$S^2_{nad}\{Y_1\} = \frac{82{,}729}{4} = 20{,}68$$

It is known that if the calculated value of the criterion is smaller than the table value, then that coefficient proves that the calculations were carried out correctly.

$$F_{R1} = \frac{S^2_{nad}\{Y\}}{S^2\{\overline{Y}\}} = \frac{20{,}68}{22{,}75} = 0{,}90$$

$$F_j\left[P_D = 0{,}95;\ f\left\{S^2_{nad}\{Y\}\right\} = 15-6-(3-1) = 5; f\{S^2_u\} = 3-1 = 2\right] = 4{,}74$$

$$F_{R1} = 0{,}90 < 4{,}74 = F_j$$

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

Analysis of the mathematical model of determining the number of breaks in Tanda threads

Since the equation constructed to determine the characteristics of the output parameter for research is three-dimensional, it is X_i =0 considered as one of the input factors in the analysis (the central state), and we construct a two-dimensional graph by transforming the models into 3 equations the regression model on the number of yarn breaks in the weaving loom Y $_1$ as the equation when the number of yarn breaks in the weaving loom is (x_3 =0).

$$Y_{R1} = 52{,}3 + 2{,}63x_1 + 2{,}50x_2 + 7{,}81x_1^2 + 4{,}68x_2^2$$

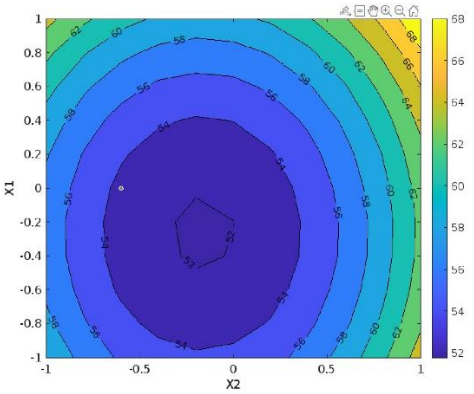

Figure 1: Regression model for the number of threads breaking, in which the graph of the dependence of the air volume supplied to the device and the distance between the threads and the humidification device

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As can be seen from the graph, when the incoming second (x_1) and third (x_2) factors change from the accepted minimum (-1) to the maximum (1) value, and x_3 =0, using the average value of the first factor (Y_1), the values are depicted in terms of the number of warp thread breaks on the loom. Using the drawing on the device for wetting the tanda threads on the weaving loom x_1 - volume of air

supplied to the device (mm 3) 2 ·10-2 ÷7.5·10-2 at intervals and x_2 – the distance between the weft threads with the moistening device, (mm) 20 ÷ 40 values (Y_1), the graph of the number of breaks of the weft threads on the weaving loom

is described. In this case, it was found that the number of breakages of the weft threads on the loom has the lowest value when the volume of air supplied to the device is 7.5·10-2 3 mm and the distance between the weft threads and the wetting device is 40 mm.

We rewrite the regression model according to the 7.5·10-2 number of threads breaking on the weaving loom Y_1 , and the air volume supplied to the device is mm 3 (x_1 =0) as an average condition.

$$Y_{R1} = 52{,}3 + 2{,}50x_2 + 2{,}13x_3 + 4{,}68x_2^2 + 3{,}81x_3^2$$

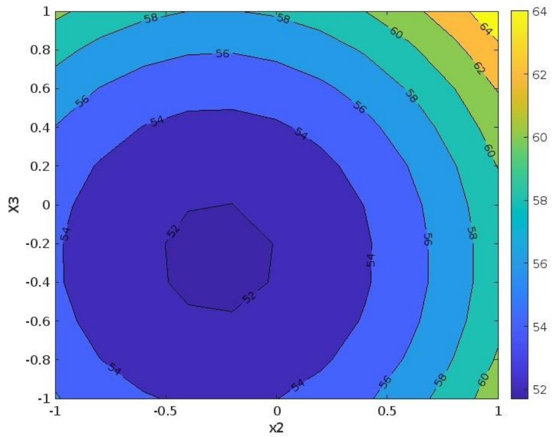

Figure 2: Regression model for the number of weft yarn breakages on weaving looms and graph of relationship between weft thread spacing and air temperature during wetting with a wetting device

As can be seen from the graph, the values of the first (x_3) and third (x_2) factors are depicted in terms of the number of warp thread breaks on weaving looms when the input changes from the accepted minimum (-1) to the maximum (1) value and x_1 =0, using the average value of the second factor (Y_1). A device for wetting the tanda threads on the weaving loom using the drawing x_2 -the distance between the weft threads and the weft thread, (mm) in the range of 20 ÷ 40, x_3 air temperature in the wetting range (°C) 10 ÷ 15, and (Y_1) the number of weft thread breaks on the loom is reaching its lowest values.

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We rewrite the equation for the average condition of the weft thread spacing, (mm) (x_2 =0) with the wetting device of the regression model according to the number of weft yarn breaks on the weaving looms.

$$Y_{R1} = 52{,}3 + 2{,}63x_1 + 2{,}13x_3 + 3{,}81x_3^2$$

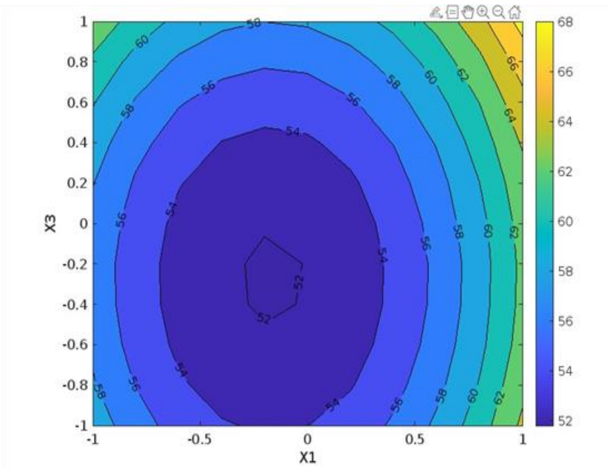

Figure 3: The graph of dependence of the air volume supplied to the regression device and the air temperature during humidification according to the number of thread breaks on the weaving loom

Values of the number of breaks of warp yarns on the weaving loom are depicted when the incoming first (x_1) and second (x_3) factors change from the accepted minimum (-1) to the maximum (1) value and x_2 =0, .using the average value of the third factor (Y_1). A device for wetting threads on a weaving loom using a drawing x 1 - volume of air supplied to the device mm 3,2·10-2 ÷7.5·10-2 ., in the range x_3 – the air temperature in humidification is in the range 10 ÷ 15 and (Y_1) on the weaving loom, the number of yarn breaks is reaching the smallest values

CONCULATION

1. (Y_1), the graph of the number of breaks of the weft threads on the weaving loom is described. In this case, it was found that the number of breakages of the weft threads on the loom has the lowest value when the volume of air supplied to the device is ˙7.5·10-2 3 mm and the distance between the weft threads and the wetting device is 40 mm.
2. As can be seen from the graph, the values of the first (x_3) and third (x_2) factors are depicted in terms of the number of warp thread breaks on weaving looms when the input changes from the accepted minimum (-1) to the maximum value and x_1 =0, using the average value of the second factor (Y_1). A device for wetting the tanda threads on the weaving loom using the drawing x_2- the distance between the weft threads and the weft thread, (mm) in the range of 20 ÷ 40, x_3 air temperature in the wetting range (℃) 10 ÷ 15 , and (Y_1) the number of weft thread breaks on the loom is reaching its lowest values.

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3. Values of the number of breaks of warp yarns on the weaving loom are depicted when the incoming first (x_1) and second (x_3) factors change from the accepted minimum (-1) to the maximum (1) value and x_2 =0, .using the average value of the third factor (Y_1). A device for wetting threads on a weaving loom using a drawing x 1 - volume of air supplied to the device mm 3,2·10-2 ÷7.5·10-2 .,,"ᵛ in the range x_3 – the air temperature in humidification is in the range 10 ÷ 15 and (Y_1) on the weaving loom, the number of yarn breaks is reaching the smallest values

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