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OBTAINING AND ANALYZING CORRELATIONAL MATHEMATICAL MODELS OF THE SIZING PROCESS

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Abstract: In this article, the influence of incoming and outgoing factors affecting the process of carding yarns in carding machine, as well as the quality of winding on the weaving bobbin, etc., are analyzed. The selected factors in the process of measuring the experiment in accordance with all the requirements of the theory of mathematical planning are the linear density of the yarn, the resistance of the air and the moisture of the raw materials. the possibility of disruption of processes and results is taken into account.

Keywords: yarn, fiber, warp, tension, speed, luquor, wiving, compression, machine, factor.

Introduction. The process of grinding warp yarns on machine sizing depends on the following factors: X_1- fiber content of warp yarns, X_2- warp yarns linear density, X_3- yarns tension, X4- machine speed, X5- room temperature, X6- relative humidity of the room, X7- he quality of the winding on the weaving reel, etc.

For incoming factors concentration of size luquor, %; compression shaft pressure, kPa; The temperature of the middle drum of the sizing machine, C received. The breaking strength of the yarns was taken as the output factors.

The selected factors meet all the requirements of the theory of mathematical planning of the experiment, the factors are not interchangeable with each other, they can be measured with the help of existing tools, in a wide range of minimum and maximum values, and they can be accepted with the necessary accuracy. [1].

During the experiment, factors such as waspr yarns line density, sizing machine speed, room temperature, room relative humidity, warp yarns humidity were kept constant. [2].

In the sizing process, the linear density of waro yarn, the air resistance and the moisture content of the raw material are small influencing factors, taking into account their instability in time and the possibility of distortion of various processes and results in a large number of experiments, their influence mitigated by randomization of experiments [3].

Methodology & empirical analysis. At the first stage, the initial input factors are set. In order to obtain an experimental-statistical mathematical model and determine the degree of influence of various factors on the optimization index, a rotatable central composite experiment was conducted, which not only evaluates the influence of each factor on the optimization index, but also their interaction. allows. Based on the analysis of a priori data, the results of preliminary experiments and the technical capabilities of the weaving machine, the value and intervals of the main factors were selected, the level of the factors and the intervals are listed in Table 1

A central composite experiment was conducted in a matrix containing three experimental groups that were symmetrical and at different distances from the experimental center. [1].

Table 1. Values of variable factors

Experimental conditions	Actual values i-factor			oded values are the i-factor		
	X_1, %	X_2, kPa	X_3, ^{0}C	x_1	x_2	x_3
The basic level of the factor, X_{ai}	12,22	6	90	0	0	0
The range of variation for the factor, I_i	3	0,5	10	1	1	1
High level of the factor, X_{max}	15,22	6,5	100	+1	+1	+1
The low level of the factor, X_{min}	9,22	5,5	80	-1	-1	-1

The Box 3 planning matrix is used during the experiment to obtain a mathematical model of the technological process.

The results of the experiment were processed in the following sequence

1. Determining the variance of the output parameter is the sum of the squared deviations divided by the number of the corresponding degrees of freedom.

$$S_u^2\{Y\} = \frac{1}{m-1}\sum_{i=1}^{m}(Y_i - \bar{Y})^2$$

where m = 3 is the number of repetitions in the matrix experiment; N = 14 is the number of experiments in the matrix.

$$S_1^2\{Y\} = \frac{1}{3-1}\left[(276,5-276,5)^2 + (277,1-276,5)^2 + (275,9-276,5)^2\right] = 0,36.$$

$S_2^2\{Y\} = 0,20$; $S_3^2\{Y\} = 0,06$; $S_4^2\{Y\} = 0,12$; $S_5^2\{Y\} = 1,17$; $S_6^2\{Y\} = 0,92$; $S_7^2\{Y\} = 1,47$; $S_8^2\{Y\} = 0,30$; $S_9^2\{Y\} = 0,42$; $S_{10}^2\{Y\} = 0,73$; $S_{11}^2\{Y\} = 1,11$; $S_{12}^2\{Y\} = 1,29$; $S_{13}^2\{Y\} = 0,16$; $S_{14}^2\{Y\} = 0,36$.

Table 2. Results of active experience

U	Planning matrix with coded and natural values of factors						Tensile strength of thread, N			
	x_1	x_2	x_3	X_1, %	X_2, kPa	X_3, ^{0}C	Y_1	Y_2	Y_3	Y_u
1	+	+	+	15,22	6,5	100	276,5	277,1	275,9	276,5
2	-	+	+	9,22	6,5	100	275,7	276,6	276,2	276,17
3	+	-	+	15,22	5,5	100	277,3	276,8	277,1	277,07
4	-	-	+	9,22	5,5	100	258,9	259,2	259,6	259,23
5	+	+	-	15,22	6,5	80	260,6	261,2	262,7	261,5
6	-	+	-	9,22	6,5	80	257,2	258,4	259,1	258,23
7	+	-	-	15,22	5,5	80	263,3	264,2	265,7	264,4

8	-	-	-	9,22	5,5	80	255,7	255,2	256,3	255,73
9	+	0	0	15,22	6	90	262,1	260,8	261,5	261,47
10	-	0	0	9,22	6	90	261,7	262,4	260,7	261,6
11	0	+	0	12,22	6,5	90	265,2	264,3	266,4	265,3
12	0	-	0	12,22	5,5	90	274,3	275,9	273,7	274,63
13	0	0	+	12,22	6	100	278,6	277,8	278,3	278,23
14	0	0	-	12,22	6	80	275,6	276,8	276,1	276,17
∑										267,59

2. We remove sharply different values.

We will consider this operation when analyzing the first experiment of the matrix at U=1, Umax=277.1, Umin=275.9. The calculation is carried out using the Smirnov-Grabs criterion according to the formulas,

$$V_{R\max} = \frac{Y_{i\max} - \bar{Y}}{S\{Y\}} \sqrt{\frac{m}{m-1}}, \quad (2)$$

$$V_{R\min} = \frac{\bar{Y} - Y_{i\min}}{S\{Y\}} \sqrt{\frac{m}{m-1}}, \quad (3)$$

Here $S\{Y\} = \sqrt{S^2\{Y\}} = \sqrt{0,36} = 0,6$.

$$V_{R\max} = \frac{277,1 - 276,5}{0,6}\sqrt{\frac{3}{3-1}} = 1,22, \qquad V_{R\min} = \frac{276,5 - 275,9}{0,6}\sqrt{\frac{3}{3-1}} = 1,22.$$

We find the tabular value of the Smirnov-Grabs criterion using Appendix 1 $V_{J[PD=0,95;\, m=3]} = 1,412$. So $V_{R\max} < V_J$ and $V_{R\max} < V_J$ since, the considered values U_{max}=276.5, U_{min}=275.9 are not significantly different and remain for further statistical processing.

3. Testing the hypothesis of homogeneity of variance in matrix experiments. If the number of repetitions in the experiment is the same for all experiments in the matrix, then the Cochrane criterion is used to check the homogeneity of variances, the calculated value of which is determined by the following formula.

$$G_R = \frac{S^2_{u\max}}{\sum_{u=1}^{N} S^2_u\{Y\}}, \quad (4)$$

Here $S^2_{u\max}$ - he maximum variance of the output factor; *U*- number of experiments; $\sum_{u=1}^{N} S^2_u\{Y\}$ – the sum of all variances. $G_R = \frac{1,47}{8,7} = 0,169$.

The calculated value of the Cochrane criterion is compared with its value in the table $G_{J\left[P_D;N;f\{S^2_u\}=m-1=2\right]}$. (Appendix 3). If $G_R < G_J$ if, $S^2_u\{Y\}$ dispersions of are homogeneous, and the performed experiment has the characteristic of reproducibility.

$G_{J\left[P_D;N;f\{S^2_u\}=m-1=2\right]} = 0,353$. since the hypothesis of uniformity of dispersion in matrix experiments is not rejected, all experiments are equally accurate and repeatable.

4. The mean square variance of the output factor.

The average variance describes the average spread of the output factor values relative to the average values of the factors at each level, that is, the experimental error in the experiment. $S_{(1)}^2\{Y\} = \frac{1}{N}\sum_{u=1}^{N} S_u^2\{Y\}$. (5)

The number of degrees of freedom of reproduction variance is determined by the following formula:

$$f\left\{S^2\{Y\}\right\} = N\cdot(m-1) = 14\cdot(3-1) = 28. \tag{6}$$

$$S^2\{Y\} = \frac{1}{14}\cdot 8,7 = 0,62.$$

5. Regression coefficients are determined using the following formulas:

$$b_0 = -\frac{1}{16}\cdot\sum_{u=1}^{8} Y_u + \frac{1}{4}\cdot\sum_{u=9}^{14} Y_u. \tag{7}$$

$$\text{or } b_0 = 0,40625\sum_{u=1}^{N}\overline{Y_u} - 0,15625\sum_{i=1}^{m}\sum_{u=1}^{N} x_{iu}^2\cdot\overline{Y}_u. \tag{8}$$

$$b_i = 0,1\sum_{u=1}^{N} x_{iu}\cdot\overline{Y}_u, \tag{9}$$

$$b_{ij} = 0,1250\sum_{u=1}^{N} x_{iu}\cdot x_{ju}\cdot\overline{Y}_u, \tag{10}$$

$$b_{ii} = \frac{1}{16}\cdot\sum_{u=1}^{8} Y_u - \frac{1}{4}\cdot\sum_{u=9}^{14} Y_u + \frac{1}{2}\cdot\sum_{u=9}^{14} x_{iu}\cdot\overline{Y}_u, \tag{11}$$

here b_0- the Free term of the equation; b_i- linear coefficients; b_{ii}- coefficients of two-way interaction of factors; b_{ij}-coefficients of the second degree of the variabl

$$b_0 = -\frac{1}{16}\cdot(276,5+276,17+277,07+259,23+261,5+258,23+264,4+255,73)+$$

$$+\frac{1}{4}(261,47+261,6+265,3+274,63+278,23+276,17) = 271,3.$$

$$b_1 = 2,99;\ b_2 = 0,66;\ b_3 = 5,11;\ b_{12} = -2,86;\ b_{13} = 0,78;$$

$$b_{23} = 2,09;\ b_{11} = -9,76;\ b_{22} = -1,33;\ b_{33} = 5,90.$$

6. The experiment using the given matrix makes it possible to obtain a second-order mathematical model describing the influence of the factors *x1, x2, x3* on the selected optimization parameter in the following form: (12)

Based on this formula, we will make a mathematical model.

$$Y = 271,3 + 2,99x_1 + 0,66x_2 + 5,11x_3 - 9,76x_1^2 - 1,31x_2^2 + 5,9x_3^2 + 2,86x_{12} + 0,77x_{13} + 2,09x_{23}.$$

However, this mathematical model is not final, and after testing the significance of the regression coefficients, it was determined.

7. The variances of the regression coefficients are determined using the following formulas:

$$S^2\{b_0\} = 0,40625\cdot S^2\left\{\overline{Y}\right\}, \tag{13}$$

$$S^2\{b_i\} = 0,1 \cdot S^2\left\{\overline{Y}\right\}, \quad (14)$$

$$S^2\{b_{ij}\} = 0,125 \cdot S^2\left\{\overline{Y}\right\}, \quad (15)$$

$$S^2\{b_{ii}\} = 0,40625 \cdot S^2\left\{\overline{Y}\right\}, \quad (16)$$

Here S2{Y⁞} is the repeatability dispersion, which is determined by the following formula:

$$S^2\left\{\overline{Y}\right\} = \frac{1}{m} S^2\left\{Y\right\} = \frac{1}{3} \cdot 0,62 = 0,2066, \quad (17)$$

$S^2\{b_0\} = 0,40625 \cdot 0,2066 = 0,0839$; $S\{b_0\} = 0,29$.

$S^2\{b_i\} = 0,1 \cdot 0,2066 = 0,02066$; $S\{b_i\} = 0,14$.

$S^2\{b_{ij}\} = 0,125 \cdot 0,2066 = 0,0258$; $S\{b_{ij}\} = 0,16$.

$S^2\{b_{ii}\} = 0,40625 \cdot 0,2066 = 0,0839$; $S\{b_{ii}\} = 0,29$.

8. We examine the significance of the regression coefficients.

Significance is the condition in which the statistical data found in two or more sums are significantly different from each other or from the sums in other selected values than would be expected due to random variation.

To evaluate the significance of the regression coefficients, the Student's test is used (refers to the t-distribution; describes the deviation of the average value of the sum from the normal value of the total sum), its calculated value is determined by the following formula:

$$t_R\left\{b_i\right\} = \frac{|b_i|}{S\left\{b_i\right\}}, \quad (18)$$

Here S{bi} is the standard deviation of the regression coefficient b_i.

The calculated value of Student's criterion is compared with the confidence probability p_D=0.95 and the number of degrees of freedom condition t_J (Appendix 2).

$f\left\{S^2\{Y\}\right\} = N(m-1) = 14 \cdot (3-1) = 28$,

so $t_{J[P_D=0,95;\ f=28]} = 2,048$.

If $t_R > t_J$ then the obtained coefficients are significant and therefore the relationship between Y and X is significant.

$t_R\left\{b_0\right\} = \frac{271,3}{0,0842} = 3223,9$. b_0 the hypothesis about the significance of the regression coefficient is not rejected.

$t_R\left\{b_1\right\} = 144,67$. b_1 the hypothesis about the significance of the regression coefficient is not rejected.

$t_R\left\{b_2\right\} = 32,023$. b_2 the hypothesis about the significance of the regression coefficient is not rejected

$t_R\left\{b_3\right\} = 247,01$. b_3 the hypothesis about the significance of the regression coefficient is not rejected.

$t_R\{b_{12}\}=110,55$. b_{12} the hypothesis about the significance of the regression coefficient is not rejected.

$t_R\{b_{13}\}=30,092$. b_{13} the hypothesis about the significance of the regression coefficient is not rejected.

$t_R\{b_{23}\}=80,943$. b_{23} regressiya koeffitsientining ahamiyati haqidagi gipoteza rad etilmaydi.

$t_R\{b_{11}\}=116,014$. b_{11} the hypothesis about the significance of the regression coefficient is not rejected.

$t_R\{b_{22}\}=15,82$. b_{22} the hypothesis about the significance of the regression coefficient is not rejected.

$t_R\{b_{33}\}=70,136$. b_{33} the hypothesis about the significance of the regression coefficient is not rejected.

For the considered equation, we get the necessary mathematical model, which includes only significant coefficients. No coefficients were rejected based on Student's criterion

$$Y=271,3+2,99x_1+0,66x_2+5,11x_3-9,76x_1^2-1,31x_2^2+5,9x_3^2+2,86x_{12}+0,77x_{13}+2,09x_{23}.$$

The resulting equation shows the relationship between the breaking strength of the warped yarn in the warping machine, the warp concentration, the pressure in the compression shafts, and the temperature of the middle drum of the warping machine.

9. The resulting equation shows the relationship between the breaking strength of the warped yarn in the warping machine, the warp concentration, the pressure in the compression shafts, and the temperature of the middle drum of the warping machine.

$$F_R=\frac{S_{ad}^2\{Y\}}{S^2\{Y\}}=\frac{S_{nad}^2\{Y\}}{S^2\{\overline{Y}\}},\ \text{agar}\ S_{nad}^2\{Y\}>S^2\{\overline{Y}\} \tag{19}$$

$$F_R=\frac{S^2\{Y\}}{S_{ad}^2\{Y\}}=\frac{S^2\{\overline{Y}\}}{S_{nad}^2\{Y\}},\ \text{agar}\ S_{nad}^2\{Y\}<S^2\{\overline{Y}\} \tag{20}$$

Here $S_{nad}^2\{Y\}$ - (inadequate) variance resulting from non-compliance is determined by the following formula:

$$S_{nad}^2\{Y\}=\frac{\sum_{u=1}^{N}(Y_u-Y_{RU})^2}{N-N_k}, \tag{21}$$

Here N_k is the number of significant coefficients.

Results. Using the obtained mathematical model, we calculate the YRU values and summarize them in Table 3.

Table 3. Calculation results

U	Y_U	$S_u^2\{Y\}$	V_{Rmax}	V_{Rmin}	Y_{RU}	Y_U-Y_{RU}	$(Y_U$-$Y_{RU})^2$
1	276,50	0,36	1,22	1,22	274,89	1,61	2,58
2	276,17	0,20	1,18	1,27	273,07	3,10	9,61
3	277,07	0,06	1,14	1,30	275,1	1,97	3,87
4	259,23	0,12	1,28	1,16	261,82	-2,59	6,71
5	261,50	1,17	1,36	1,02	258,91	2,59	6,71
6	258,23	0,92	1,10	1,32	260,2	-1,97	3,87
7	264,40	1,47	1,31	1,11	267,5	-3,10	9,61
8	255,73	0,30	1,26	1,19	257,34	-1,61	2,58
9	261,47	0,42	1,19	1,25	264,53	-3,06	9,38
10	261,60	0,73	1,15	1,29	258,54	3,06	9,38
11	265,30	1,11	1,28	1,16	270,63	-5,33	28,41
12	274,63	1,29	1,36	1,01	269,3	5,33	28,41
13	278,23	0,16	1,11	1,31	282,32	-4,08	16,67
14	276,17	0,36	1,29	1,15	272,08	4,08	16,67
∑	267,59	8,7					154,47

$$S_{nad}^2\{Y\} = \frac{154,47}{(14-6)} = 19,308$$

So, $S_{nad}^2\{Y\} > S^2\{\overline{Y}\}$ from this 19,308>8,7 then the estimated value of Fisher's criterion is determined by the following formula.

$$F_R = \frac{S_{ad}^2\{Y\}}{S^2\{Y\}} = \frac{S_{nad}^2\{Y\}}{S^2\{\overline{Y}\}} = \frac{19,308}{8,7} = 2,21$$

Estimated value of Fisher's criterion F_R confidence probability p_D=0.95, $f\{S_{nad}^2\} = N - N_k$ and $f\{S^2\}$ the table value with the number of degrees of freedom is compared to F_J (Appendix 4). If $F_R<F_J$ if there is, then the hypothesis of the model's correspondence to the experimental data is not rejected.

$$F_{J\left[P_D=0,95;\ f\{S_y^2\}=14(3-1)=28;\ f\{S_{nad}^2\}=14-6=8\right]} = 2,29$$

$F_R<F_J$ because the hypothesis about the adequacy of the model is not rejected.

Conclusions. General conclusions The resulting mathematical model of the technological process of weaving yarns with linear density T=30 on the BENINGER weaving machine is as follows:

$$Y = 271,3 + 2,99x_1 + 0,66x_2 + 5,11x_3 - 9,76x_1^2 - 1,31x_2^2 + 5,9x_3^2 + 2,86x_{12} + 0,77x_{13} + 2,09x_{23}$$

We plot the values of the input factors based on the obtained formula (Y_r). We analyze the graph of the dependence of the incoming factors, X_1- concentration of ash and X_2- on the pressure in the compression shafts (Fig. 1). As can be seen from the graph, as the concentration of ash increases, the pressure in the compression shafts also increases, which leads to an increase in the breaking force.

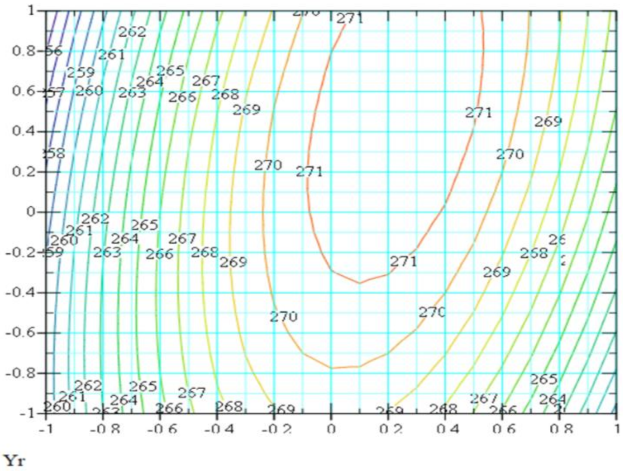


Figure 1. Dependence of sizing concentration (X_1) on compression shafts pressure (X_2) in machine sizing is isolines

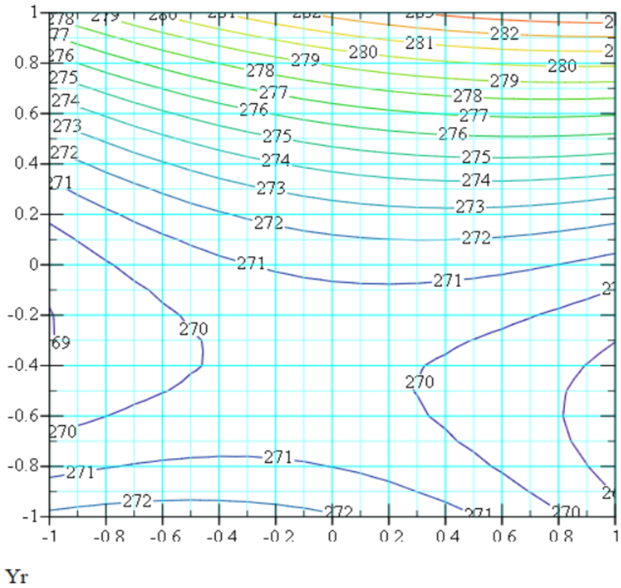


Figure 2. Dependence of the pressure on the compression shafts (X_2) on the machine sizing and the temperature of the drum (X_3) in the middle of the machine sizing are isolines

In the graph of the dependence of the pressure on the compression shafts X_2- and X_3- on the temperature of the drum in the sizing machine (Fig. 4.2), these values change (increase or decrease) relative to each other. Only as a result of a decrease in pressure on the compression shafts, the amount of sizing increases. As a result, when the temperature rises, warp yarns burns occur.

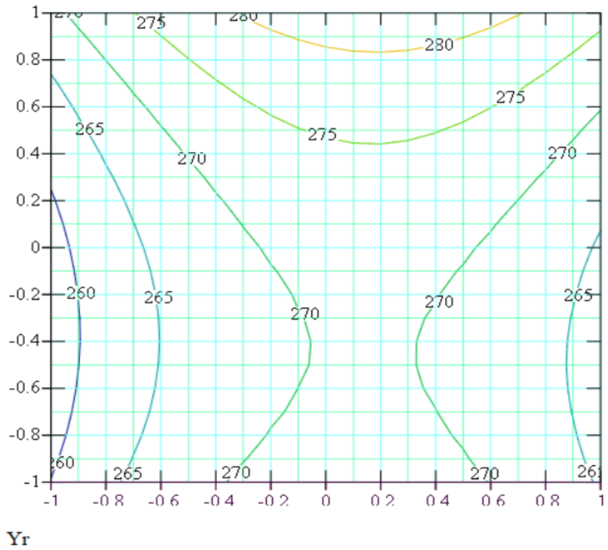
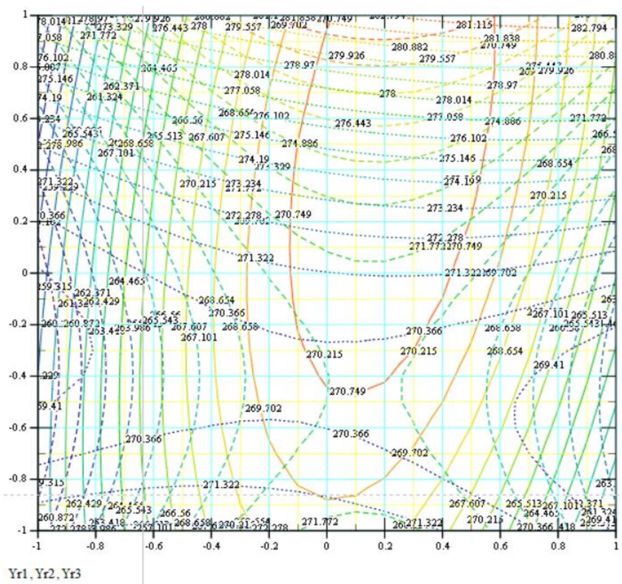


Figure 4.3. Dependence of sizing concentration (X_1) in the size luquor machine on the temperature of the drum (X_3) in the middle of the sizing machine is isolines

In the graph of the dependence of the concentration of input factors X_1-size luquor on the temperature of the drum between X_3 (Fig. 4.3), the temperature of the drum in the middle of the sizing machine decreases with the increase of size luquor concentration.



4-Figure. $Y_{r1}(x_1,x_2)$, $Y_{r1}(x_2,x_3)$, $Y_{r1}(x_1,x_3)$ intersection of graphs

Based on the intersection of the graphs of the input factors (Fig. 4.4), we can determine the values for the optimal operation of the sizing machine. In this case, option 13 means:

1. Sizing concentration, X_1=12,22 %;
2. Compression shaft pressure, X_2=6 kPa;

3. The temperature of the middle drum, X_3=100 ^{0}C Size luquored on the sizing machine warp yarns will be the most optimal option.

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