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NamMTI ILMIY-TEXNIKA JURNALI TAHRIR HAY'ATI A'ZOLARI

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DETERMINATION OF OPTIMAL PARAMETERS OF AN ADVANCED DEVICE FOR CLEANING COTTON FROM LARGE IMPURITIES BASED ON A MATHEMATICAL MODEL

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Abstract: This paper presents the determination of optimal operating parameters of a cotton cleaning machine designed for the removal of large impurities, based on a mathematical modeling approach. The study focuses on modifying the shape and diameter of the grate bars (kolosniks), which constitute the main working element of the cleaning device. Experimental data were processed using a mathematical model, and the obtained results were presented in tabular and graphical forms. The analysis of the graphs allowed determination of the optimal values of the grate bar diameter, the clearance between the saw drum and the grate bars, and the rotational speed of the saw drum, ensuring improved cleaning efficiency and reduced cotton losses.

Keywords: cotton, cottonseed, impurities, convex grate bars, cleaning efficiency, saw drum, optimization, waste composition, Fisher criterion, Student's t-test.

Introduction. Worldwide, extensive research is being conducted to improve technologies and equipment used in the primary processing of cotton, enhance the efficiency of production capacities, and implement advanced technical solutions. Particular attention is paid to the development of competitive semi-finished and finished textile products for the global cotton and textile market.

In this context, priority is given to studies aimed at selecting optimal cleaning processes depending on the initial contamination level of raw cotton and improving the operational performance of cotton cleaning equipment. Special emphasis is placed on the development of energy-efficient designs of working elements and optimization of technological regimes in cotton cleaning processes.

In the Republic of Uzbekistan, comprehensive measures are being implemented to expand the production of high-quality finished products, deepen localization, and increase the export potential of domestic manufacturers.

Methodology & empirical analysis. Experimental studies were conducted on a UXK-type unit equipped with newly designed convex-surface grate bars. The optimal parameters of the main working elements of the machine were theoretically investigated using a mathematical modeling approach.

It is well known that the diameter of the grate bars plays a significant role in improving cleaning efficiency and reducing the amount of cotton particles discharged together with impurities. In addition, the clearance between the saw drum and the grate bars, as well as the rotational speed of the saw drum, significantly affect both cleaning efficiency and cotton losses.

Therefore, the optimal values of the grate bar diameter, the clearance between the saw drum and the grate bars, and the saw drum rotational speed were determined based on theoretical investigations using a mathematical model.

Input Factors:

Grate bar diameter: X1=20÷30 mm,
 Clearance between saw drum and grate bars X2=12÷14 mm,
 Saw drum rotational speed X3=250÷350 mm.

Output Parameters:

Y1- Cleaning efficiency of the machine, %
 Y2- Cotton content in waste material

Table 1. Selection of the Variation Levels and Ranges of the Investigated Factor

| Names and Designations of the Factors | Variation Levels | | | Range of Variation |
|---|------------------|-----|-----|--------------------|
| | -1 | 0 | 1 | |
| x ₁ – Grate Bar Diameter (mm) | 20 | 25 | 30 | 5 |
| x ₂ - Clearance Between the Saw Drum and the Grate Bars (mm) | 12 | 14 | 16 | 2 |
| x ₃ - Saw Drum Rotational Speed (rpm) | 250 | 300 | 350 | 50 |

Table 2. A central composite experimental design (CCD) was selected due to its simplicity and widespread application in textile engineering research. Based on experimental results, second-order multifactor regression models were developed

| № | Factors | | | x ₁ x ₂ | x ₁ x ₃ | x ₂ x ₃ | x ₁ ² | x ₂ ² | x ₃ ² | Y ₁ | Y ₂ | S _u ² (Y ₁) | S _u ² (Y ₂) |
|----|----------------|----------------|----------------|-------------------------------|-------------------------------|-------------------------------|-----------------------------|-----------------------------|-----------------------------|----------------|----------------|---|---|
| | x ₁ | x ₂ | x ₃ | | | | | | | | | | |
| 1 | + | + | 0 | + | 0 | 0 | + | + | 0 | 77 | 14,6 | 17,8 | 1,5 |
| 2 | + | - | 0 | - | 0 | 0 | + | + | 0 | 88 | 11,8 | 14,9 | 1,2 |
| 3 | - | + | 0 | - | 0 | 0 | + | + | 0 | 72 | 17,3 | 31,8 | 0,8 |
| 4 | - | - | 0 | + | 0 | 0 | + | + | 0 | 83 | 14,7 | 33,4 | 1,6 |
| 5 | + | 0 | + | 0 | + | 0 | + | 0 | + | 87 | 11,4 | 7,9 | 1,1 |
| 6 | + | 0 | - | 0 | - | 0 | + | 0 | + | 75 | 18,4 | 15,4 | 1,4 |
| 7 | - | 0 | + | 0 | - | 0 | + | 0 | + | 73 | 14,6 | 18,4 | 1,2 |
| 8 | - | 0 | - | 0 | + | 0 | + | 0 | + | 69 | 21,6 | 8,9 | 1,6 |
| 9 | 0 | + | + | 0 | 0 | + | 0 | + | + | 71 | 12,9 | 16,6 | 0,9 |
| 10 | 0 | + | - | 0 | 0 | - | 0 | + | + | 72 | 19,9 | 16,9 | 1,2 |
| 11 | 0 | - | + | 0 | 0 | - | 0 | + | + | 87 | 10,1 | 14,6 | 1,5 |
| 12 | 0 | - | - | 0 | 0 | + | 0 | + | + | 72 | 19,2 | 10,8 | 1,5 |
| 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 91 | 8,9 | 6,8 | 0,6 |
| 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 91 | 9,1 | 8,9 | 1,1 |
| 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 91 | 9,1 | 9,7 | 0,7 |

Based on the results of the experimental-theoretical analysis, it was established that the investigated process is described by a higher-order equation. Therefore, in order to obtain a second-order regression mathematical model, a central composite design (CCD) was selected and implemented, as it is comparatively simpler and more convenient than other methods and is widely used in studies of technological processes in the textile industry.

On the basis of the experimental results, a second-order multivariate regression mathematical model was developed. As a result of the experiments, the regression model can be expressed in the following general form:

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

or, since three factors are involved in the present experiment, it takes the following form:

$$Y_R = b_0 + b_1 x_1 + b_2 x_2 + b_3 x_3 + b_{12} x_1 x_2 + b_{13} x_1 x_3 + b_{23} x_2 x_3 + b_{11} x_1^2 + b_{22} x_2^2 + b_{33} x_3^2$$

In the equation, b_0, b_1, \dots are the regression coefficients, and x_1, x_2, x_3 represent the coded values of the factors.

Calculation of regression coefficients for optimizing the machine cleaning efficiency (Y_1):

The regression coefficients were calculated as follows:

$$b_0 = \frac{1}{N_u} \sum_{u=1}^{N_u} \bar{Y}_u = \frac{1}{3} (91 + 91 + 91) = 91$$

$$b_1 = g_3 \sum_{u=1}^N x_{1u} \bar{Y}_u$$

$$g_2=0,166$$

$$g_3=0,125$$

$$g_4=0,25$$

$$g_5=0,125$$

$$g_6=0,0625$$

$$g_7=0,3125$$

$$b_{12}=0,125(77+88-72-83+87+75-73-69)=3,75$$

$$b_{23}=0,125(77-88+72-83+71+72-87-72)=-4,75$$

$$b_{33}=0,125(87-75+73-69+71-72+87-72)=3,75$$

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

$$b_{12}=0,25(77-88-72+83)=0,00$$

$$b_{13}=0,25(87-75-73+69)=2,00$$

$$b_{23}=0,25(71-72-87+72)=-4,00$$

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

$$\sum x_1^2 \bar{Y}_u = 77+88+72+83+87+75+73+69 = 624,00$$

$$\sum x_2^2 \bar{Y}_u = 77+88+72+83+71+72+87+72 = 622,00$$

$$\sum x_3^2 \bar{Y}_u = 87+75+73+69+71+72+87+72 = 606,00$$

$$\sum \bar{Y}_u = 77+88+72+83+87+75+73+69+71+72+87+72+91+91+91 = 1199,0$$

$$\sum_{i=1}^M \sum x_i^2 \bar{Y}_u = 624+622+606 = 1852,0$$

$$b_{11} = 0,125*106,5+0,0625*308,0-0,166*190,4 = 0,35$$

$$b_{22} = 0,125*104,4+0,0625*308,0-0,166*190,4 = 0,04$$

$$b_{33} = 0,125*97,1+0,0625*308,0-0,166*190,4 = -0,82$$

Taking into account the determined regression coefficients, the equation can be written as follows

$$Y_R = 91+3,75*x_1-4,75*x_2+3,75*x_3+0*x_1x_2+2*x_1x_3-4*x_2x_3-5,28*x_1x_1-5,53*x_2x_2-7,53-x_3x_3$$

The significance of the regression coefficients was evaluated. For this purpose, the variance of the response parameter was determined.

$$S^2\{Y\} = S_m^2\{Y\} = \frac{1}{N_u - 1} \sum_{u=1}^{N_u} S^2\{\bar{Y}\}$$

Here:

$$S_m^2\{Y\} = 25,4$$

$$S_m^2\{Y\} = 25$$

$$S^2\{\bar{Y}\} = \frac{1}{3 - 1} * 25,40 = 12,7$$

and, on this basis, the variance associated with the estimation of the regression coefficients was calculated:

$$S^2\{b_0\} = g_1 S^2\{\bar{Y}\} = 0,2*12,7 = 2,54$$

$$S^2\{b_i\} = g_3 S^2\{\bar{Y}\} = 0,125*12,7 = 1,59$$

$$S^2\{b_{ij}\} = g_4 S^2\{\bar{Y}\} = 0,25*12,7 = 3,175$$

$$S^2\{b_{ii}\} = g_7 S^2\{\bar{Y}\} = 0,3125*12,7 = 3,97$$

The standard deviation of the regression coefficient estimates was calculated:

$$S\{b_0\} = 1,59; S\{b_i\} = 1,26; S\{b_{ij}\} = 1,78; S\{b_{ii}\} = 1,99.$$

Then, the calculated value of Student's t-test was obtained using the following equation:

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

$$t_R\{b_0\} = \frac{|91|}{1,59} = 57,23$$

$$t_R\{b_1\} = \frac{|3,75|}{1,26} = 2,98$$

$$t_R\{b_2\} = \frac{|4,75|}{1,26} = 3,77$$

$$t_R\{b_{13}\} = \frac{|2|}{1,78} = 1,12$$

$$t_R\{b_{23}\} = \frac{|4|}{1,78} = 2,25$$

$$t_R\{b_{11}\} = \frac{|5,28|}{1,99} = 2,65$$

$$t_R\{b_3\} = \frac{|3,75|}{1,26} = 2,98 \qquad t_R\{b_{22}\} = \frac{|5,53|}{1,99} = 2,78$$

$$t_R\{b_{12}\} = \frac{|0|}{1,78} = 0,00 \qquad t_R\{b_{33}\} = \frac{|7,53|}{1,99} = 3,78$$

The coefficients $b_{11}, b_{12}, b_{13},$ and b_{23} were determined to be statistically insignificant with respect to the investigated parameters. The tabulated value of Student's t-test was adopted as follows:

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

It is well known that if the calculated value of the criterion is smaller than its tabulated value, the corresponding coefficient is considered statistically insignificant and is therefore excluded from the regression equation.

Taking into account that the coefficients $b_{12}, b_{13},$ and b_{23} were found to be insignificant for the investigated parameters, a revised regression equation was formulated.

The regression equation containing only the significant coefficients can be rewritten as follows:

$$Y_1 = 91 + 3,75 * x_1 - 4,75 * x_2 + 3,75 * x_3 - 5,53 * x_2^2 - 7,53 * x_3^2$$

To evaluate the adequacy of the developed regression mathematical model, the calculated value of the Fisher criterion was used.

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

here

$$S^2\{\bar{Y}\} = \frac{\sum_{u=1}^N S^2\{Y\}}{N_u - 1} = \frac{25,40}{2} = 12,7$$

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

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

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

$$Y_1 = 91 + 3,75 * x_1 - 4,75 * x_2 + 3,75 * x_3 - 5,53 * x_2^2 - 7,53 * x_3^2$$

$$Y_{R1} = 91+3,75-4,75-5,53 = 84,47$$

$$Y_{R7} = 91-3,75+3,75-7,53 = 83,47$$

$$Y_{R2} = 91+3,75+4,75-5,53 = 93,97$$

$$Y_{R8} = 91-3,75-3,75-7,53 = 75,97$$

$$Y_{R3} = 91-3,75-4,75-5,53 = 76,97$$

$$Y_{R9} = 91-4,75+3,75-5,53-7,53 = 76,94$$

$$Y_{R4} = 91-3,75+4,75-5,53 = 86,47$$

$$Y_{R10} = 91-4,75-3,75-5,53-7,53 = 69,44$$

$$Y_{R5} = 91+3,75+3,75-7,53 = 90,97$$

$$Y_{R11} = 91+4,75+3,75-5,53-7,53 = 86,44$$

$$Y_{R6} = 91+3,75-3,75-7,53 = 83,47$$

$$Y_{R12} = 91+4,75-3,75-5,53-7,53 = 78,94$$

It is known that if the calculated value of the criterion is smaller than its tabulated value, the model is considered adequate, confirming that the calculations have been carried out correctly.

In order to simplify the calculations, the following table was constructed.

Table 3. Comparison of calculated and experimental results.

| No | \bar{Y}_u | Y_{Ru} | $(Y_{Ru} - \bar{Y}_u)$ | $(Y_{Ru} - \bar{Y}_u)^2$ |
|-------------|-------------|----------|------------------------|--------------------------|
| 1 | 77 | 84,47 | 7,47 | 55,80 |
| 2 | 88 | 93,97 | 5,97 | 35,64 |
| 3 | 72 | 76,97 | 4,97 | 24,70 |
| 4 | 83 | 86,47 | 3,47 | 12,04 |
| 5 | 87 | 90,97 | 3,97 | 15,76 |
| 6 | 75 | 83,47 | 8,47 | 71,74 |
| 7 | 73 | 83,47 | 10,47 | 109,62 |
| 8 | 69 | 75,97 | 6,97 | 48,58 |
| 9 | 71 | 76,94 | 5,94 | 35,28 |
| 10 | 72 | 69,44 | -2,56 | 6,55 |
| 11 | 87 | 86,44 | -0,56 | 0,31 |
| 12 | 72 | 78,94 | 6,94 | 48,16 |
| Jami | | | | 464,2 |

$$\sum_{u=1}^{N-N_u+1} (Y_{Ru} - \bar{Y}_u)^2 = 464,202 \qquad S_{nad}^2\{Y\} = \frac{464,20}{4} = 116,05$$

$$F_R = \frac{S_{nad}^2\{Y\}}{S^2\{\bar{Y}\}} = \frac{116,05}{12,7} = 9,14 \qquad F_J = 19,25$$

$$F_R = 9,14 < 19,25 = F_J$$

Therefore, the developed regression mathematical model adequately represents the investigated process with sufficient accuracy.

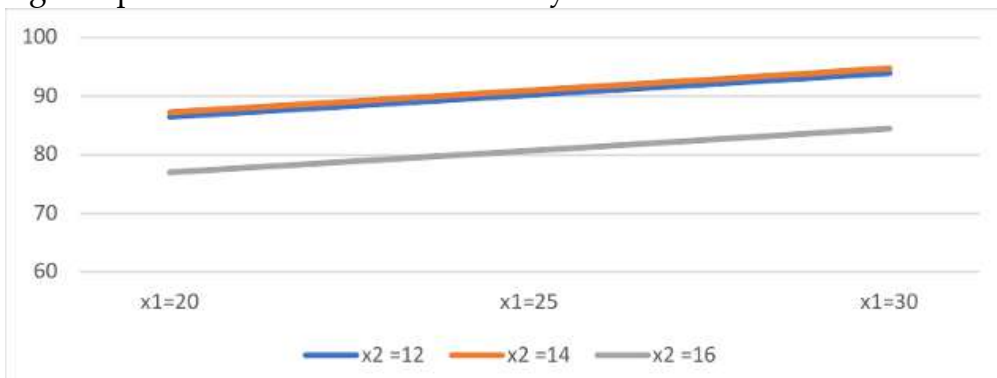


Figure 1. Effect of the clearance between the grate grid and the saw drum on cleaning efficiency at different distances (12 mm, 14 mm, and 16 mm)

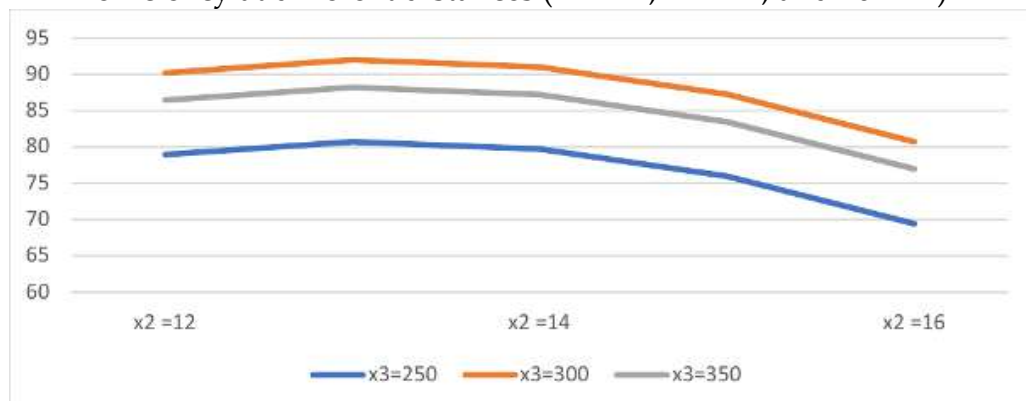


Figure 2. Effect of saw drum rotational speed on cleaning efficiency at different rotational speeds (250 rpm, 300 rpm, and 350 rpm)

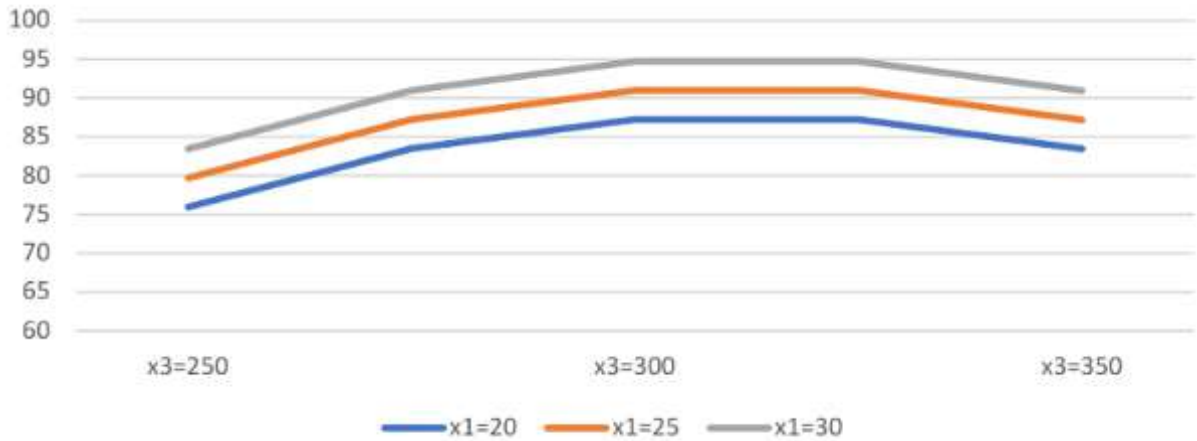


Figure 3. Effect of grate bar diameter on cleaning efficiency for different diameters (20 mm, 25 mm, and 30 mm)

Calculations for the optimization of the cotton particle content in the waste material (Y_2) were performed.

The regression coefficients were calculated as follows:

$$b_0 = \frac{1}{N_u} \sum_{u=1}^{N_u} \bar{Y}_u = \frac{1}{3} (8,9 + 9,1 + 9,1) = 9,03$$

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

$$g_2=0,166; \quad g_3=0,125; \quad g_4=0,25; \quad g_5=0,125; \quad g_6=0,0625; \quad g_7=0,3125$$

$$b_1=0,125(14,6+11,8+(-17,3)+11,4+18,4+(-14,6)+(-21,6))= - 1,50$$

$$b_2=0,125(14,6+(-11,8)+17,3+(-14,7)+12,9+19,9+(-10,1)+(-19,2))= 1,11$$

$$b_3=0,125(11,4+(-18,4)+14,6+(-21,6)+12,9+(-19,9)+10,1+(-19,2))= - 3,76$$

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

$$b_{12}=0,25(14,6+(-11,8)+(-17,3)+14,7) = 0,05$$

$$b_{13}=0,25(11,4+(-18,4)+(-14,6)+21,6) = 0,00$$

$$b_{23}=0,25(12,9+(-19,9)+(-10,1)+19,2) = 0,53$$

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

$$\sum x_1^2 \bar{Y}_u = 14,6 + 11,8 + 17,3 + 14,7 + 11,4 + 18,4 + 14,6 + 21,6 = 124,40$$

$$\sum x_2^2 \bar{Y}_u = 14,6 + 11,8 + 17,3 + 14,7 + 12,9 + 19,9 + 10,1 + 19,2 = 120,5$$

$$\sum x_3^2 \bar{Y}_u = 11,4 + 18,4 + 14,6 + 21,6 + 12,9 + 19,9 + 10,1 + 19,2 = 128,1$$

$$\begin{aligned} \sum \bar{Y}_u &= 14,6 + 11,8 + 17,3 + 14,7 + 11,4 + 18,4 + 14,6 + 21,6 + 12,9 + 19,9 + 10,1 \\ &\quad + 19,2 + 8,9 + 9,1 + 9,1 = 213,6 \\ \sum_{i=1}^M \sum x_i^2 \bar{Y}_u &= 124,4 + 120,5 + 128,1 = 373,0 \\ b_{11} &= 0,125 * 124,4 + 0,0625 * 373 - 0,166 * 213,6 = 3,40 \\ b_{22} &= 0,125 * 120,5 + 0,0625 * 373 - 0,166 * 213,6 = 2,92 \\ b_{33} &= 0,125 * 128,1 + 0,0625 * 373 - 0,166 * 213,6 = 3,87 \end{aligned}$$

Taking into account the determined regression coefficients, the equation can be written as follows:

$$Y_R = 9,03 + (-1,5) * x_1 + 1,11 * x_2 + (-3,76) * x_3 + 0,05 * x_1 x_2 + (0) * x_1 x_3 + 0,53 * x_2 x_3 + 3,4 * x_1 x_1 + 2,92 * x_2 x_2 + 3,87 * x_3 x_3$$

The statistical significance of the regression coefficients was evaluated. For this purpose, the variance of the output (response) parameter was determined.

$$S^2\{\bar{Y}\} = S_m^2\{Y\} = \frac{1}{N_u - 1} \sum_{u=1}^{N_u} S^2\{\bar{Y}\}$$

$$S^2\{Y\} = 2 \qquad S_m^2\{Y\} = 2,4$$

and, on this basis, the variance associated with the estimation of the regression coefficients was calculated:

$$\begin{aligned} S^2\{b_0\} &= g_1 S^2\{\bar{Y}\} = 0,2 * 1,2 = 0,24 \\ S^2\{b_i\} &= g_3 S^2\{\bar{Y}\} = 0,125 * 1,2 = 0,15 \\ S^2\{b_{ij}\} &= g_4 S^2\{\bar{Y}\} = 0,25 * 1,2 = 0,3 \\ S^2\{b_{ii}\} &= g_7 S^2\{\bar{Y}\} = 0,3125 * 1,2 = 0,38 \end{aligned}$$

The standard deviation of the regression coefficient estimates was determined:

$$S\{b_0\} = 0,49; \quad S\{b_i\} = 0,39; \quad S\{b_{ij}\} = 0,55; \quad S\{b_{ii}\} = 0,61$$

Subsequently, the calculated value of Student's t-test was determined using the following equation:

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

$$\begin{aligned} t_R\{b_0\} &= \frac{|9,03|}{0,49} = 18,43 & t_R\{b_{13}\} &= \frac{|0|}{0,55} = 0,00 \\ t_R\{b_1\} &= \frac{|1,5|}{0,39} = 3,85 & t_R\{b_{23}\} &= \frac{|0,53|}{0,55} = 0,96 \\ t_R\{b_2\} &= \frac{|1,11|}{0,39} = 2,85 & t_R\{b_{11}\} &= \frac{|3,4|}{0,61} = 5,57 \\ t_R\{b_3\} &= \frac{|3,76|}{0,39} = 9,64 & t_R\{b_{22}\} &= \frac{|2,92|}{0,61} = 4,79 \\ t_R\{b_{12}\} &= \frac{|0,05|}{0,55} = 0,09 & t_R\{b_{33}\} &= \frac{|3,87|}{0,61} = 6,34 \end{aligned}$$

The tabulated value of Student's t-test was taken as follows:

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

It is known that if the calculated value of the criterion is smaller than its tabulated value, the corresponding coefficient is considered statistically insignificant and is therefore excluded from the equation.

In the present study, the coefficients b_{12} , b_{13} , and b_{23} were found to be insignificant for the investigated parameters.

The equation was rewritten using only the statistically significant coefficients:

$$Y_R = 9,03 - 1,5 * x_1 + 1,11 * x_2 - 3,76 * x_3 + 3,4 * x_1 x_1 + 2,92 * x_2 x_2 + 3,87 * x_3 x_3$$

To determine whether the above-derived regression mathematical model is adequate or inadequate, the calculated value of the Fisher criterion was used.

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

here:

$$S^2\{\bar{Y}\} = \frac{\sum_{u=1}^N S^2\{Y\}}{N_u - 1} = \frac{2,40}{2} = 1,2$$

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

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

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

$$Y_2 = 9,03 - 1,5 * x_1 + 1,11 * x_2 - 3,76 * x_3 + 3,4 * x_1^2 + 2,92 * x_2^2 + 3,87 * x_3^2$$

$$Y_{R1} = 9,03 - 1,5 + 1,11 + 3,4 + 2,92 = 14,96$$

$$Y_{R2} = 9,03 - 1,5 - 1,11 + 3,4 + 2,92 = 12,74$$

$$Y_{R3} = 9,03 + 1,5 + 1,11 + 3,4 + 2,92 = 17,96$$

$$Y_{R4} = 9,03 + 1,5 - 1,11 + 3,4 + 2,92 = 15,74$$

$$Y_{R5} = 9,03 - 1,5 - 3,76 + 3,4 + 3,87 = 11,04$$

$$Y_{R6} = 9,03 - 1,5 + 3,76 + 3,4 + 3,87 = 18,56$$

$$Y_{R7} = 9,03 + 1,5 - 3,76 + 3,4 + 3,87 = 14,04$$

$$Y_{R8} = 9,03 + 1,5 + 3,76 + 3,4 + 3,87 = 21,56$$

$$Y_{R9} = 9,03 + 1,11 - 3,76 + 2,92 + 3,87 = 13,17$$

$$Y_{R10} = 9,03 + 1,11 + 3,76 + 2,92 + 3,87 = 20,69$$

$$Y_{R11} = 9,03 - 1,11 - 3,76 + 2,92 + 3,87 = 10,95$$

$$Y_{R12} = 9,03 - 1,11 + 3,76 + 2,92 + 3,87 = 18,47$$

In order to simplify the calculations, Table 3.3 was constructed.

Table 3.3. Comparison of calculated and experimental results.

Table 4

| No | \bar{Y}_u | Y_{Ru} | $(Y_{Ru} - \bar{Y}_u)$ | $(Y_{Ru} - \bar{Y}_u)^2$ |
|----|-------------|----------|------------------------|--------------------------|
| 1 | 14,6 | 14,96 | 0,36 | 0,13 |
| 2 | 11,8 | 12,74 | 0,94 | 0,88 |
| 3 | 17,3 | 17,96 | 0,66 | 0,44 |
| 4 | 14,7 | 15,74 | 1,04 | 1,08 |
| 5 | 11,4 | 11,04 | -0,36 | 0,13 |
| 6 | 18,4 | 18,56 | 0,16 | 0,03 |
| 7 | 14,6 | 14,04 | -0,56 | 0,31 |
| 8 | 21,6 | 21,56 | -0,04 | 0,00 |
| 9 | 12,9 | 13,17 | 0,27 | 0,07 |

| | | | | |
|----|------|-------|-------|------|
| 10 | 19,9 | 20,69 | 0,79 | 0,62 |
| 11 | 10,1 | 10,95 | 0,85 | 0,72 |
| 12 | 19,2 | 18,47 | -0,73 | 0,53 |
| | | Total | | 5,0 |

It is known that if the calculated value of the criterion is smaller than the tabulated value, the model is considered adequate, thereby confirming that the calculations were performed correctly.

$$F_R = \frac{S_{nad}^2\{Y\}}{S^2\{\bar{Y}\}} = \frac{1,24}{1,2} = 1,03$$

$F_j = 19,25$
 $F_R = 1,03 < 19,25 = F_j$

Thus, the obtained regression mathematical model describes the investigated process with sufficient accuracy [65].

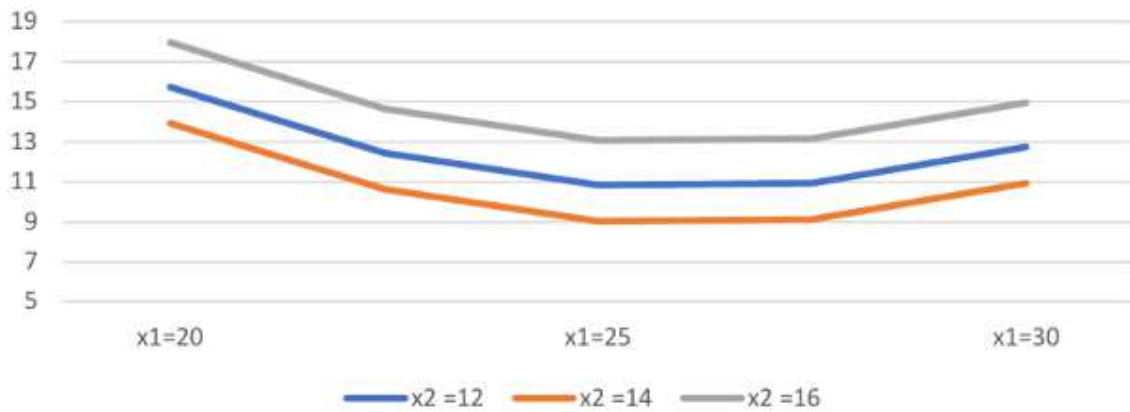


Figure 4. Dependence of the amount of cotton particles in the waste material on the clearance between the grate grid and the saw drum at different distances (12, 14, and 16 mm)

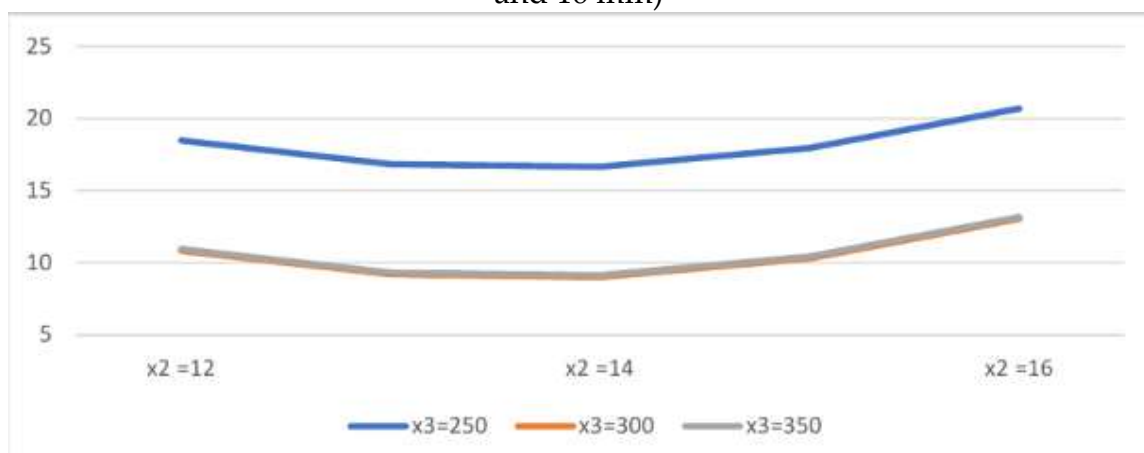


Figure 5. Dependence of the amount of cotton particles in the waste material on the saw drum rotational speed at different speeds (250, 300, and 350 rpm)

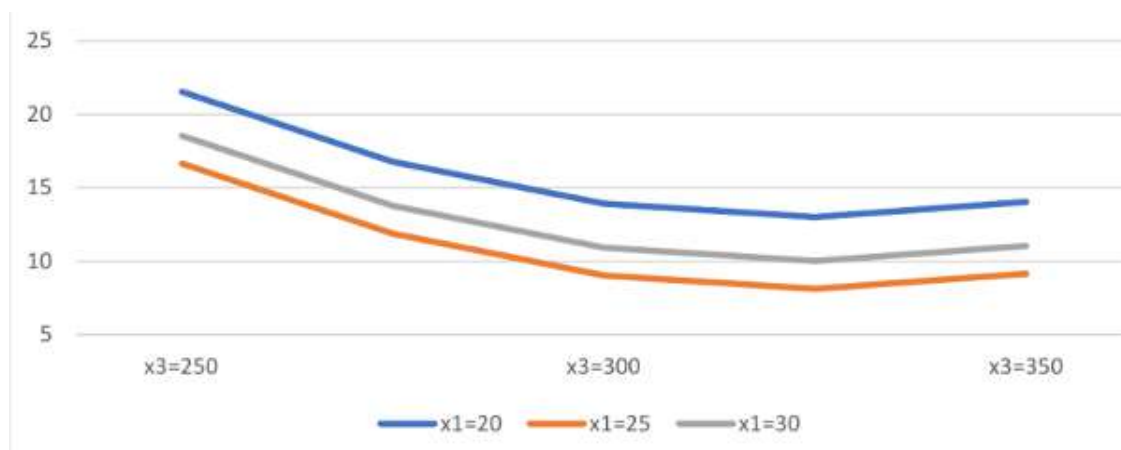


Figure 6. Dependence of the amount of cotton particles separated into the waste material on the grate bar diameter at different diameters (20, 25, and 30 mm)

Conclusions. Based on mathematical modeling and experimental validation, optimal operating parameters of the cotton cleaning device were determined. The regression equations were verified using Student’s and Fisher’s criteria, and graphical analysis confirmed the reliability of the results.

The obtained findings demonstrate that the proposed design and operating parameters significantly improve cleaning efficiency while minimizing cotton losses, thereby enhancing the overall performance of cotton cleaning machines.

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