

DETERMINATION OF OPTIMAL PARAMETERS OF GEOMETRICAL DIMENSIONS OF AN AERODYNAMIC CLEANING DEVICE

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Abstract

In this article, a new aerodynamic cleaning device is adapted to the air pipeline of the pneumatic transport system, to the inlet of the separator device, i.e. instead of the diffuser. The guide is installed on the upper part of the working chamber of the new cleaning device, i.e. the optimal geometric values of the deviation angle of the columnar grid, the distance between the piles of the columnar grid and the distance from the installed The place of the columnar grid to the beginning of the inlet to the working chamber is established on the basis of experiments. The results obtained are used for implementation in production.

Key words

working chamber, pneumatic transport, cleaning device, optimal value, column mesh, deflection angle, regression coefficient.

1. INTRODUCTION

Received cotton raw material is heavy and stiff in composition. The presence of foreign bodies can cause breakage of the working parts of the enterprise's technological equipment, especially the teeth of the chainsaw, shorten its service life, and even cause fires. Heavy impurities also cause serious damage to the quality of fiber and secondary products. In order to reduce the negative effects on the upper part, devices are used in the pneumatic transport system to clean the cotton from heavy and solid foreign bodies.

The new aerodynamic cleaning device is installed in the air duct of the pneumatic transport system, at the inlet of the separator device, i.e., in place of the diffuser (Fig. 1). In order to increase the degree of vibration of the collected cotton balls, the aerodynamic cleaning device is installed on a grate with a variable angle of inclination in the upper part of the working chamber of the device. It differs from other types of cleaning structures in that it is possible to separate heavy and solid objects and other types of impurities from cotton raw materials using a guide without damaging the cotton raw materials.

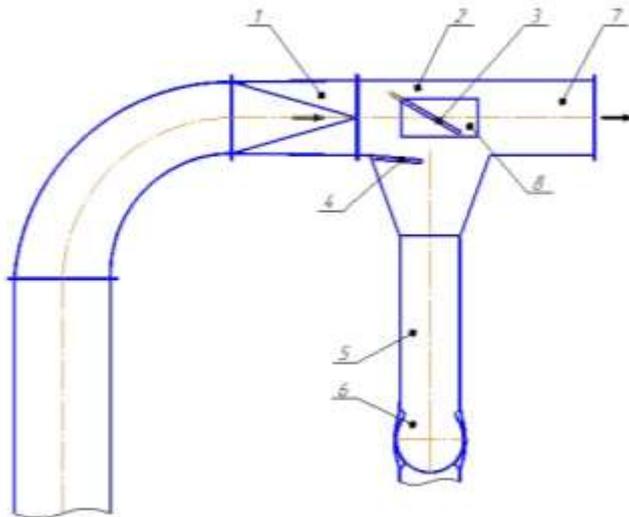


Figure 1. New aerodynamic cleaning device

1 - inlet pipe, 2 - working chamber of the device, 3 - 4 - directional valves with a grid, 5 - collector for separated foreign bodies, 6 - drum-shaped valve, 7 - outlet, 8 - plastic mirror

In order to increase the efficiency of the new aerodynamic cleaning device, it is necessary to determine the most suitable type of deflector with a comb grille for the upper part of the working chamber of the device, as well as at what angle of inclination and at what distance from the entrance to the chamber it should be installed. The factors listed were recognized as having a significant impact on efficiency based on practical and theoretical research.

2. Materials and Methods

Achieving high efficiency in the process of aerodynamic cleaning of cotton raw materials directly depends on the values of the selected input parameters.

The experiments were carried out using multifactorial design, that is, a TOT 2³ experiment was conducted. Here, the number of 2-levels; the number of 3-factors; the number of trials 2³=8 [1].

Factors and output parameters that influence the implementation of the optimization process are selected.

The angle of inclination of the deflector, i.e. the grate with a grate, installed in the upper part of the cleaner working chamber α° (degrees) (X_1), b - distance between the piles of the grate in mm (X_2) and a - distance from the installation site of the grate to the beginning of the entrance to the working chamber in mm (X_3) Rational values were chosen based on [1].

(-1) and upper (+1) values of the input parameters.

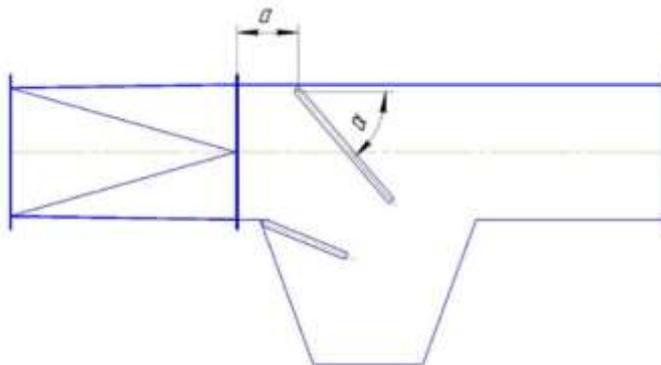
The output parameter Y_1 is the cleaning efficiency of the device, %.

Here, Y_1 is the efficiency of the cleaning device in separating heavy impurities and other impurities from cotton, in percent. To ensure the required accuracy, the experiments were carried out three times, and their average values are given in the table [2] (Table 2).

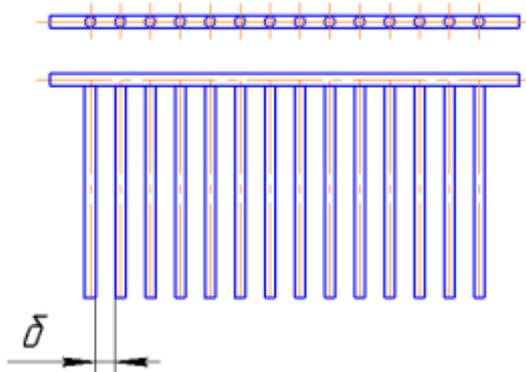
Table 1

Input factor values

Names and units of measurement of factors	Determinin ation	Natural values of factors	
		-1	+1
angle of inclination of the grate with bars; α° (degrees)	X_1	30	70
distance between piles; mm	X_2	20	30
The distance of the grate with bars from the entrance to the working chamber; mm	X_3	100	140



a)



b)

Figure 2. Input factors of the new aerodynamic cleaning device

Table 2

Table summarizing the results of experiments

No.	Factors				Interrelated factors				Th alue	Serial nce
	X ₀	X ₁	X ₂	X ₃	X ₁ X ₂	X ₁ X ₃	X ₂ X ₃	X ₁ X ₂ X ₃	Y	S ² (Y)
1	+	-	-	-	+	+	+	-	93	0.5
2	+	+	-	-	-	-	+	+	98	0.5
3	+	-	+	-	-	+	-	+	93	1.5
4	+	+	+	-	+	-	-	-	96	1
5	+	-	-	+	+	-	-	+	91	0,5
6	+	+	-	+	-	+	-	-	95	0,5
7	+	-	+	+	-	-	+	-	90	0.5
8	+	+	+	+	+	+	+	+	93	1

Based on the experimental results, we determine the arithmetic mean value of the optimization parameters for each test [1].

$$Y = \frac{\sum_{i=1}^N Y_i}{m} \quad (1)$$

$$Y = \frac{\sum_{i=1}^N Y_i}{m} = \frac{749}{3} = 249,6; \quad Y_i = 749;$$

The value of the dispersions was calculated as follows.

$$S^2\{Y\} = \frac{\sum(Y_i - Y_1)^2}{m-1} \quad (2)$$

here m is the number of repetitions.

$$S_1^2\{Y\} = \frac{(94 - 93)^2 + (93 - 93)^2 + (93 - 93)^2}{3 - 1} = 0,5$$

$$S_2^2\{Y\} = \frac{(97 - 98)^2 + (98 - 98)^2 + (98 - 98)^2}{3 - 1} = 0,5$$

$$S_3^2\{Y\} = \frac{(92 - 93)^2 + (92 - 93)^2 + (94 - 93)^2}{3 - 1} = 1,5$$

$$S_4^2\{Y\} = \frac{(96 - 96)^2 + (97 - 96)^2 + (95 - 96)^2}{3 - 1} = 1$$

$$S_5^2\{Y\} = \frac{(91 - 91)^2 + (90 - 91)^2 + (91 - 91)^2}{3 - 1} = 0,5$$

$$S_6^2\{Y\} = \frac{(95 - 95)^2 + (94 - 95)^2 + (95 - 95)^2}{3 - 1} = 0,5$$

$$S_7^2\{Y\} = \frac{(90 - 90)^2 + (91 - 90)^2 + (90 - 90)^2}{3 - 1} = 0,5$$

$$S_8^2\{Y\} = \frac{(94 - 93)^2 + (93 - 93)^2 + (92 - 93)^2}{3 - 1} = 1$$

Homogeneity of dispersion was determined using the Cochran criterion [1, 2]:

$$G_x = \frac{S^2\{Y\}_{max}}{\sum S^2\{Y\}} \quad (3)$$

here G_x is the calculated value of the Cochran criterion;

$S^2\{Y\}_{max}$ - maximum variance of the i -th test;

$S^2\{Y\}$ - the sum of all series variances.

$$G_x = \frac{S^2\{Y\}_{max}}{\sum S^2\{Y\}} = \frac{1,5}{6} = 0,25$$

To determine the experimental recovery, the calculated value of the Cochran criterion was compared with the table.

In our case, for TOT 2³ and $P = 0,95$. 0,95-confidence probability.

G_{jad} - Tabulated value of the Cochran criterion,

$G_{jad} = (f_1 \text{ va } f_2) \quad P = 0,95$ when,

here ($f_1 = N = 8$; $f_2 = m - 1 = 3 - 1 = 2$) = 0,5157

(N - number of degrees of freedom) [1]

If $G_x < G_{jad}$ so, the experiment is repeated and we can proceed to calculate the regression coefficients.

$G_x = 0,25$; According to Appendix $G_{jad} = 0,51571$;

Our results $G_x < G_{jad}$ satisfy the inequality $0,25 < 0,5157$. So, we can proceed to calculate the regression coefficients [1].

$$Y_R = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_{12}x_1x_2 + b_{13}x_1x_3 + b_{23}x_2x_3 + b_{123}x_1x_2x_3 \quad (4)$$

Let's calculate the coefficients in the equation:

$$b_0 = \frac{1}{N} \sum Y \quad (5)$$

$$b_0 = \frac{1}{8} (y + y + y + y + y + y + y + y) = \frac{1}{8} (93 + 98 + 93 + 96 + 91 + 95 + 90 + 93) = 93,625$$

$$b_i = \frac{1}{N} \sum X_i Y \quad (6)$$

$$b_{ji} = \frac{1}{N} \sum X_i X_j Y \quad (7)$$

here i is the test procedure,

j - order of factors

Significance t_R of the regression coefficients was determined using the Student test [2, 3] :

$$t_R\{b_i\} = \frac{|b_i|}{s\{b_i\}} \quad (8)$$

$$S^2\{b_i\} = \frac{S^2\{Y\}}{N} \quad (9)$$

where $S^2\{Y\}$ is the variance of the series. It was determined using the following formula [1]:

$$S^2\{Y\} = \frac{1}{m} S^2\{\bar{Y}\} \quad (10)$$

here m is the number of repetitions of tests.

$S^2\{\bar{Y}\}$ - recovery variance. It was determined using the following formula [1,2]:

$$S_m^2\{\bar{Y}\} = \frac{1}{N} S^2\{Y\} \quad (11)$$

here N is the number of tests

$S^2\{Y\}$ - sum of series variances

observed coefficients.

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

The calculated value of the Student criterion was compared with the reported critical value [1].

$$f = (m - 1) \cdot N = (3 - 1) \cdot 8 = 16$$

$$m = 3; N = 8$$

$$t_{jad}[P = 0.95; f = 16] = 2,12$$

If there are regression coefficients, $t_R > t_{jad}$ they are significant.

So, in our example, $b_0, b_1, b_2, b_3, b_{12}$ the coefficients are significant and the regression equation, after removing the non-significant coefficients, looks like this [1].

$$Y_R = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_{12}x_1x_2 \quad (12)$$

We check the obtained equation for adequacy. The check is carried out using the Fisher criterion. The calculated value of the Fisher criterion [1]:

$$F_R = \frac{S_{ad}^2\{Y\}}{S^2\{Y\}}; \quad N - M > 0 \quad (13)$$

here:

M -number of significant regression coefficients,

N -test in a general example,

m - number of repeated tests,

$S_{ad}^2\{Y\}$ -adequacy variance.

$S^2\{Y\}$ -series variance.

$$S^2\{Y\} = 0,25;$$

$$S_{ad}^2\{Y\} = \frac{m}{N-M} \sum (Y_i - Y_{Ri})^2 \quad (3.23)$$

$$S_{ad}^2\{Y\} = \frac{3}{8-5} \cdot 0,37 = 0,37;$$

$$N = 8; M = 5; \quad m = 3$$

3. Results

Based on equation (13), we determine the calculated value of the Fisher criterion:

Table 3

Calculation table for checking the model using Fisher's criterion

No.	Y_i	Y_{Ri}	$(Y_i - Y_{Ri})$	$(Y_i - Y_{Ri})^2$
1	93	93,375	-0.375	0.14
2	98	97,875	0.125	0.015
3	93	92,875	0.125	0.015
4	96	95,875	0.125	0.015
5	91	90,625	0.375	0.14
6	95	95,125	-0.125	0.015
7	90	90,125	-0.125	0.015
8	93	93,125	-0.125	0.015

4. Discussion

Therefore, the regression equation derived from the results will be as follows.

$$Y_R = 93,625 - 1,875x_1 + 0,625x_2 + 1,375x_3 - 0,375x_1x_2$$

The regression coefficients in the regression equation are of great importance in characterizing the output factor.

In our scientific research, when analyzing the equation for the efficiency of cleaning cotton raw materials, which was chosen as the output parameter, we construct graphs of the area of change according to the values of the input factors [1].

The input parameters are the distance a from the inlet of the working chamber of the device to the inlet of the device, mm (Fig. 2.a); and the distance between the guide, i.e. the distance between the bars of the grate with bars, is b, The appearance of our mathematical model in mm (Fig. 2.b) has become more apparent.

$$X_1 = 0;$$

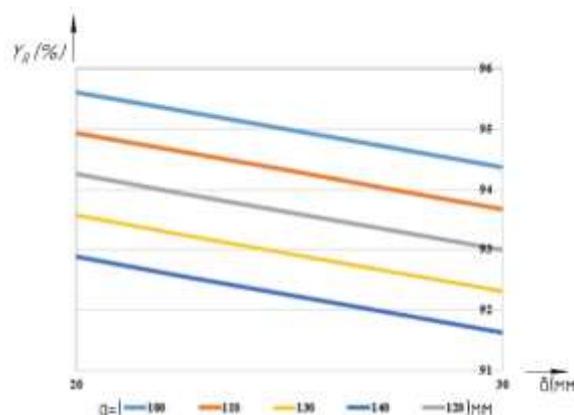


Figure 3. According to the mathematical model , the cleaning efficiency when $X_1 = 0$, %

As can be seen from the graph in Figure 3, the incoming X_3 When the accepted values of the factors X_2 change from the minimum (-1) to the maximum (+1), the cotton cleaning efficiency values also change . The distance of the (X_3) factor guide relative to the inlet of the working

chamber of the device is $a = 100$ mm At the minimum value of the factor (X_2) , i.e. (-1) , the distance between the guide, i.e., the grid piles with the grid is $b = 20$ mm, i.e. (-1) minimum and $b = 30$ mm, i.e. (+1) maximum, the cleaning efficiency indicators reach correspondingly $Y_R = 95\%$ equal $Y_R = 94\%$ values [1, 2].

(X_3) factor $a = 140$ mm That is, at a maximum value of (+1) and a minimum value of (-1) of the factor (X_2) , the cleaning efficiency indicators of the device $Y_R = 92\%$ reached equal values in the corresponding behavior. $Y_R = 91\%$

As you can see from the graph, the largest value Y_R of this is 95 %.

the distance between the guide, i.e. the grid stakes - b mm (Fig. 2.a) and the distance of the working chamber of the device relative to the inlet - a , mm (Fig. 2.a) The graphical representation of our mathematical model is as follows [3, 4]:

$$X_2 = 0;$$

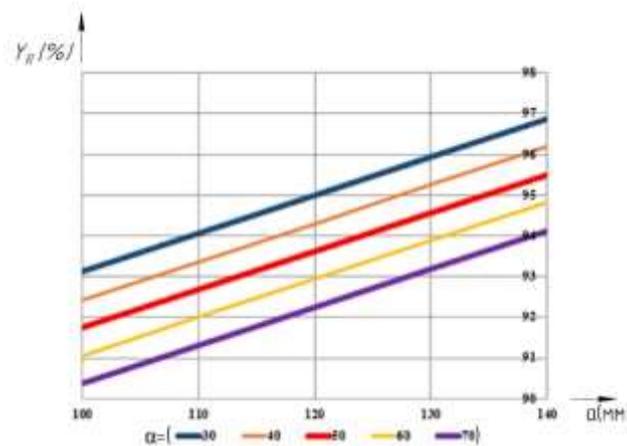


Figure 4. According to the mathematical model , the cleaning efficiency when $X_2 = 0$, %

As can be seen from the graph in Figure 4, the incoming X_1 and X_3 factors change from a minimum (-1) to a maximum (+1), the cotton cleaning efficiency increases [1, 2]. (X_1) The angle of inclination of the guide is $a = 30^\circ$, i.e. at a minimum value of (-1) , the distance of the (X_3) factor of the guide relative to the inlet of the working chamber of the device is $a = 100$ mm, At the minimum values of (-1) and the maximum values of $a = 140$ mm or (+1), the cleaning efficiency indicators $Y_R = 93\%$ reached $Y_R = 97\%$ the corresponding values [1, 5, 6].

(X_1) factor $a = 70^\circ$, That is, at a maximum value of (+1) and a minimum value of (-1) of the factor (X_3) , the cleaning efficiency indicators of the device $Y_R = 90\%$ reach corresponding and equal values. $Y_R = 94\%$

As can be seen from the graph in Figure 4, the largest value Y_R of the bond was 97%.

on the input factors, the distance between the guide, i.e. the grid piles with the grid - b mm (Figure 2.b) and the angle of inclination of the guide a° (Figure 2.a), is as follows [1]:

$$X_3 = 0;$$

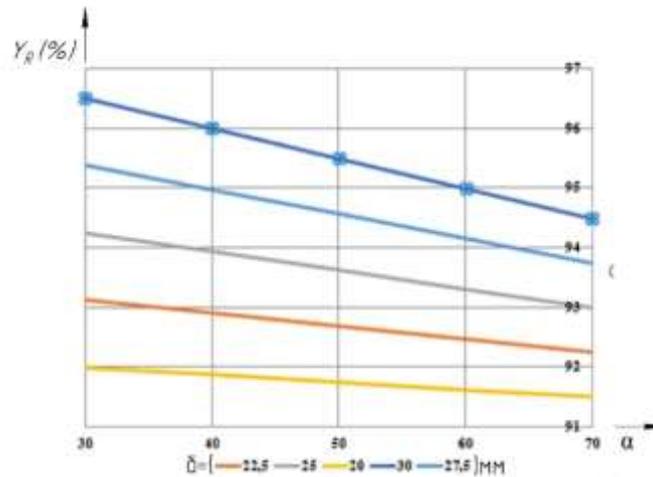


Figure 5. According to the mathematical model , the cleaning efficiency when $X_3 = 0$, %

As can be seen from the graph in Figure 5, the incoming X_2 When the accepted values of the factors X and 1 change from the minimum (-1) to the maximum ($+1$), the cotton cleaning efficiency values decrease. The (X_2) factor guide, i.e. the distance between the piles of the grating with a grid [1, 2] $b = 20$ mm, i.e. (-1) at the minimum value, the (X_1) factor guide angle $a = 30^\circ$, i.e. (-1) at the minimum and $a = 70^\circ$, i.e. ($+1$) at the maximum values, the cleaning efficiency indicators reached the corresponding $Y_R = 92\%$ and $Y_R = 91\%$ equal values [1].

(X_2) factor $b = 30$ mm, That is, at a maximum value of ($+1$) and a minimum value of (-1) of the factor (X_1), the cleaning efficiency indicators of the device $Y_R = 96\%$ reached equal values, respectively $Y_R = 94\%$

As can be seen from the graph in Figure 5, the largest value Y_R of the bond was 96% [1].

5. Conclusion

Based on scientific research, the following optimal values of the geometric dimensions of the new cleaning device were determined: the angle of inclination of the deflector is $a = 30^\circ$, the distance between the deflector, i.e. the grate with a grate, is $b = 30$ mm, and the distance of the deflector from the entrance to the working chamber of the device is $a = 140$ mm.

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