

The theoretical and experimental basis for calculating and justifying the parameters and regimes of the working areas of the cleaning zone of fibrous materials

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Abstract. In the article, there is the scheme and principle of the work of the cotton cleaner from small litter includes a composite pin drum with elastic elements and a vibrating mesh surface on elastic hinges. Theoretically, the torsional-vibrational motion of a two-mass system of a composite shoe drum has been studied, and the regularities of the dependence of changes in the parameters of the pin drum have been obtained. Based on the approximate analytical solution of the integro-differential equation, the law of angular vibrations of the net surface on the elastic supports of the cotton cleaner is studied. Experimental studies revealed regularities of loading and a change in the speed of rotation of the drum. The results of the full-factor experimental studies of the sample of the composite fluke drum are given. Based on the study of each of the three factors on the changes in the cleansing effect of cotton, the graphical dependencies of the parameters are postrene. The best values of the factors at which a high purifying effect of cotton from small weeds are achieved are recommended. Production tests revealed that the cleaning effect in comparison with the existing version of the drum spindle in the recommended increases by an average of 2.7%.

1 Introduction

In the world market, it is important to obtain textile fibers, especially cotton fibers of high quality [1]. At the same time, up to now, the existing technique and technology for cleaning fibrous materials from small litter does not meet modern requirements [2].

Development of an effective scheme for the zone of fine cleaning of fibrous materials. To ensure efficient cleaning of fibrous materials from small sludge, a new purifier scheme has been developed [3,4]. The main elements of the cleaning zone (Fig. 1) are the pin drum 1 equipped with an elastic sleeve 4 between the ring headset 2 and the shaft 3 of the drum 1 and also the mesh surface 5 installed in the machine casing 6 by means of elastic elements (bushings) 7 in the hinges. In the process of work, due to the elastic elements 4 and 7, torsional vibrations of the ring headset 2 and the mesh surface 5 with the required amplitudes and frequencies are performed to provide the necessary cleaning effect.

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2 Analysis

When determining the amplitude of the angular vibrations of the drum headset, the system was considered as two mass rotational system [5].

The resulting system of differential equations describing the dynamics of the motion of the drum wheel in the steady state has the form

$$\begin{aligned} \frac{J_1 d^2 \phi_1}{dt^2} + c(\phi_1 - \phi_2) + b \left(\frac{d\phi_1}{dt} - \frac{d\phi_2}{dt} \right) &= M_y \sin \omega t \\ \frac{J_2 d^2 \phi_2}{dt^2} - b \left(\frac{d\phi_1}{dt} - \frac{d\phi_2}{dt} \right) - c(\phi_1 - \phi_2) &= M_c \end{aligned} \quad (1)$$

where, J_1, J_2 - moments of inertia of the internal cylinder with flanges (shaft) and a loaded cylinder with a headset of drum pins; ϕ_1, ϕ_2 - angular movements of the inner cylinder and the headset; c, b - coefficients of rigidity and dissipation of the elastic element; M_y - amplitude of the disturbance in steady state; M_c - resistance from dragged raw cotton (fibrous material).

The solution of problem (1) is carried out with the following values of the parameters: $M_y = 1,5 \div 2,0 N/m$; $\omega = 45 \div 50 c^{-1}$; $c = 400 \div 600 Nm/rad$; $b = 7,2 \div 10 Nms/rad$. On the basis of a numerical solution of the problem, graphical dependences of the variation $\Delta\phi_2$ on the variation of M_c, J_2 and c , which are presented in Fig. 2 and Fig. 3.

Analysis of the results shows that with increasing values of the rigidity of the elastic element, the amplitude of the oscillations ϕ_1 and ϕ_2 decreases.

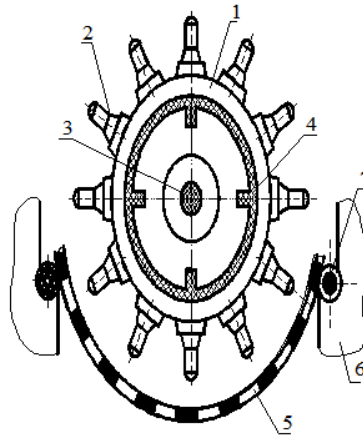


Fig. 1. Drum with elastic elements

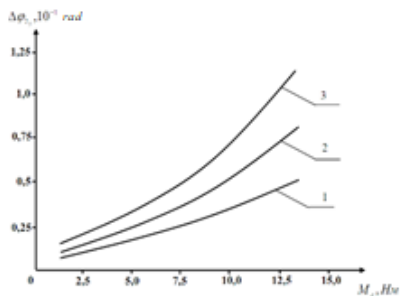


Figure 2. Dependences of the swing of the oscillations of the angular movements of the ring headset on the technological load where, 1- $c = 800Nm/rad$;
 2- $c = 600Nm/rad$;
 3- $c = 400Nm/rad$.

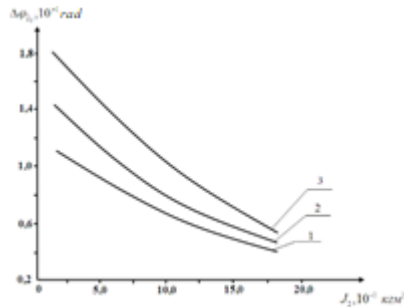


Figure 3. Regularities in the variation of the swing of the oscillation of the headset from changes in its moment of inertia and the stiffness coefficient of the elastic element where, 1- $c = 800Nm/rad$;
 2- $c = 600Nm/rad$; 3- $c = 400Nm/rad$.

It can be seen from the graphs obtained that with increasing technological resistance from raw cotton pulped by cotton barrel, the range of angular vibrations of the drum headset is increased by a nonlinear regularity. Thus, at $c = 400Nm/rad$ and the increase in M_c from 2,5Nm to 12,5Nm, the swing $\Delta\phi_2$ increases from 0,01rad to 0,054rad, and at $c = 800Nm/rad$ the angular displacement $\Delta\phi_2$ is within $(0,24 - 1,03) \cdot 10^{-1}rad$. To select the necessary amplitudes of angular vibrations of the headset, it is advisable to select the values of the moment of inertia J_2 . According to the analysis of the graphs in Figure 3 it can be noted that the increase in J_2 from 0,042kgm² to 0,17kgm² range $\Delta\phi_2$ decreases from 0,16rad to 0,059rad at $c = 400Nm/rad$, and at a stiffness value of an elastic rubber sleeve 600Nm/rad $\Delta\phi_2$ decreases from 0,127rad to 0,052rad. In this case, it is important to select the necessary values of the moment of inertia of the drum, as well as the rigidity of the rubber bushing, since a significant increase in the inertia of the drum leads not only to equalization of the rotation, but also to an additional expenditure of energy due to the massiveness of the drum. And increasing the circular rigidity of the rubber bush also reduces the swing of the drum's circular oscillations, and also increases the natural frequency of the drum's circular oscillations, which can lead to a resonance mode of motion, which is undesirable only for an effective process of cleaning raw cotton from small litter. So to ensure the swing of the angular vibrations of the drum headset within $(0,08 - 0,11)rad$, the recommended values are $J_2 = (0,068 - 0,12)kgm^2$, $c = (550 - 650)Nm/rad$.

In the working area for cleaning raw cotton from small litter, one of the main technological parameters is the distance between the ends of the drum pins and the mesh surface. Angular vibrations of the mesh surface vary from the technological parameter. In principle, this gap should not exceed the size of the cotton fly. With a significant increase in the clearance between the pins and the mesh surface, braking can lead to further stopping the pulling of cotton flies over the mesh surface, and in some cases also slaughtering the system. Therefore, it is important to determine the maximum angular displacement and the speed of the mesh surface of the cleaner fibrous material from small litter.

The differential equation of small forced angular vibrations of the mesh surface under the condition that there is no dissipation of the elastic support according to (1) has the form:

$$\ddot{\phi} + p_0^2\phi = \frac{lF(t)}{\zeta I_0 + ml^2} \tag{2}$$

Taking into account the following initial conditions, $\dot{\phi}(0) = \phi_0$, $\phi(0) = 0$ we represent the solution of equation (2) according to [6] in the form:

$$\dot{\phi}_k = \dot{\phi}_0 \cos p_0 t_k + \frac{l}{I_0 + ml^2} \int_0^{t_k} \cos p_0 (t_k - \tau) \cdot F(\tau) d\tau$$

To determine the law of variation of the disturbing force at $t_k = 2\pi/p_0$, an extreme value of the angular velocity $\dot{\phi}(t_k)$ of the mesh surface

$$\dot{\phi}_k = -\dot{\phi}_0 + \frac{l}{I_0 + ml^2} \int_0^{t_k} \cos(3\pi - p_0\tau) F(\tau) d\tau \quad (3)$$

Consequently, $\dot{\phi}_k = \dot{\phi}_{kmax}$ with the following law of variation of the disturbing force from raw-cotton:

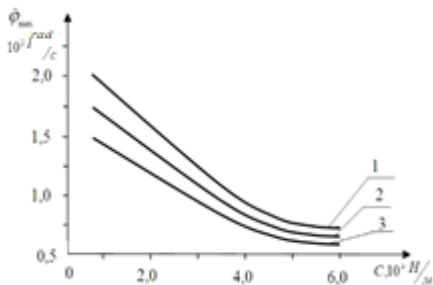
$$F(\tau) = \begin{cases} + F_0 \sin 0 \leq \tau \leq \frac{\pi}{2p_0}; \\ - F_0 \sin \frac{\pi}{2p_0} \leq \tau \leq \frac{3\pi}{2p_0}; \\ + F_0 \sin \frac{3\pi}{2p_0} \leq \tau \leq \frac{5\pi}{2p_0}; \\ - F_0 \sin \frac{5\pi}{2p_0} \leq \tau \leq 3 \frac{\pi}{p_0} = t_k \end{cases} \quad (4)$$

These regularities correspond to the number of tine rows, the rotation frequency and the phase of their arrangement.

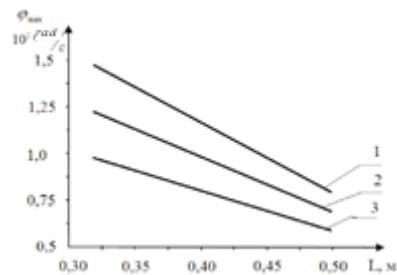
Integrating Eq. (3) with allowance for the found law of variation of the perturbing force, we have:

$$\left| \dot{\phi}_{max} \right|_0 \frac{6lF_0}{L(I_0 + ml^2) \sqrt{\frac{c}{I_0 + ml^2}}} \quad (5)$$

The numerical solution (5) is carried out at the following values of the main parameters of the cotton fine cleaning section: $I_0 = (0.012 \div 0.02) kgm^2$; $c = (2.5 \div 6.5) \cdot 10^4 N/m$; $m = (0.025 \div 0.045) kg$, $L = (0,35 - 0,55)m$. In Figure 4 shows the graphical dependences of the change in the maximum value of the angular velocity of the oscillations of the mesh surface with the variation of the stiffness coefficient of the elastic support for different values of the moment of inertia of the mesh surface with respect to the hinged support.



where, 1 - $I_0 = 0,012 kgm^2$; 2 - $I_0 = 0,016 kgm^2$; 3 - $I_0 = 0,02 kgm^2$.



where, 1 - $m = 25g$; 2 - $m = 35g$; 3 - $m = 45g$;

Fig. 4. Graphical dependences of the change in the maximum angular velocity of vibrations of the mesh surface from the change in the rigidity of the elastic support

Figure 5. Dependences of the change in the maximum angular velocity of vibrations of the mesh surface from the change in the distance between its supports

Analysis of the graphs shows that with increasing rigidity of the elastic support, the maximum angular velocity of the mesh surface of the cotton cleaner is reduced by a nonlinear regularity. Thus, with an increase in the stiffness coefficient from $1,7 \cdot 10^4 N/m$ to $6,2 \cdot 10^4 N/m$ at $I_0 = 0,012 kgm^2$, the angular velocity $\dot{\phi}_{max}$ decreases from $1,6 \cdot 10^2 rad/s$ to $0,76 \cdot 10^2 rad/s$, and at the moment of inertia of the mesh surface $I_0 = 0,02 kgm^2$, $\dot{\phi}_{max}$ decreases from $1,36 \cdot 10^2 rad/s$ to $0,73 \cdot 10^2 rad/s$. It should be noted that for large values of $\dot{\phi}_{max}$, not only the maximum dynamic reaction is provided, but also the effect of cleaning raw cotton from small litter is significantly increased. Therefore, the following parameter values are recommended: $c = (2,5 \div 4,2) \cdot 10^4 N/m$; $I_0 = (0,012 \div 0,015) kgm^2$. In Figure 5. shows the obtained graphical dependences $\dot{\phi}_{max}$. The analysis of the constructed graphs shows that an increase in the distance between the supports of the mesh surface leads to a decrease in the maximum value of the angular velocity of the mesh vibrations according to a linear regularity. Thus, with an increase in the distance L from 0,33 m to 0,51 m, the angular velocity decreases from $1,43 \cdot 10^2 rad/s$ to $0,877 \cdot 10^2 rad/s$ with the weight of cotton acting on the mesh of 0,025 kg, and at a cotton weight of 0,035 kg, $\dot{\phi}_{max}$ decreases from $1,134 \cdot 10^2 rad/s$ to $0,74 \cdot 10^2 rad/s$. It should be noted that the difference between the reference distance decreases with the increase between the reference distance 1,2,3 (see Figure 5). This is explained by the fact that for large values of L , the influence of the mass of cotton becomes insignificant on the angular velocity of the grid. Recommended values are: $L = (0,35 \div 0,45)m$; $m \leq (25 \div 35)gr$.

3 Experimental part

Drum drive is carried out from the DC motor. The latter is connected to an autotransformer of the type AOMN-40-220-75. This allows you to change the drum speed in a wide range. The force dynamic loading of various structures was determined by strain gauging in bench conditions. The experimental study was carried out in three regimes with a triple repetition. The drum rotational speed was $350,400,450 min^{-1}$. Serve raw cotton $4kg/s$. In Fig. 6 shows a typical oscillogram where the following are recorded: M_{kr} - is the torque at the shaft of the spinner, ω_b - is the angular velocity and n - is the number of revolutions per minute of the drum, and ε - is the angular acceleration, and τ - is the time. In the steady state of the system, when the technological load is not included from the raw cotton, the amplitude of the moment oscillations on the drum shaft does not exceed 10-15% of the nominal value. When the technological load is switched on from raw cotton, the amplitude of the moment oscillations on the drum shaft sharply increases, but the nature of low-frequency and high-frequency oscillations is clearly expressed. Random fluctuations are caused by the load of raw cotton.

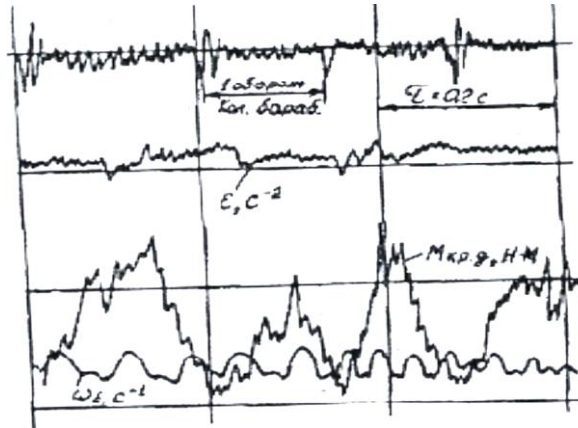


Fig. 6. Sample of the oscillogram when the technological load from the cotton to the pin drum.

Changes in the angular velocity of the drum correspond to the change in the transmission ratio of the belt drive. In this case, the unevenness of the rotation of the drum varies within 0,015 ... 0,02. On the basis of the results obtained, the shape and nature of the technological loads on the pin cylinder from raw cotton are revealed. The determination of these loads was carried out by the difference in the amplitude of the values of the torque on the shaft of the drum of the load and idle operating modes of the system. The obtained results were used for dynamic theoretical studies of the machine unit with the mechanism of the pin drum.

The results of full-flow experiments on the effect of the parameters of the cotton cleaning zone on fine sludge on the cleaning effect. To determine the effect of the main parameters of the fine-cleaning section on the cleansing effect of fine rubbish, a prototype composite drum spinner with an elastic bushing was made and full factor experiments were carried out. Table 1 shows the limits of change in input factors.

Table 1. Limits of change in input factors

Name factors	Coding	Factor Values					Limits of Change
		-1,682	-1	0	+1	+1,682	
Rotary drum rotation frequency, $n - min^{-1}$	X ₁	364	380	430	480	514	50
The gap between the pint drum and the mesh, $t - mm$	X ₂	16	17	20	23	25	3
The circular stiffness of the elastic bushing of the pin drum, $\nu - Nm/rad$	X ₃	0,1318	0,2	0,3	0,4	0,4682	0,1

The output parameter selects the efficiency of cotton cleaning. Its actual values are denoted by the letter M. The experimental results of the output parameters and the dispersion are given in Table 2.

The number of experiments is determined by the following expression:

$$N = 2^k + 2k + n_0 = 2^3 + 6 + 6 = 20,$$

(6)

where, N - is the number of experiments; k - is the number of factors; n₀ – is average number of experiment values.

The calculated average arithmetic value of the cleansing effect based on the results of the experiments was introduced in the 11th column of the Table 2. In this case, the arithmetic mean is determined as follows;

$$\bar{Y} = \frac{Y_{i1}+Y_{i2}+Y_{i3}}{3} \tag{7}$$

To obtain a regression model depicting a stationary surface, central compositional planning experiments are performed using the following matrix:

Table 2. Planning for the central composite experiment

U	X ₁	X ₂	X ₃	(X ₁) ²	(X ₂) ²	(X ₃) ²	X ₁ X ₂	X ₁ X ₃	X ₂ X ₃	\bar{Y}_u
1	+	+	+	+	+	+	+	+	+	38,45
2	+	+	-	+	+	+	+	-	-	36,6
3	+	-	+	+	+	+	-	+	-	43,2
4	+	-	-	+	+	+	-	-	+	41,3
5	-	+	+	+	+	+	-	-	+	36,4
6	-	+	-	+	+	+	-	+	-	33,9
7	-	-	+	+	+	+	+	-	-	38,6
8	-	-	-	+	+	+	+	+	+	36,1
9	-1,68	0	0	2,822	0	0	0	0	0	35
10	1,68	0	0	2,822	0	0	0	0	0	41,1
11	0	-1,68	0	0	2,822	0	0	0	0	40,9
12	0	1,68	0	0	2,822	0	0	0	0	35,2
13	0	0	-1,68	0	0	2,822	0	0	0	36,25
14	0	0	1,68	0	0	2,822	0	0	0	39,9
15	0	0	0	0	0	0	0	0	0	38,5
16	0	0	0	0	0	0	0	0	0	38,2
17	0	0	0	0	0	0	0	0	0	38,6
18	0	0	0	0	0	0	0	0	0	38,8
19	0	0	0	0	0	0	0	0	0	38,3
20	0	0	0	0	0	0	0	0	0	38,9

Using the above formulas on the basis of tables, we find the following values for the regression coefficients:

$$\begin{aligned} \sum x_{1u}Y_u &= 24,8; \text{ } \sum x_{2u}Y_u &= -23,45; \text{ } \sum x_{3u}Y_u &= 14,88; \text{ } \\ \sum x_{1u}x_{2u}Y_u &= -5,05; \text{ } \sum x_{1u}x_{3u}Y_u &= -1,25; \text{ } \sum x_{2u}x_{3u}Y_u &= -0,05; \text{ } \\ \sum x_{1u}^2Y_u &= 519,3; \text{ } \sum x_{2u}^2Y_u &= 519,3; \text{ } \sum x_{3u}^2Y_u &= 519,45; \end{aligned}$$

Now we form the regression equation and count on the regression coefficient. Regression equations:

$$Y = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_{12}x_1x_2 + b_{13}x_1x_3 + b_{23}x_2x_3 + b_{123}x_1x_2x_3 + b_{11}x_1^2 + b_{22}x_2^2 + b_{33}x_3^2 \tag{8}$$

Then we determine by the regression coefficient:

$$b_0 = a_1 \sum_1^N y_u - a_2 \sum_1^N x_{iu}y_u = 0,1663 \cdot 764,2 - 0,0568 \cdot (519,3 + 519,3 + 519,45) = 38,5;$$

$$\begin{aligned}
 b_1 &= a_3 \sum_1^N x_{1u} y_u = 0,0732 \cdot 24,8 = 1,81; & b_2 &= a_3 \sum_1^N x_{2u} y_u = 0,0732 \cdot (-23,43) = -1,71; \\
 b_3 &= a_3 \sum_1^N x_{3u} y_u = 0,0732 \cdot 14,88 = 1,08; & b_{12} &= a_4 \sum_1^{n_s} x_{1u} x_{2u} y_u = 0,125 \cdot (-5,05) = -0,63; \\
 b_{13} &= a_4 \sum_1^{n_s} x_{1u} x_{3u} y_u = 0,125 \cdot (-1,25) = -0,15; & b_{23} &= a_4 \sum_1^{n_s} x_{2u} x_{3u} y_u = 0,125 \cdot (-0,05) = -0,006; \\
 b_{11} &= a_5 \sum_1^N x_{1u}^2 y_u + a_6 \sum_1^k \sum_1^N x_{1u}^2 y_u - a_7 \sum_1^N y_u = 0,0625 \cdot 519,3 + 0,0069 \cdot (519,3 + 519,3 + 519,45) - 0,0568 \cdot 764,2 = -0,2 \\
 b_{22} &= a_5 \sum_1^N x_{2u}^2 y_u + a_6 \sum_1^k \sum_1^N x_{2u}^2 y_u - a_7 \sum_1^N y_u = 0,0625 \cdot 519,3 + (-27,53) = -0,2; \\
 b_{33} &= a_5 \sum_1^N x_{3u}^2 y_u + a_6 \sum_1^k \sum_1^N x_{3u}^2 y_u - a_7 \sum_1^N y_u = 0,0625 \cdot 519,45 + (-27,53) = -0,191;
 \end{aligned}$$

Based on the calculations, the regression equation:

$$Y = 38,81 + 1,81x_1 - 1,71x_2 + 1,08x_3 - 0,63x_1x_2 - 0,15x_1x_3 - 0,006x_2x_3 - 0,2x_1^2 - 0,2x_2^2 - 0,191x_3^2 \quad (9)$$

The output values of the factors determined from the compiled regression equations are presented in Table 3.

Table 3. Compiled regression equations

N ₀	\bar{Y}_i	Y_{Ri}	$\bar{Y}_i - Y_{Ri}$	$(\bar{Y}_i - Y_{Ri})^2$	N ₀	\bar{Y}_i	Y_{Ri}	$\bar{Y}_i - Y_{Ri}$	$(\bar{Y}_i - Y_{Ri})^2$
1	38,45	38,40	0,055	0,003	11	40,9	40,91	-0,007	0,000
2	36,6	36,54	0,058	0,003	12	35,2	35,15	0,055	0,003
3	43,2	43,10	0,100	0,010	13	36,25	36,22	0,029	0,001
4	41,3	41,22	0,079	0,006	14	39,9	39,88	0,019	0,000
5	36,4	36,34	0,060	0,004	15	38,5	38,61	-0,110	0,012
6	33,9	33,86	0,039	0,001	16	38,2	38,61	-0,410	0,168
7	38,6	38,52	0,080	0,006	17	38,6	38,61	-0,010	0,000
8	36,1	36,02	0,084	0,007	18	38,8	38,61	0,190	0,036
9	35	34,98	0,023	0,001	19	38,3	38,61	-0,310	0,096
10	41,1	41,08	0,024	0,001	20	38,9	38,61	0,290	0,084
Total:									0,44

We define the variances of the output parameters:

$$S^2\{Y\} = \frac{\sum_1^6 (y_{0i} - \bar{y}_0)}{n_0 - 1} = \frac{0,36}{6 - 1} = 0,072 \quad (10)$$

Using the above expressions, the variances of the regression coefficients are determined:

$$\begin{aligned}
 |S\{b_0\}| &= \sqrt{S^2\{b_0\}}; & S^2\{b_0\} &= a_1 \cdot S^2\{Y\} = 0,1663 \cdot 0,072 = 0,011; & S\{b_0\} &= 0,01; \\
 |S\{b_i\}| &= \sqrt{S^2\{b_i\}}; & S^2\{b_i\} &= a_3 \cdot S^2\{Y\} = 0,0732 \cdot 0,072 = 0,005; \\
 S\{b_i\} &= 0,07; & |S\{b_{ij}\}| &= \sqrt{S^2\{b_{ij}\}}; & S^2\{b_{ij}\} &= a_4 \cdot S^2\{Y\} = 0,125 \cdot 0,072 = 0,008; \\
 S\{b_{ij}\} &= 0,08; \\
 |S\{b_{ii}\}| &= \sqrt{S^2\{b_{ii}\}}; & S^2\{b_{ii}\} &= a_5 \cdot S^2\{Y\} = 0,0625 \cdot 0,072 = 0,004; & S\{b_{ii}\} &= 0,06.
 \end{aligned}$$

Using the Student's criterion in calculating the calculated values, we check the significance of the regression coefficients. For certain coefficients of regression, we determine the values of the Student's criteria.

$$\begin{aligned}
 t_R\{b_0\} &= \frac{b_0}{S\{b_0\}} = \frac{38,58}{0,1} = 385,9; & t_R\{b_1\} &= \frac{b_1}{S\{b_i\}} = \frac{1,81}{0,07} = 25,85; \\
 t_R\{b_2\} &= \frac{b_2}{S\{b_i\}} = \frac{-1,71}{0,07} = 24,5; & t_R\{b_3\} &= \frac{b_3}{S\{b_i\}} = \frac{1,08}{0,07} = 15,58; \\
 t_R\{b_{12}\} &= \frac{b_{12}}{S\{b_{ij}\}} = \frac{-0,63}{0,08} = -7,9; & t_R\{b_{13}\} &= \frac{b_{13}}{S\{b_{ij}\}} = \frac{-0,15}{0,08} = -1,95; \\
 t_R\{b_{12}\} &= \frac{b_{12}}{S\{b_{ij}\}} = \frac{-0,006}{0,08} = -0,078; & t_R\{b_{11}\} &= \frac{b_{11}}{S\{b_{ii}\}} = \frac{0,2}{0,06} = -3,32; \\
 t_R\{b_{22}\} &= \frac{b_{22}}{S\{b_{ii}\}} = \frac{-0,2}{0,06} = -3,32; & t_R\{b_{33}\} &= \frac{b_{33}}{S\{b_{ii}\}} = \frac{-0,21}{0,06} = -3,5.
 \end{aligned}$$

The calculated values of the Student's criteria are compared with the tabulated values. The following conditions must be satisfied:

$$t_x)t_{jad}, \quad t_j[P_D = 0,95; f\{S_M^2\} = 6 - 1 = 5] = 2,57 \tag{11}$$

For the output factor, the purifying effect of raw cotton is selected for small sors. If the set condition is satisfied, the regression coefficient will be significant. But if the condition is fulfilled, these regression coefficients will be insignificant and removed from the subsequent calculations. Based on the results of the calculation, the values of $t_{Rb_{23}}$ less than the values selected from the table will be insignificant, the remaining coefficients are considered significant are used in the following calculations [9]. In this case, the regression equation will be as follows:

$$Y = 38,81 + 1,81x_1 - 1,71x_2 + 1,08x_3 - 0,63x_1x_2 - 0,2x_1^2 - 0,2x_2^2 - 0,21x_3^2 \tag{12}$$

he regression tests the obtained equations for adequacy based on the Fisher criterion. The Fisher criterion is defined by the following expressions:

$$F_R = \frac{S_{a0}^2(Y)}{S^2(\bar{Y})} \tag{13}$$

$$S_{a0}^2 = \frac{\sum_1^{20} (y_u - \bar{y}_0)^2 - \sum_1^6 (y_{oi} - \bar{y}_0)}{20 - 6 - 5} = \frac{0,44 - 0,377}{9} = 0,005; \tag{14}$$

$$F_{cal} = \frac{S_{a0}^2}{S_{(y)}^2} = \frac{0,005}{0,079} = 0,074. \tag{15}$$

The table value of the Fisher test F_j when compared with the calculated value of $F_x = 0,074(3,48 = F_j$ condition was satisfied and the adequacy of the expression was determined.

The table value of the Fisher test from the application is determined by the following condition.

$$F_j [P_D = 0,95; f\{S_{ab}^2\{Y\}\} = 20 - 6 - (6 - 1) = 9; f\{S_M^2\} = 6 - 1 = 5] = 3,48 \quad (16)$$

Hence the regression model obtained is considered adequate and can be used in the following studies.

For practical use of the results, the transition from the coded values (X_1, X_2, X_3) to real values (n, t, v), which is carried out according to the following formula:

$$X_1 = \frac{n-n_0}{\Delta n}; \quad X_2 = \frac{t-t_0}{\Delta t}; \quad X_3 = \frac{v-v_0}{\Delta v}; \quad (17)$$

n_0, t_0, v_0 - real values of parameters, $\Delta n, \Delta t, \Delta v$ - intermediate values. (17) substituting in the formula the values n_0, t_0, v_0 и $\Delta n, \Delta t, \Delta v$ we obtain the following:

$$X_1 = \frac{n-430}{50}; \quad X_2 = \frac{t-20}{3}; \quad X_3 = \frac{v-72,5}{12,5}; \quad (18)$$

From (18) we obtain equations for the output parameters:

$$Y = 38,58 + 1,81 \cdot \frac{1}{50} \cdot (n - 430) - 1,71 \cdot \frac{1}{3} \cdot (t - 20) + 1,08 \cdot \frac{1}{12,5} \cdot (v - 72,5) - 0,63 \cdot \frac{1}{150} \cdot (n - 430) \cdot (t - 20) - 0,199 \cdot \frac{1}{2500} \cdot (n - 430)^2 - 0,199 \cdot \frac{1}{9} \cdot (t - 20)^2 - 0,191 \cdot \frac{1}{12,5^2} \cdot (v - 72,5)^2;$$

$$Y = 38,58 + 0,036n - 15,56 - 0,57t + 11,4 + 0,08 \cdot v - 6,26 - 0,004 \cdot (n \cdot t - 20 \cdot v - 430 \cdot t + 860) - 8 \cdot 10^{-5} \cdot (n^2 - 860 \cdot n + 184900) - 0,022 \cdot (t^2 - 40t + 400) - 0,001 \cdot (v^2 - 145 \cdot v + 52 \cdot 56,25) =$$

$$= 28,16 + 0,036 \cdot n - 0,57 \cdot t + 0,08 \cdot v - 0,004 \cdot n \cdot t + 0,08 \cdot n + 1,72 \cdot t - 3,44 - 8 \cdot 10^{-5} \cdot n^2 + 0,068 \cdot n - 14,71 - 0,022 \cdot t^2 + 0,88 \cdot t - 8,8 - 0,001 \cdot v^2 + 0,145 \cdot v - 5,25 =$$

$$= -4,04 + 1,84n + 2,03t + 0,225v - 4 \cdot 10^{-3}n \cdot t - 8 \cdot 10^{-5} \cdot n^2 - 0,022t^2 - 10^{-3}v^2; \quad (19)$$

To optimize the parameters, equation (19) was given in the following form:

$$M_z = -4,04 + 1,84n + 2,03t + 0,225v - 4 \cdot 10^{-3}n \cdot t - 8 \cdot 10^{-5} \cdot n^2 - 0,022t^2 - 10^{-3}v^2 \quad (20)$$

Numerical solution (7) was produced by Excel program. Fig. 7 shows the graphical dependences of the change in the purifying effect on the change in factor X_1 . In this case, in Figure 7, the new one is obtained for low values of X_2 and X_3 , the second curve for intermediate values, the third curve for high values of factors X_2 and X_3 .

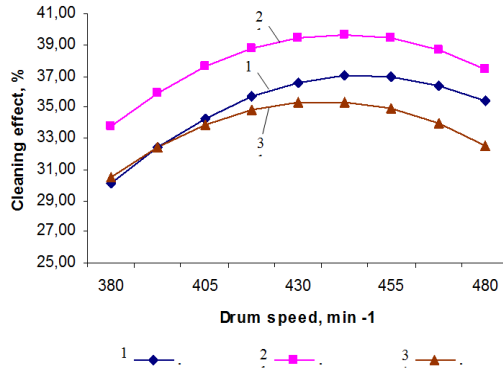


Fig. 7. The graphs change the cleaning effect of changing the rotational speed of the composite spear drum with a rubber bush

With a drum rotational speed of 380 min^{-1} , the cleaning effect is 30% (see Fig. 7, graph 1), $n = 450 \text{ min}^{-1}$ the cleaning effect is up to 36.8%, and further increase to $n = 480 \text{ min}^{-1}$, the cleaning effect is reduced to 38%. In the second graph in the Fig. 7 at $X_2 = 20 \text{ mm}$, $X_3 = 0,30 \cdot 10^4 \text{ Nm/rad}$, the cleaning effect reaches 33,8%, at $n = 380 \text{ min}^{-1}$, and at $n = 447 \text{ min}^{-1}$, the cleaning effect is 39,6%, and at $n = 480 \text{ min}^{-1}$, $M_z = 37,2\%$. In the third graph in Figure 7 with $X_2 = 23 \text{ mm}$, $X_3 = 0,40 \cdot 10^4 \text{ Nm/rad}$ and $n = 438 \text{ min}^{-1}$, the cleaning effect will be 29,7%, and at $n = 480 \text{ min}^{-1}$ $M_z = 35,2\%$, with $n = 480 \text{ min}^{-1}$, it drops to 32.1%.

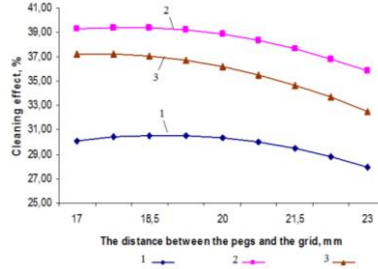


Fig. 8. Charts change the cleaning effect of changing the distance from the end of the picks to the grid

At the values of $X_1 = 380 \text{ min}^{-1}$ and $X_3 = 0,20 \cdot 10^4 \text{ Nm/rad}$, the cleaning effect was 30,1%, and at $X_2 = 17 \text{ mm}$, $M_z = 30,8\%$, at $X_2 = 23 \text{ mm}$ cleaning effect is reduced to 28% (the first graph in Figure 8). In the second graph in Fig. 8 with $X_1 = 430 \text{ min}^{-1}$, $X_3 = 0,30 \cdot 10^4 \text{ Nm/rad}$, the purifying effect was 39,2%. At $X_2 = 17 \text{ mm}$, and $X_2 = 18 \text{ mm}$, $M_z = 39,8\%$, and at 23 mm the cleaning effect is reduced to 36%. In the third graph in Fig. 8, the greatest purifying effect of cotton from small litter comes to 37.4% at $X_1 = 480 \text{ min}^{-1}$, $X_3 = 0,40 \cdot 10^4 \text{ Nm/rad}$ and $X_2 = 18 \text{ mm}$.

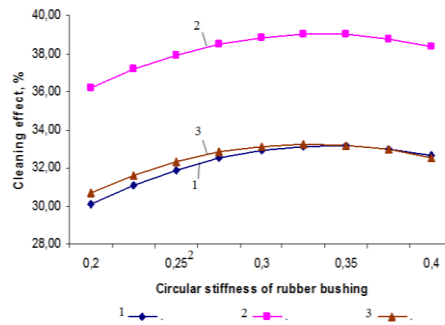


Fig. 9. Charts change the cleaning effect of changing the coefficient of circular rigidity of the rubber bushing.

In Fig. 9, (graph 3) at $X_1 = 380 \text{ min}^{-1}$, $X_2 = 17 \text{ mm}$ and at $X_3 = 0,20 \cdot 10^4 \text{ Nm/rad}$, the cleaning efficiency was 30,1%, and at $X_3 = 0,30 \cdot 10^4 \text{ Nm/rad}$ received the greatest cleaning effect of 33,2%. Analysis of graphs 2 and 3 in Figure 9 showed that the maximum value of $M_z = 38,3\%$ was obtained for $X_3 = 0,35 \cdot 10^4 \text{ Nm/rad}$.

According to the analysis of the conducted studies, the recommended values are $n = 444 \text{ min}^{-1}$, $t = 19 \text{ mm}$, $v = 0,35 \cdot 10^4 \text{ Nm/rad}$, at which the maximum effect of cleaning cotton from small litter is 39,9%.

Analysis of the test results of the developed design of the fibrous material cleaner: The prototype purifier was installed in the cotton production line in the cotton plant. The initial weakening of raw cotton has a significant effect on the cleaning effect. During the tests, the moisture content and initial weakening of the compared cleaning sections of the production lines were maintained in the same range. Analyzes were carried out at the factory laboratory

Table 4. The results of a comparative technological production test for 1st and 2nd cleaning lines mod. 1XK

Indicator in%	After the upgraded section of the unit in the 1st line (mod. 1XK)	After the serial unit in the 2nd line (mod. 1XK)
Humidity (%)	10,1/8,1	10,1/8,1
	9,4/8,4	9,4/8,4
	9,6/8,2	9,6/8,2
Weediness (%)	4,8/2,85	4,8/3,2
	4,5/2,75	4,5/3,05
	4,2/2,45	4,2/2,9
After cleaning, the cleaning effect	40,6	33,3
	38,9	32,2
	40,3	30,9

When carrying out the tests, the recommended design of the drum spinner in the raw cotton cleaner from small (Mod. 1 XK) litter showed high reliability, stability of operation. The results of the tests showed that the cleaning effect increased by an average of 2.7% compared to the existing version of the drum spinner. Due to additional torsional vibrations of the spinner drum, effective isolation of weed impurities is ensured and the process of braking of cotton is eliminated. The results of comparative technological tests on the cleaning

line with the serial and experimental designs of the cleaning sections of the (Mod. 1 XK) aggregates are given in Table 2 [7,8].

4 Conclusion

An effective scheme for the construction of a cleaner for fibrous material from small litter has been developed. The oscillations of the headset and the net surface are theoretically studied, their parameters are justified. Experiments studied the loading of the pin drum. Based on the analysis of the existing designs of cotton cleaners from small litter, a new effective scheme of the cleaner was recommended. The full-factor experiments proved the optimal values of the parameters of the cleaning zone.

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