Development of an effective construction scheme and analysis of oscillations of the cotton fiber cleaner saw cylinder

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Abstract. A construction scheme and principle of operation of a fibrous material cleaner with saw cylinders on elastic bearing support are given in the article. The results of theoretical research of oscillations of the saw cylinder of the fiber cleaner are presented. The parameters of the system are substantiated based on the analysis of the law of oscillations of the cylinder and graphic dependencies.

1 Introduction

ZOVP fiber cleaner for cleaning cotton fiber from litter and defects consists of a body with inlet and outlet for the flow of fiber with air, blinds and weed chamber [1].

The shortcoming of this fiber cleaner is its insufficient width and performance, increased damage to the fibers.

Direct-flow single-stage fiber cleaner brand 1VPU is purposed for cleaning cotton fiber from litter and defects, which consists of a body with inlet and outlet for the flow of fiber with air, blinds, a weed chamber containing a saw cylinder with inter-saw spacers, a discharge pipe, the wall of which contains curved and straight sections, and an inlet pipe, and the axes of the pipes intersect at an acute angle, a grate, a carbon monoxide chamber with louvered grates and a wiping brush. The longitudinal axis of the inlet pipe is tangent to the circumference of the saw spacer, and the shortest distance between the teeth of the saw cylinder and the transition point of the curved section of the wall of the outlet pipe to the straight one is equal to the difference between the radii of the saw cylinder and the saw blade [2].

The shortcoming of this fiber cleaner is the large mass of the saw cylinder, and hence the difficulty in setting the gaps between the ends of the saw teeth and the grate, the insufficient rigidity of the fiber cleaner.

Consequently, in the course of work, the cleaning of the fiber from litter and defects worsens, and the reliability of the fiber cleaner operation decreases.

Direct-flow single-stage saw fiber cleaner consists of a body with inlet and outlet for the flow of fiber with air, blinds, a weed chamber, sidewalls, saw cylinder with a drive, grates under the saw cylinder, additionally equipped with a saw cylinder and grates.

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The ends of both saw cylinders are installed in bearing frame placed on shelves fixed on the sidewalls of the body, and a vertical wall, i.e. partition installed in the middle part of the housing. In addition, each saw cylinder is equipped with a separate drive [3].

The shortcoming of this design is a large percentage of fiber in trash, as well as a low fiber cleaning effect.

2 Efficient construction scheme of the fiber cleaner

In order to improve the cleaning effect and increase the reliability of the design, a new one was developed [4].

The essence of the design is that a direct-flow single-stage saw fiber cleaner containing a body with inlet and outlet for the flow of fiber with air, blinds, a weed chamber, two saw cylinders coaxially mounted on bearings are placed on the shelves by means of rubber bushings fixed on the sidewalls of the frame, and a vertical walls, i.e. partitions installed in the middle part of the body, while the gaps *t* between the grates under the saw cylinders are made decreasing from t_{in}=65 mm to t_{out}=50 mm in the course of pulling through the fibrous material, and the working elements of the trapezoidal shape of the grates are installed in them by means of rectangular rubber pads shape, each saw cylinder is equipped with a separate drive that turns off the chain drive. The design allows increasing the cleaning effect due to elastic bearing supports that reduce the bending of the saw cylinder shafts, reduces the departure of fibers into the sorrow by gradually reducing the gaps between the grates, and also increases the reliability of the saw cylinders by including chain drives in their drive.

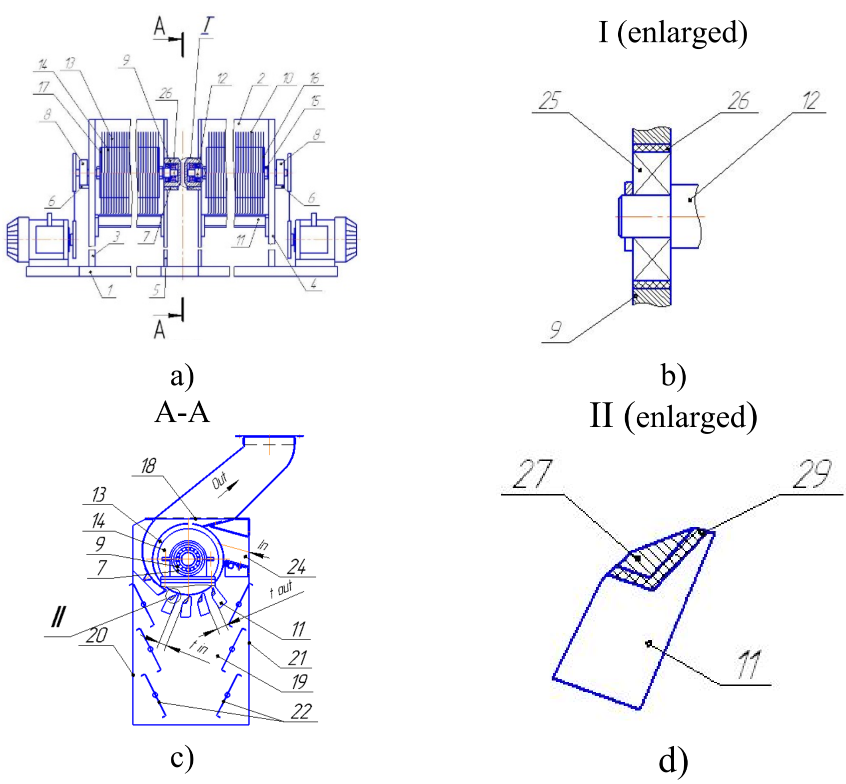


Fig. 1. Fiber cleaner construction scheme.

The structural scheme of a direct-flow single-stage saw fiber cleaner is shown in Fig. 1a. Let us note the design features that allow to increase the efficiency of the device, and also affect the improvement of the capture of fibers by the saw teeth. The basis of the structure is frame 1 (Fig. 1a). The housing, designated 2, contains extreme 3 and 4, and middle walls-partitions 5. Shelves 6 and 7 are installed on these walls-partitions. These shelves are used to fasten housings 8 and 9 for the bearing, indicated by the number 25. It is characteristic that in these housings 8 and 9, these bearings 25 are installed using rubber bushings 26. This is shown in fig. 1b. An enlarged image is shown here in Fig. 1e for the rubber gasket 29. The basic design principle is important, which is aimed at reducing the gaps between the gratings in the process of pulling the fibrous material. This is reflected in the structural diagram as follows. We see in the figure that the gaps between the gratings 11 are made decreasing. The interval of decrease from the input to the output as the fibrous material is drawn is from t_{in}=65 mm to t_{out}=50 mm.

Fig. 1c shows saw cylinders marked with the number 10. It follows from the figure that these saw cylinders contain shafts marked 12 with saws put on them, which are marked as 13 in the diagram (see Fig. 1c). A slight misalignment during the installation of the shafts 12, which can be found in the diagram as designated 20, improves the grip of the fibers by the teeth of the saw 13. It is to improve the grip of the fibers by the teeth of the saw 13 that the shafts 12 are installed not only with a slight misalignment, but also with some gaps between them. These gaps are 6 mm. The installation of saw blades 14 is shown in Fig. 1c. Two tie nuts, marked 15, and four slanting washers, marked 16 and 17, allow you to achieve the necessary saw misalignment. The device tightens these nuts and washers on the shafts. The use of two coupling nuts 15 and four slanting washers 16 and 17 provides a given saw skew. We note several elements that are not reflected in this figure, but are important for understanding its design. This is a litter removal mechanism. It is installed at the bottom of the body of the fiber cleaner, where there is a weed chamber 19. The trash removal mechanism is essential for the efficient operation of a direct-flow single-stage saw fiber cleaner. Related to this is the need to install in the housing in the front 20 and rear 21 walls of the shutters, marked 22. The inlet and outlet of the fiber is carried out through the following structural elements, which are provided with the housing of the fiber cleaner. The number 24 indicates the inlet for the flow of the fiber with air, and the number 18 indicates the outlet for the flow of the fiber with air.

The operation of the fiber cleaner can be described as follows, given the figure presented. The fiber, which is transported by the air stream, during the operation of the fiber cleaner, enters from the gin through the inlet 24. The separation of the fiber is carried out on the partition 5. Thus, the fiber is divided into two parts and fed to the rotating saw cylinders 10. Further, the teeth of the saw 13, due to a slight inclination, capture and tear the fiber. This process is carried out while moving along the grate 11. A process that is not shown in the figure, but which should be discussed in the article, is the process of removing impurities. These include weed impurities, cotton motes and vices. All of them, which are heavier than the fiber itself, deviate more in the radial direction. In this regard, they are the first to fall through the gaps of the gratings 11 and enter the weed chamber 19. Thus, they are removed from the fiber cleaner. At the same time, the cleaned fiber is blown off the saw teeth. The process of blowing off the cleaned fiber is carried out by the same air flow that passed into the gaps between the saws 13, and then was directed through the outlet 18. The fiber flow with air in the fiber cleaner housing is directed to the outlet neck associated with the total fiber outlet.

Consider adjusting the air supply to the fiber and fiber waste cleaner. This process is carried out with the help of dampers 22. It should be noted changes in the operation of the saw cylinders due to unbalanced masses, as well as fibers captured and dragged along the grate 11. In this situation, the shafts 12 of the saw cylinders 10 are bent. This leads to a change in technological gaps. However, in our design, this effect of bending and changing technological gaps is excluded. This is achieved in the design recommended by us due to the deformation of the rubber bushings 26. Moreover, the implementation of the input and output gaps between the gratings 11 (from t_{in}=65 mm to t_{out} =50 mm) allows, when pulling the fibrous material, to significantly reduce the departure of fibers into the bend of the litter. It should be noted the phenomena associated with the friability of the fiber. The looseness of the fibers increases as the fiber is drawn. This, in turn, is associated with a decrease in the gaps between the gratings 11. It is this that significantly reduces the exit of fibers with debris through these gaps. The interaction of the fiber with structural elements is carried out gently. The softness of the interaction is achieved due to the fluctuations of the working bodies of the trapezoid shape 27 (Fig. 1d). Thus, when the rectangular rubber pads 30 are deformed, the interaction of the fibers will be soft. This reduces fiber damage. Weed impurities are more effectively separated due to fluctuations of the working bodies of a trapezoidal shape.

An important aspect of the reliable operation of the design is the use of chain drives 23, 28 in the saw cylinder drives 10. The use of chain drives is associated with the need to ensure uniform cleaning modes. Also, such transmissions provide high reliability of the proposed design.

3 Dynamic and computational model of the saw cylinder oscillations

The saw cylinder of the fiber cleaner, mounted on elastic bearing supports, oscillates both vertically and in oblique fusibility. According to technological requirements, it is important to maintain a gap between the teeth of the saw cylinder and the fiber remover [5,6]. Therefore, it is necessary to determine the maximum value of the oscillation amplitude of the saw cylinder of the cotton cleaner. The construction scheme of the oscillatory system is shown in Figure 2.

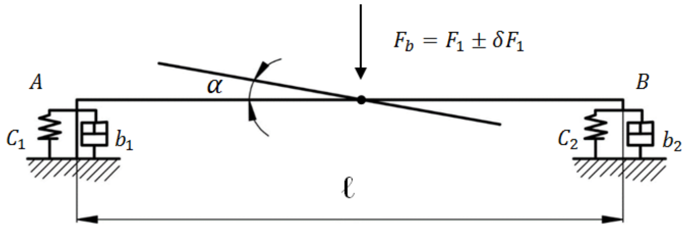


Fig. 2. Design scheme of the oscillatory system.

In order to obtain a mathematical model of oscillations of the saw cylinder, we use the Lagrange equation of the second kind [7, 8];

$$\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{y}_i}\right) - \frac{\partial T}{\partial y_i} + \frac{\partial \Phi}{\partial \dot{y}_i} + \frac{\partial \Pi}{\partial y} = Q(y)_i \quad (1)$$

where T, Π are kinetic and potential energies of the system, respectively; Φ is the dissipative Rayleigh function; Q is generalized force; t is time; y is a generalized coordinate.

If we consider that $C_1 \neq C_2$, then the potential and kinematic energy of oscillations of the saw cylinder are [7; 8]:

$$\Pi = \frac{C_1}{2}\left(y - \frac{\alpha l}{2}\right)^2 1 + \frac{C_2}{2}\left(y - \frac{\alpha l}{2}\right)^2$$
$$T = \frac{1}{2} m_n \dot{y}^2 + \frac{1}{2} J_b (J_b \varphi \dot{\alpha}_2) \quad (2)$$

where m_B, J_B are mass and moment of inertia of the saw cylinder, respectively; C_1, C_2 are the stiffness coefficients of elastic supports.

Dissipative Rayleigh function is [9]

$$\phi = \frac{b_1}{2}(\dot{y} - \frac{\dot{\alpha\ell}}{2})^2 + \frac{b_2}{2}(\dot{y} - \frac{\dot{\alpha\ell}}{2})^2 \quad (3)$$

where, b_1, b_2 are the dissipation coefficients of elastic supports; α is the angle of inclination of the axis of the saw cylinder.

$$m_n\,\ddot{y} + C_1\left(y - \frac{\alpha\ell}{2}\right) + C_2\left(y - \frac{\alpha\ell}{2}\right) + b_1\cdot\left(\dot{y} - \frac{\dot{\alpha\ell}}{2}\right) + b_2\left(\dot{y} - \frac{\dot{\alpha\ell}}{2}\right) = F_b$$

$$J_n\ddot{\alpha} = \frac{e_1c_1}{2}\left(y - \frac{\alpha\ell}{2}\right) + \frac{C_2\ell}{2}\left(y - \frac{\alpha\ell}{2}\right) - \frac{b_1\ell}{2}\left(\dot{y} - \frac{\dot{\alpha}\,\ell}{2}\right) + M_b \quad (4)$$

where, F_b, M_b are the force and moment of the perturbation; ℓ is length of saw cylinder

Let us consider solution (4) with the same parameters of elastic supports. Wherein:

$$C=C_1=C_2; \quad X=0; \quad b=b_1=b_2$$

Then the first equation (4) has the form;

$$m_n\,\ddot{y} + 2cy + 2b\dot{y} = F_b \quad (5)$$

With a harmonic change in the disturbing force from the cleaned cotton, the solution (5) according to [10. 11] has the form:

$$y = (C_1 cosK_1 t + C_2 Sin\cdot hK_1 t)e^{\frac{bt}{m}} + \frac{F_1 S\cdot h(pt - artg\frac{bp}{c-p^2})}{m_n\sqrt{\left[(\frac{2c}{m_n})^2 - p^2\right] + \frac{\varphi b^2}{m_n^2}p^2}} \quad (6)$$

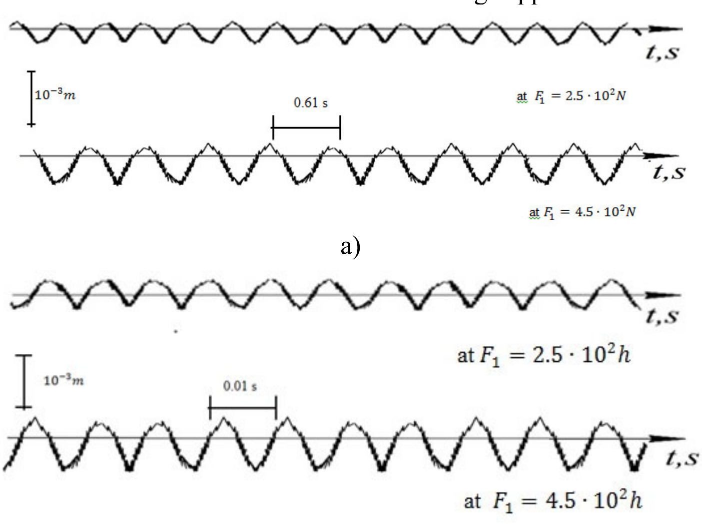
It should be noted that due to the deformation of the elastic bearing supports in the static mode, the axis of the saw cylinder in the initial stage, at t=0, is lowered y_{CT}.

The numerical solution of the problem is carried out with the following values of the parameters: m_n=(150÷225) kg; n_n =1500 rpm; e=2.72;

$C_1=C_2=(3.5\div5.0)\cdot10^4$ N/m; $b_1=b_2$ (5.0÷6.0) N/s

$F_1=(2.5\div4.5)\cdot10^2$ N; $\delta F_1 = (0.08\div0.1)F_1$;

Solution of problem (5) was carried out considering the random component of the load δF from the cotton fiber. The patterns of changes in vertical oscillations from the saw cylinder from changes in the stiffness coefficients of elastic bearing supports are shown in Figure 3.



a- at c=5.0· $10^4 N/m$ b- at c=3.5· $10^4 N/m$

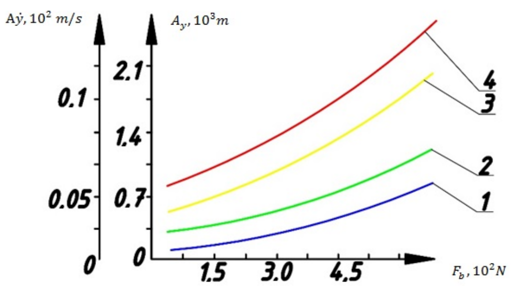
Fig. 3. Patterns of changes in vertical oscillations from the saw cylinder from changes in the stiffness coefficients of elastic bearing supports.

Analysis of the obtained patterns of changes in the displacements and speeds of the oscillation of the saw cylinder shows that with an increase in the performance of the fiber cleaner, that is, an increase in the values of $F_в$ the oscillation amplitude y and $\ddot{y}$ increase, but the oscillation frequency remains unchanged.

Since the frequency of the disturbing force remains constant, it should be noted that the system operates in the setting mode. Based on the processing of the obtained patterns of change in y and $\ddot{y}$, graphic dependences of the parameters of the oscillatory system were constructed.

Graphical dependences of the change in the amplitude of oscillations of vertical displacements and speed on the change in the perturbing force are shown in Fig. 4. It can be seen from them that with the drag of the perturbing force, Ay and A$\dot{y}$ increase according to a nonlinear pattern. Thereby, when $F_в$ changes from $1.0·10^2$ N to $4.5·10^2$ N, the amplitude of oscillations of the saw cylinder displacements with its mass of $2.0·10^2$ kg, the value of Ay increases from $0.08·10^{-3}$ m to $0.39·10^{-3}$ m, and the value of A$\dot{y}$ increases from $0.02·10^2$ m/s to $0.08·10^2$ m/s.

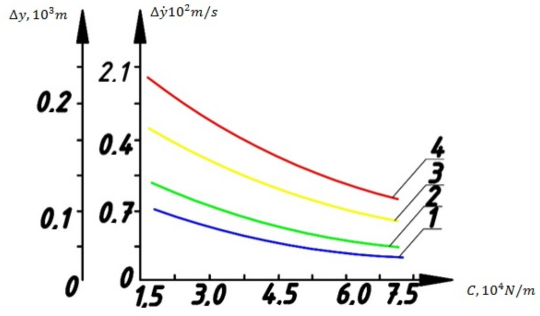
With a decrease in the mass of the saw cylinder to $1.25·10^2$ kg, the amplitude of movements reaches $0.54·10^{-3}$ m, the amplitude of speed fluctuations reaches $0.132·10^2$ m/s.



1.2- Ay= f(F_b); 3.4- A$\dot{y} = f$(F_b); 1.3-m_n=$2.0·10^2 kg$; 2.4-m_n=$1.25·10^2 kg$;

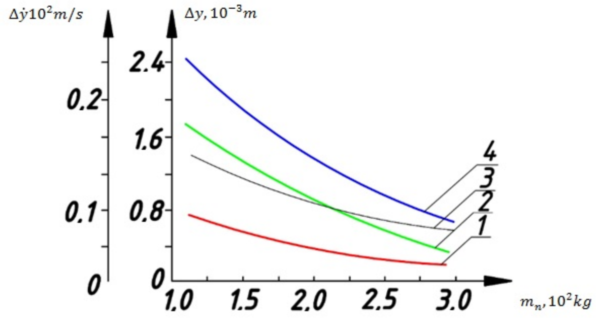
Fig. 4. Graphic dependences of the change in the amplitude of oscillations of vertical displacements and speed on the change in the disturbing force.

Therefore, to ensure A$y \leq (0.25÷0.35)·10^{-3}$ m it is recommended $F_b \leq (0.4÷0.42)·10^{-3}$ N.



1.2- Ay= f(C); 3.4- A$\dot{y} = f$(C); 1.3- F_b =$(3.5\pm0.25)\cdot10^2 N$; 2.4- F_b =$(2.5\pm0.27)\cdot10^2 N$;

Fig. 5. Graphic dependences of the change in the range of fluctuations of vertical displacements and the rate of increase in the stiffness coefficient of rubber bearing supports.



1.2- Аy= f(m$_n$); 3.4- А$\dot{y}$ $= f$(m$_n$); 1.3- F$_b$ =(2.5$\pm$0.21) $\cdot$ $10^2 N$; 2.4- F$_b$ =(3.5$\pm$0.25) $\cdot$ $10^2 N$;

Fig. 6. Graphical dependences of the change in the range of movement and speed fluctuations from the saw cylinder on the change in its mass.

Graphical dependences of the change in the range of oscillations of movement along the vertical and speed from the increase in the stiffness coefficient of rubber bearing supports are shown in Fig. 5. Analysis of the graphs shows that with an increase in the stiffness coefficient of rubber bearing supports from $1.5\cdot10^4$ N/m to $6.0\cdot10^4$ N/m, the oscillation range of the saw cylinder axis at F$_b$ = (2.5±0.21)$\cdot10^2$ N, Δy decreases from $0.8\cdot10^{-3}$ m to $0.28\cdot10^{-3}$ m, and $\Delta\dot{y}$ decreases from $0.162\cdot10^2$ m/s to $0.061\cdot10^2$ m/s. With an increase in F$_b$ to (3.5±0.25)$\cdot10^2$ n, value of Δy decreases to $0.39\cdot10^{-3}$ m, $\Delta\dot{y}$ decreases to 0.087 m/s. The recommended values are C ≥(4.5÷5.2)$\cdot10^4$ N/m, at which Δy≤ $0.35\cdot10^{-3}$ m is provided.

As we know, the saw cylinder of the fiber cleaner is massive. Therefore, it is important to study the influence of m$_n$ on the oscillation range of the saw cylinder. Graphical dependences of the change in the range of oscillation of the movement and speed of the saw cylinder on the change in its mass are shown in Fig. 6.

Increase in m$_n$ from $1.2\cdot10^2$ kg to $2.5\cdot10^2$ kg leads to a decrease in Δy from $0.75\cdot10^{-3}$ m to $0.25\cdot10^{-3}$ m and a decrease in $\Delta\dot{y}$ from $0.142\cdot 10^2$ m/s to $0.064\cdot10^2$ m/s at F$_b$ = (2.5±0.21)$\cdot10^2$ N, the decrease in Δy reaches $0.63\cdot10^{-3}$ m, and $\Delta\dot{y}$ decreases to $0.81\cdot 10^{-3}$ m/s. Therefore, for a sufficient reduction in the range of fluctuation Δy and $\Delta\dot{y}$, the recommended values are

m$_n$ = (2.0÷2.2)$\cdot10^2$ kg.

4 Conclusion

A new effective construction scheme of the fiber cleaner with an elastic bearing support of the saw cylinder is recommended. Theoretical studies determined the regularities of vertical oscillations of the cylinder, and the main parameters of the system are substantiated.

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