Development and Substantiation of Parameters of An Effective Device for Removing Fibers from the Lower Part of the Saw Gin

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Abstract. The article is developed a scheme for the construction of equipment for removing fibers separated from saw teeth in saw gin, removing fibers from the bottom with air based on the analysis of their structures. The advantages and disadvantages of existing constructions have been studied. Comparative comparisons are given. The air consumption that occurs in the device, the velocity, as well as the coverage of the space between the surfaces of the pipe and the saw cylinder by the forced air at a large angle, the air velocity gaps formed between the outer surface of the saw and the grate-bar, factors that reduce efficiency when removing fibers from the saw teeth are considered. The air consumption that occurs in the device, the speed, as well as the coverage of the space between the surfaces of the pipe and the saw cylinder by the forced air at a large angle, the airspeed gaps formed between the outer surface of the saw and the grate-bar, factors that reduce efficiency when removing fibers from the saw teeth are considered. The parameters of the air chamber, visor, guide tube and receiver tubes mounted on the saw gin's bottom fiber stripping device have been studied. Theoretical studies have obtained a mathematical model that represents the movements of fibers in the removal of air from the saw teeth, the laws of motion of fibers in coordinate terms have been determined. Link graph analysis has determined the recommended values of fiber stripping zone parameters.

Keywords. Saw gin, teeth, fiber, forces, inertia, weight, velocity, acceleration, air, low of motion, coordination, reaction, centrifugal force, angular velocity.

Introduction. Stripping the fiber from the saw teeth is done using a rotating brush drum or an air stream supplied from the slit to the saw cylinder. In air-assisted fiber separators, active airflow creates a vacuum in the fiber stripping zone, removing the fiber from the saw teeth and directing it to the receiving tube. The static pressure in the air chamber is almost equal to the dynamic pressure on the outer edge of the slit. The efficiency of the air stripping device will depend on the width of the slit, the flow rate of the active current, the time of contact of the saw teeth with the working current, the length and curvature of the guide part, the discharge coefficient, the shape and location of the transmission pipes to the fiber intake and fiber cleaner [1-4].

The bottom fiber stripping device of the 5dp-130 saw cotton cleaner is known. This construction of the lower fiber stripping device has a housing, an air chamber mounted on it, a triangular visor, a guide pipe with a round cross section and a receiving pipe. In this case, the space between the surface of the guide pipe and the saw cylinder will be at an angle of 52° with respect to the horizontal axis of the saw cylinder [5-7].

The disadvantage of this construction is the high air consumption and loss of speed due to the triangular shape of the visor, as well as the coverage of the space between the surfaces of the pipe and the saw cylinder by the forced air at a large angle. In addition, the air velocity decreases due to an increase in the space formed between the outer surface of the saw and the grate-bar, which reduces the efficiency of removing fibers from the saw teeth.

The closest to the proposed saw is the gin's bottom fiber stripper, which includes a body, an air chamber mounted on it, a visor, a guide tube, and a receiving tube. The visor is in the shape of a circular part, while the guide pipe is made with rectangular protrusions with a height of H=2.0-4.0 mm, with rounded edges [8].

The disadvantage of this construction is that due to instability to vibrations and the reduction of the live cross section of the guide pipe, the construction is unreliable, as a result of which the gaps between the guide pipe, visor and saw are not constant. In addition, a decrease in air pressure in the fiber transmission pipe caused by a decrease in air consumption due to a 12-25 % contraction of the gap was not taken into account, which leads to a sharp decrease in productivity and frequent clogging of the saw gin.

It is important to increase the performance of the saw gin machine by increasing the efficiency of removing fiber from the teeth of the saw cylinder and reducing the energy consumption for the fiber stripping process.

Scheme of effective device of fiber removable equipment separated by saw teeth in the saw gin. The fiber stripping device is illustrated with drawings, where Figure 1 gives the overall scheme of the device, Figure 2 gives the A-A cut in Figure 1, Figure 3 gives the B-B cut in Figure 1, and Figure 4 gives the 3D image of the air nozzle construction. The device consists of a body 1 (body of gin) with a spiral-shaped air chamber 2 mounted inside, which contains a comb-shaped air nozzle with air ducts 3, a guidance cylinder 4, a receiving pipe 5, and a fiber transmission pipe 6, which connects gin to a fiber cleaner 9.

Combs of comb 3 are made with a thickness of s = 6 mm and a width of t = 8 mm, they are located in the zones between saw 7, saw cylinder 8, whose steps are equal to the step between saw cylinder saws. As a result, an individual air duct is created for each saw with a gap width of a = 5 mm and a length of b = 10 mm. The radius of the guide cylinder 4 was chosen to be r = 140-160 mm, which made it possible to increase the length of the intensive fiber stripping zone and the time spent by the saw teeth in the intensive contact zone. The interior 6 of the fiber transmission pipe is made in a waveform with waves parallel to the air flow, in which the friction force is reduced due to the shrinkage of the fiber contact surface, and the installation of the fiber transmission pipe at an angle allows the fiber to travel the shortest path from the receiving pipe 5 to the fiber cleaner. This eliminates excess resistance and compensates for the pressure drop in the pipes. The device works as follows. Under a certain pressure from the fan (not shown in the picture), air flow is sent through the pipes to the air chamber 2 and smoothly narrows along the surface of the spiral shape of the chamber, through the holes of the nozzle, through the middle of the surfaces of the guide cylinder 4 and the saws of the saw cylinder 7. According to the design of the air nozzle, the cross-sectional area of each saw blade of the saw cylinder 8 is 50 mm 2, and individual channels are formed in the amount equal to the number of saw blades. In this case, the air acting on

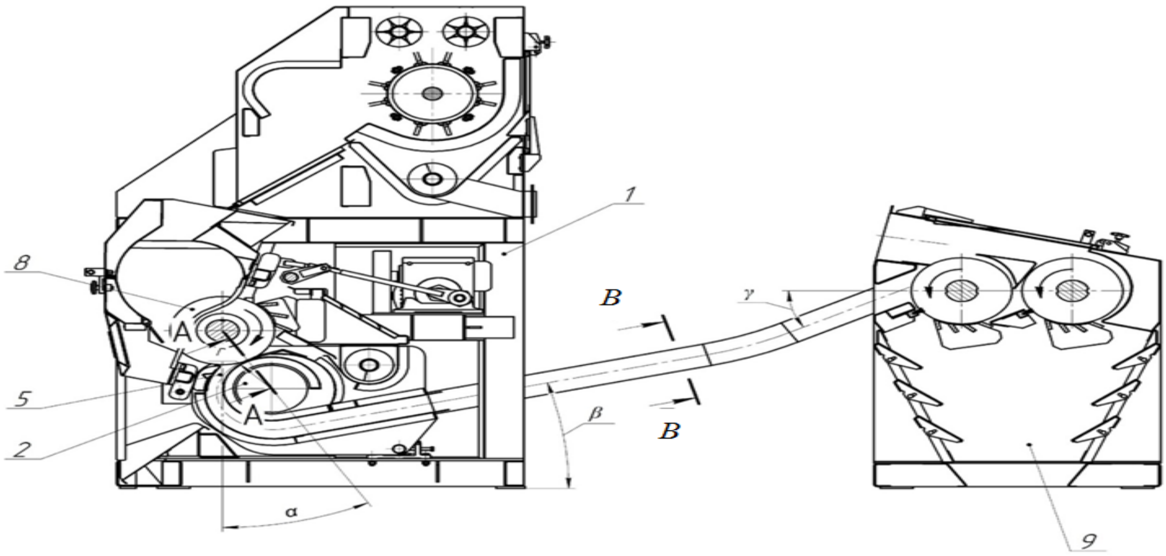


Fig.1. Improved fiber removable device for a saw gin

the fibers captured by the 8-saw 7 teeth of the saw cylinder at a certain speed directs them 5 to the receiving

pipe. It should be noted that an air nozzle with separate channels for each saw leads to a decrease in the volume of space by 40-45%, which significantly increases the air speed comb shape directs the effect of air flow directly to the saw teeth, which increases the efficiency of removing fibers from the teeth of the saw cylinder. The fiber is then transported through the fiber transfer pipe 6 and enters the fiber cleaner 9.The improved construction makes it possible to increase the velocity of air flow in the workplace and consumes less air, and increases the efficiency of the saw cylinder to remove fibers from the saw teeth [9].

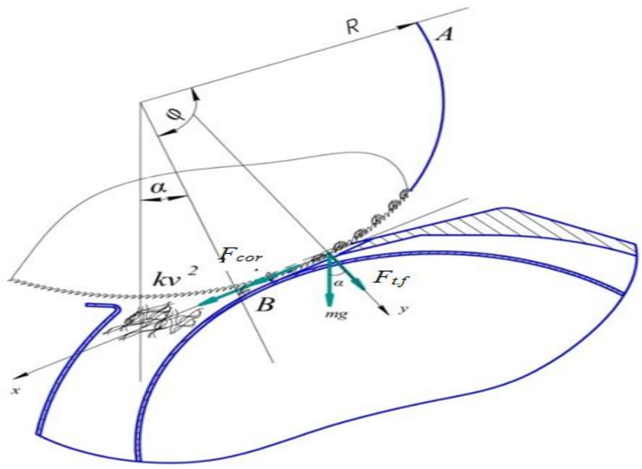
A mathematical model of the representing fiber motion in the separation of the refined fiber from the bottom of the saw gin.

The theoretical analysis of the movement of the saw demon in separating the separated fibers from the saw teeth using air is distinguished by the device of lowering the fiber from the saw demon entering the air chamber, which consists of a tube in the networks attached to the channel from which the fiber is released from the cylinder air hammer mounted on it, the slit width and length are b = 10 mm, the directing cylinder of the air chamber has a radius of r = 140-160 mm, the inner part of the fiber stripping channel is carried out in parallel with the wavelet channel spiral-shaped pipe, forming an angle of b=15 ° to the horizon, while the second end is connected an angle of γ=30° to the fiber cleaner.

Accordingly, since the air released from the air nozzle is blown separately from each saw cylinder, the total volume of the cavity is reduced by 40-45% compared to the existing structure, due to which the air pressure (velocity) is significantly maintained even if the air consumption falls, as well as the efficiency of the air flow directed to the saw teeth. In addition, the air in contact with the curved surface of the spiral air chamber has a low resistance to movement, and the structure of the fiber transmission pipe compensates for the decrease in pressure in it, which increases the efficiency of fiber stripping. The construction makes it possible to significantly increase the productivity of saw gin by increasing the efficiency of removing fiber from the saw teeth of the saw cylinder, increasing the velocity of airflow in the work area of the fiber stripping device, increasing the time spent in the intensive contact zone of saw teeth and reducing air consumption, which leads to a decrease in energy costs.

Figure 2. Scheme of the influencing forces in improved of lowering the fiber from the bottom

$F_{m.q}$ - the centrifugal force, $k \cdot \vartheta^2$ - the airflow force, $F_{m.q} = m \cdot \omega^2 \cdot l;$ ω - the angular velocity of the saw cylinder; *l* - the length of the saw; *m* - the mass of the fibers, $\mathrm{F}_{\text{кор}} = 2 \cdot m \cdot \omega \cdot \dot{x}$ - the cariolis force [10, 11]. The calculation scheme did not take into account the fact that the values of the friction force of the fibers with



the surface of the saw cylinder teeth are small.

From Figure 2 above, let us consider the theory of the coverage angle φ of the arrayed disk acting along the arc AB and its transmissions in the result in absorbing the fibers, first giving the differential equation for the OX axis of the fibers [12-14]:

$$\mathrm{m}\cdot\ddot{\mathrm{x}} = F_{kor} + k\cdot\vartheta^2 + m\cdot g\cdot\sin\alpha$$

$$\mathrm{m}\cdot\ddot{\mathrm{x}} - 2\cdot m\cdot\omega\cdot\dot{x} = k\cdot\vartheta^2 + m\cdot g\cdot\sin\alpha$$

$$\ddot{\mathrm{x}} + 2\cdot\omega\cdot\dot{x} = \frac{k}{m}\cdot\vartheta^2 + g\cdot\sin\alpha \qquad (1)$$

A second-order non-homogeneous differential equation (1) is defined the same- homogeneous and private solutions.

We look for the homogeneous part in this form: $\dot{x}_1 = \lambda e^{\lambda t}, \ddot{x}_1 = \lambda^2\cdot e^{\lambda t}$. We substitute this expression into equation (1). $\lambda_1 = 0$; $\lambda_2 = -2\cdot\omega$;

$$x_1 = c_1\cdot e^{\lambda_1 t} + c_2\cdot e^{\lambda_2 t}$$

$$x_1 = c_1 + c_2\cdot e^{-2\cdot\omega\cdot t} \qquad (2)$$

We are looking for a private solution in this form [13, 14]:

$$x_2 = A\cdot\cos\alpha + B\cdot\sin\alpha \qquad (3)$$

$$\dot{x}_2 = -A\cdot\sin\alpha + B\cdot\cos\alpha;$$

$$\ddot{x}_2 = -A\cdot\cos\alpha - B\cdot\sin\alpha;$$

We put the determined values in equation (2).

$$-A\cdot\cos\alpha - B\cdot\sin\alpha - 2\cdot A\cdot\omega\cdot\sin\alpha + 2\cdot B\cdot\omega\cdot\cos\alpha = g\cdot\sin\alpha \qquad (4)$$

By equating the coefficients of $\sin\alpha$ and $\cos\alpha$ in the expression (4), we determine the constant values A and B.

$$\begin{cases} -A + 2\cdot\omega\cdot B = 0 \\ -2\cdot\cdot\omega\cdot A - B = g \end{cases}$$

$$A = \frac{2\cdot g\cdot\omega}{4\cdot\omega^2 + 1}; \quad B = \frac{g}{4\cdot\omega^2 + 1};$$

We substitute these values into equation (3).

$$x_2 = \frac{2\cdot g\cdot\omega}{4\cdot\omega^2 + 1}\cdot\cos\alpha + \frac{g}{4\cdot\omega^2 + 1}\cdot\sin\alpha \qquad (5)$$

The general solution for the motion of fibers along the OX axis under the influence of air flow is as follows [15-17]:

$$x = c_1 + c_2\cdot e^{-2\cdot\omega\cdot t} + \frac{2\cdot g\cdot\omega}{4\cdot\omega^2 + 1}\cdot\cos\alpha + \frac{g}{4\cdot\omega^2 + 1}\cdot\sin\alpha + \frac{k}{m}\cdot\vartheta^2 \qquad (6)$$

From the expression (6) we use the initial and boundary conditions in determining the constant values C_1 and C_2.

Define from $(x)_{t=0} = 0;\ (\dot{x})_{t=0} = 0;$

$$\begin{cases} C_1 + C_2 + \dfrac{2\cdot g\cdot\omega}{4\cdot\omega^2+1} + \dfrac{k\cdot\vartheta^2}{m} = 0 \\ -2\cdot\omega\cdot C_2 + \dfrac{g}{4\cdot\omega^2+1} = 0 \end{cases}$$

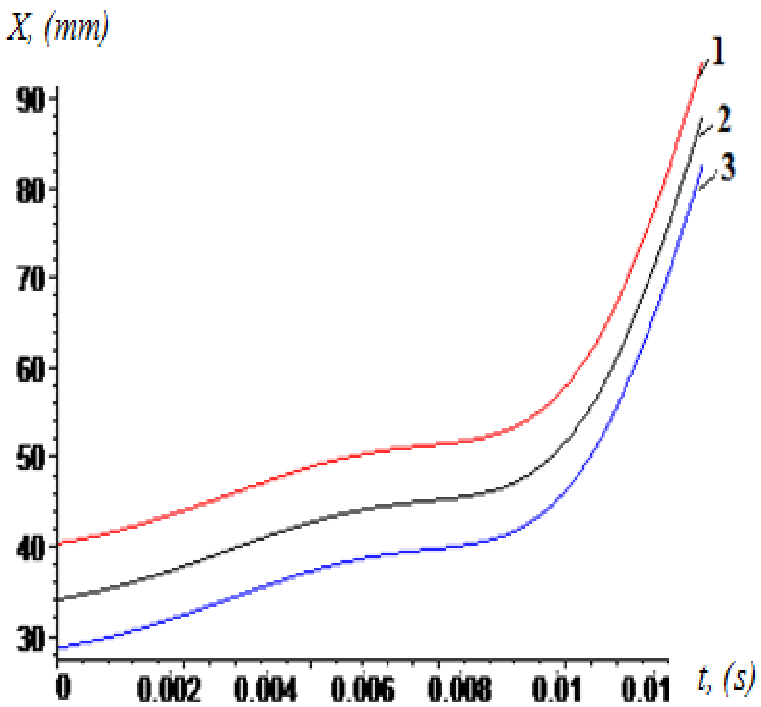
$$C_2 = \frac{g}{2\cdot\omega\cdot(4\cdot\omega^2+1)};\ C_1 = -\frac{g}{2\cdot\omega\cdot(4\cdot\omega^2+1)} - \frac{k\cdot\vartheta^2}{m}$$

The determined C_1 and C_2 values were substituted into equation (6).

$$x = -\left(\frac{g}{2\cdot\omega\cdot(4\cdot\omega^2+1)} + \frac{k\cdot\vartheta^2}{m}\right) + \frac{g}{2\cdot\omega\cdot(4\cdot\omega^2+1)}\cdot e^{-2\cdot\omega\cdot t} + \frac{2\cdot g}{4\cdot\omega^2+1}\cdot\cos\alpha + \frac{g}{4\cdot\omega^2+1}\cdot\sin\alpha \quad (7)$$

Numerical solution of the problem and analysis of the results. The process of separating fibers from the saw gin was analyzed graphically using the Maple program, using the equation (7) that expresses the dependence of the air velocity on the process. The following parameters are given in the calculation: $g = 9{,}81\,m/s^2$; $\alpha = 27^0 \div 30^0$; $\varphi = 80^0$; $\omega = 35\,s^{-1}$.

Figure 3. Time-dependent graph of directional air velocities extracting fibers from saw teeth at different



values $\vartheta_1 = 75\,m/s$; $\vartheta_2 = 80\,m/s$; $\vartheta_3 = 85\,m/s$

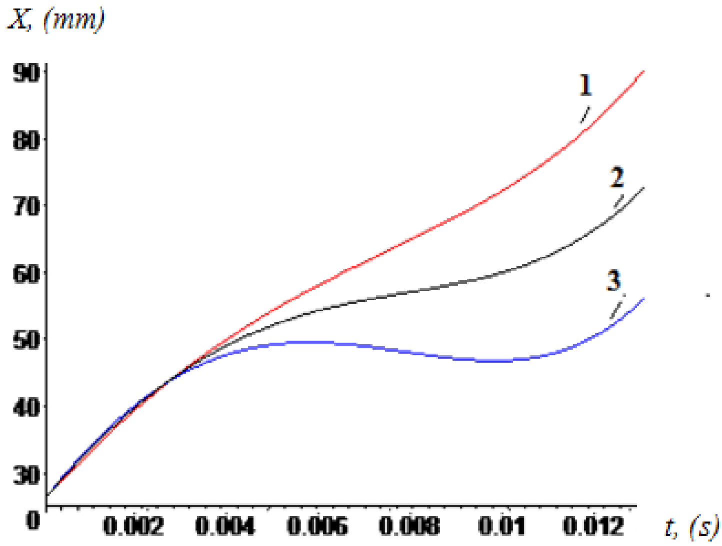


Figure 4. Time-dependent graph of the angle of deviation of the directional air tube in the extraction of fibers from the saw teeth at the values of various $\alpha_1 = 27^0; \alpha_2 = 29^0; \alpha_3 = 31^0$

From the analysis of the above graphs, when separating their fibers from the saw teeth, the direction of the air flow is presented, as well as the movement of their tube on the axis of the OX under the influence of the angle of deviation. In this case, the issue of completely separating the fibers from the saw teeth, depending on the distance from which the fibers are separated by external forces acting on the fibers, when separating the fibers, the movement of the fibers is analyzed at different values of the directional air velocities, as well as at different values of the angle of deviation of the This was achieved by setting the guide air velocity to $\vartheta_1 = 75$ m/s and the guide air duct deflection angle to $\alpha_1 = 27^0$, which resulted in efficient transfer of the fibers from the saw teeth to the air duct.

We will compose the differential equation of motion along the OY axis under the influence of forces when separating the fiber flow from the saw.

$$m\ddot{y} = F_{m.q} + mg \cdot \cos\alpha \qquad (8)$$

We define the second-order non-homogeneous differential equation as the homogeneous and private solutions from equation (8), the following external forces are formed by the action of saw teeth on the fibers.

$F_{m.q}$ - the centrifugal force, *mg* - weight force, $F_{m.q} = m \cdot \omega^2 \cdot l;$ ω - the angular velocity of the saw blade; *l* - the length of the saw teeth; *m* - the mass of the fibers,

$$m \cdot \ddot{y} = -m \cdot \omega^2 \cdot l + m \cdot g \cdot \cos\alpha \qquad (9)$$

We divide both sides of the expression (9) by the mass m.

$$\ddot{y} = -\omega^2 \cdot l + g \cdot \cos\alpha \qquad (10)$$

Substitute the expression (10) $\vartheta = \omega \cdot l \Rightarrow \omega = \frac{\vartheta}{l} = \frac{\dot{y}}{l}$ into the above expression.

$$\ddot{y} + \frac{1}{l} \cdot \dot{y}^2 = g \cdot \cos\alpha \qquad (11)$$

The expression (11) from the non-homogeneous part, we calculate the non-homogeneous part using the designation $\ddot{y} = \frac{d(\dot{y})^2}{dt} \cdot \frac{2dy}{2dy} = \frac{d(\dot{y})}{2dt}$.

$$\frac{d(\dot{y})^2}{dt} + \frac{1}{l} \cdot \dot{y}^2 = 0 \tag{12}$$

We calculate the homogeneous part of the solution of equation (12) by setting $\frac{dz}{2dt} - \frac{1}{l} \cdot z = 0 \Rightarrow$ $\frac{dz}{2dt} - \frac{1}{l} \cdot z = 0 \Rightarrow \frac{dz}{z} = \frac{2}{l} \cdot dt$ this expression differentiates.

$$\ln z = \frac{2}{l} \cdot t \Rightarrow z = e^{\frac{2}{l} \cdot t} \cdot C_1 \tag{13}$$

Substituting $\dot{y}^2 = z$ into the above expression, we represent the movement of fibers under the influence of air flow along the OY axis. $\dot{y}^2 = e^{\frac{2}{l} \cdot t} \cdot C_1 \Rightarrow \dot{y} = e^{\frac{t}{l}} \cdot C_1 \Rightarrow y = l \cdot e^{\frac{t}{l}} \cdot C_1$ Using the initial condition, we determine the constant value of C_1. $(y)_{t=0} = l_0$ is equivalent to $C_1 = \frac{l_0}{l}$

$$y_1 = l_0 \cdot e^{\frac{t}{l}} \tag{14}$$

the private solution of the expression is

$$y_2 = A \cdot t + B \tag{15}$$

we look for derivatives from this expression and define the invariants by putting them in equation (11).

$$\dot{y}_2 = A; \; \ddot{y}_2 = 0$$

$$\frac{1}{l} \cdot A^2 = g \cdot \cos\alpha \tag{16}$$

By equating the corresponding coefficients of this equality, we define the value of A and B.

$$A = \sqrt{g \cdot l \cdot \cos\alpha} \tag{17}$$

We substitute the values determined from the system of equations (17) into the equality (15) and determine the particular solution.

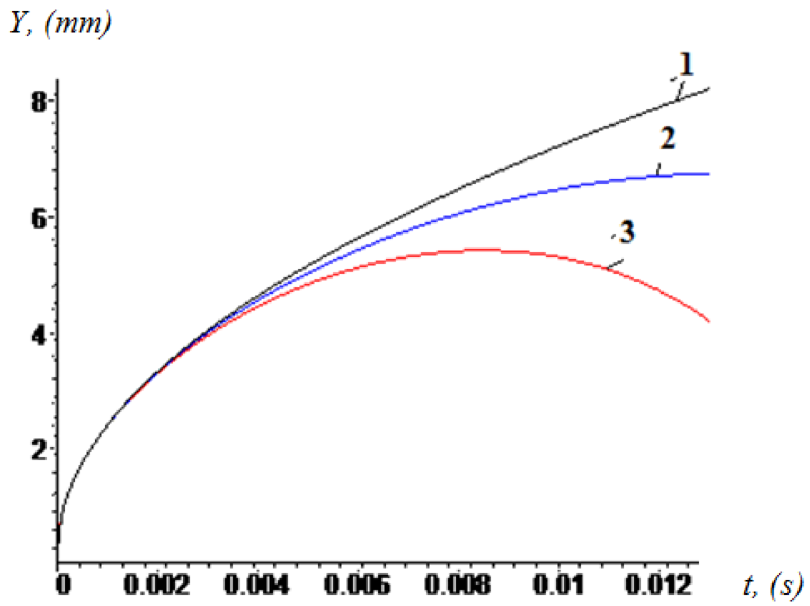
$$y_2 = \sqrt{g \cdot l \cdot \cos\alpha} \cdot t \tag{18}$$

We determine the general trajectory equation of the fibers moving along the OY axis along the air flow.

$$y = y_1 + y_2 = l_0 \cdot e^{\frac{t}{l}} + \sqrt{g \cdot l \cdot \cos\alpha} \cdot t \tag{19}$$

The expression (19) is described the movement of the fibers in the saw teeth along the OY axis under the influence of the air flow. The analysis of this expression is presented in graphs using the Maple program. The following parameter values are used in the calculation: $Y,(mm)$

Figure 5. A time-dependent graph of the angle of inclination of the air tube pointing on the lunar axis at different



values $\alpha_1 = 27^0$, $\alpha_2 = 29^0$, $\alpha_3 = 31^0$ when extracting fibers from the saw teeth

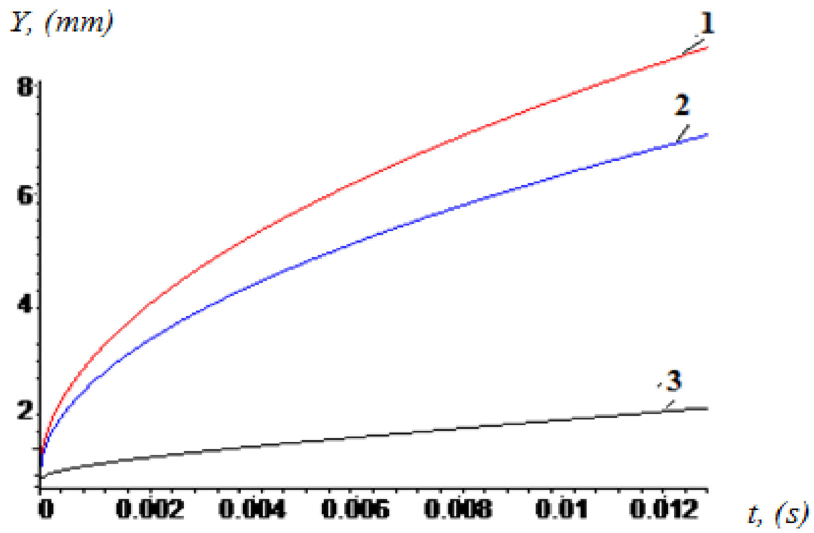


Figure 6. A time-dependent graph of directional air velocities on the lunar axis at different values $\vartheta_1 = 75\ m/s$; $\vartheta_2 = 80\ m/s$; $\vartheta_3 = 85\ m/s$ when extracting fibers

The trajectory of movement of the fibers separated from the saw teeth on the axis of the OY is given. When separating the fibers, it has been found that the velocity of the guide in the transmission to the pipe through the directional air flow varies in time between the values of $\vartheta_1 = 75\ m/s$ and the angle of deviation of the directing air pipe $\alpha_1 = 27^0$.

Conclusion. An effective structural scheme of air-assisted stripping equipment has been developed for the fibers separated from the saw teeth. Based on theoretical studies, the analytical style determines the laws of movement in the removal of fibers from the saw teeth, the recommended values of the parameters are determined.

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