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THEORETICAL ANALYSIS OF THE SEPARATION PROCESS OF FLUFF FROM THE TEETH OF THE LINTER SAW IN THE AIR CHAMBERS OF THE LINTER BATTERY AND THE AERODYNAMIC MODE

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Abstract

In this article, the results of a theoretical study of the effect of dynamic air pressure and velocity changes in the aerodynamic mode of existing 5LP linters on the efficiency of fluff separation from linter saw teeth and the effect of air pressure and velocity in the air chamber on fluff separation from saw cylinder teeth are presented.

Keywords: linter, fluff, air chamber, aerodynamics, dynamic pressure, speed, saw angle, nozzle, movement.

Main Part

The coordinate head is placed on the section of the starting part of the air tube chamber of the linter battery and we direct the $0x$ axis along the center line of the camera. We assume that the cross-section of the air duct chamber changes according to the law of $S = s(x)$, the movement parameters in any section of it are: air speed - $u_0(x)$ (index 0), let the chamber be affected by the air flow with speed u_{00} moving in the $x = 0$ section (Fig. 1).

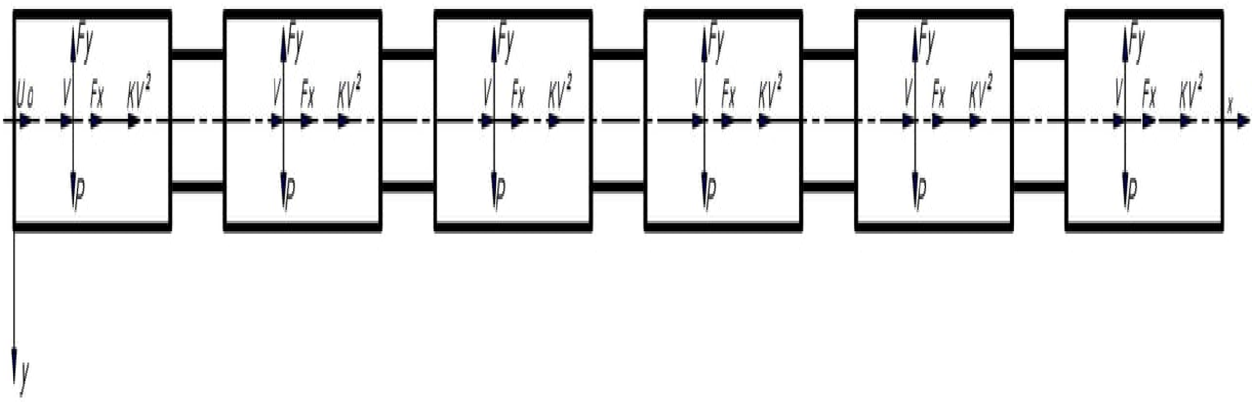

Fig 1. Air movement analysis of available 6 5LP linters battery aerodynamic air chambers.

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From the analysis of the movement of incompressible fluids in cylindrical pipes [1], the equation of the one-dimensional movement of the air flow components passing through the air pipe chamber can be written in the following form based on the law of conservation of mass:

$$\rho_0 u_0 \frac{du_0}{dx} = -\frac{\rho_0}{\rho_0^{(0)}} \frac{dp}{dx} + k(u_1 - u_0) \qquad (1)$$

$$\rho_0 u_0 s = u_{00} \rho_{00} s_0 = const, \ \rho_0 = m\rho_0^{(0)}, \rho_0 = \frac{m}{m_0}\rho_{00}, \qquad (2)$$

where: ρ_0, - air density in the air pipe;

$\rho_0^{(0)}$ -x= Air density along the length of the air pipe of cross-section L;

k - aerodynamic resistance coefficient;

u_1 - x= The final speed of the air in section L;

ρ_{00}, u_{00}, - air density and initial velocity in section $x = 0$ of the air pipe.

Air speed u_{00} can be found based on the performance of air pipe $Q_0(кг/с)$:

$$u_{00} = Q_0 / m_0 \rho_{00} s_0, \qquad (3)$$

Equations (2) and (3) give the following equations that determine the speed and density of air flowing through each linter in the air duct:

$$u_0 = \frac{m_0}{m}\frac{s_0}{s}u_{00}, , \ \frac{\rho_0}{\rho_0^{(0)}} + \frac{\rho_1}{\rho_0^{(0)}} = 1 \qquad (4)$$

Using expression (2), we make equation (1) look like this:

$$\rho_0^{(0)} u_0 \frac{du_0}{dx} = -\frac{dp}{dx} + \frac{\rho_0^{(0)}}{\rho_0} k(u_1 - u_0) \qquad (5)$$

$$\rho_1^{(0)} u_1 \frac{du_1}{dx} = -\frac{dp}{dx} - \frac{\rho_1^{(0)}}{\rho_1} k(u_1 - u_0) \qquad (6)$$

From the system of equations (5) and (6), we extract the air pressure $\frac{dp}{dx}$ of each air pipe in the linter and get the following:

$$\rho_0^{(0)} u_0 \frac{du_0}{dx} - \rho_1^{(0)} u_1 \frac{du_1}{dx} = \left(\frac{\rho_0^{(0)}}{\rho_0} + \frac{\rho_1^{(0)}}{\rho_1}\right) k(u_1 - u_0) = \frac{k}{m(1-m)}(u_1 - u_0), \qquad (7)$$

According to equations (4), the density and velocity of the components in any section of the air pipe can be expressed by the porosity of the medium $m(x)$ [1].

We assume that the cross-sectional area of the air pipe is 0.0294 m^2, which is equal to the length of the saw cylinder. After subtracting the air velocity from equation (4) using equation (7), it satisfies the following equation:

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$$\frac{dm}{dx}=\frac{P_1(m)}{P_0(m)}\frac{s'(x)}{s(x)}\ 0\le x\le L \qquad (8)$$

where: $P_0=\rho_0^{(0)}u_{00}^2m_0^2(1-m)^3+\rho_1^{(0)}u_{10}^2m^3(1-m_0)^2$, $P_1=m(1-m)$

The component density $\rho_0(x)$, velocity $u_0(x)$, are expressed through air using equations (7) and (8).

We determine the cross-sectional area of the air pipe when it is equal to the length of the saw cylinder using the following formula.

$$s=\pi\cdot R^2,\ 0\le x\le L \qquad (9)$$

From the equations (5) and (6), the air flow velocity and pressure in the air pipe are graphed in their rational values using the Maple-6 program when analyzing the movement along the length of the air pipe (Fig. 2).

The calculation was performed in the following parameters: $m_0=0.8\,гр$, $u_{00}=20\,м/с$, $u_{10}=2{,}93\,м/с$, $\rho_{00}=1{,}2\,кг/м^3$, $a=1.4$ м, $h=1{,}4\,м$, $L=15\,м$, $p=24{,}6\,кг/м^2$, $S_0=0.0294\,м^2$ $Q_0=1.1\,м^3/с$

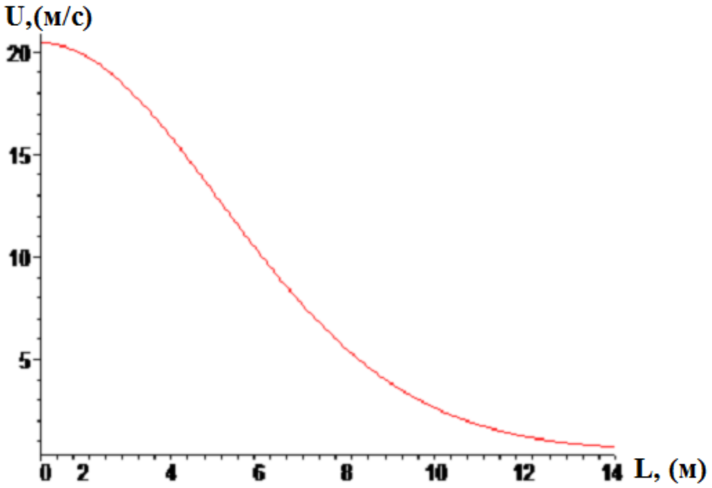

Fig 2. A graph of the variation of air velocity $u_0=20\,м/с$ and dynamic pressure $P=24{,}6\div0{,}52\,кг/м^2$ in the aerodynamic air chambers of the existing 6 5LP linters battery in the first and sixth linters air chambers.

As can be seen from the graph in Figure 2, the air velocity in the air duct of the first linter in the linter battery is 20.06 m/s, the dynamic pressure is 24.6 kg/m^2 and the static pressure is 180 kg/m^2, and the velocity in the air chamber of the sixth linter in the linter battery is 2, 93 m/s, the dynamic pressure was found to be 0.52 kg/m^2 and the static pressure was reduced to 140 kg/m^2

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It can be concluded according to those, in the existing battery of 6 linters, in the aerodynamic mode, the fluff separated from the saw cylinder of each linter does not have the opportunity to be completely removed and delivered to the suction pipe. That is, due to the sharp decrease in air flow speed, the static and dynamic pressure also decreases and is located in series we can see from Figure 2 that the air flow is not enough to blow away the separated fluff in the linter batteries. As a result, fluff extracted from the seed gets re-entered into the seed roller chamber, resulting in a decrease in linter productivity.

The ideal consumption of incompressible air is determined in the adopted scheme as follows:

$$Q = \rho_0 \cdot S \cdot (\vartheta + \vartheta_0) \qquad (10)$$

where: ρ_0 -air density $\rho_0 \approx 1{,}1$ kg/m^3.

S - cross-sectional area of the linter blowing air nozzle

$$S = h \cdot L$$

L - nozzle channel width (1520mm, h - nozzle channel height (5 мм).

Thus, the air velocity is calculated from the following formula:

$$\vartheta = \frac{Q}{\rho_0 \cdot L \cdot h} - \vartheta_0 \qquad (11)$$

When determining the air velocity, we assume that there is no air friction in the inner channel. Considering the incompressibility of the air, it is possible to consider the effect of the rotation of the cylinder on the movement of the air stream.

Let's consider the movement of the linter together with the fluff caught by the saw tooth: We determine the position of the teeth on the surface of the cylinder with certain indicators: the location of the teeth is B or B_1, $OB = R$ in the scheme, the height of the tooth is $BC = h_0$, and the angle of deviation of the tooth is marked by OBC (Fig. 3).

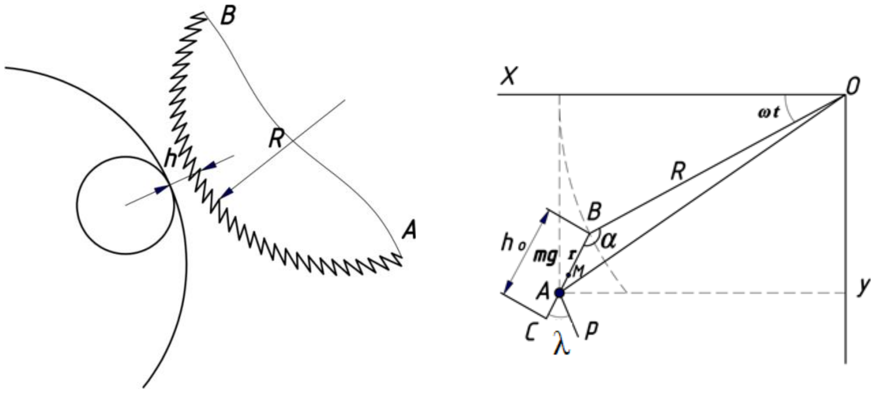

Fig 3. Analysis of the movement of fluff along the tooth of a saw cylinder.

The fluff on the saw tooth is affected by the forces of gravity and friction. Force is conditioned by the pressure of gravity. Taking the distance $BA = r$ as a generalized coordinate, we use Lagrange's type II equation to determine the movement of the fluff along the tooth [2]. Let the teeth be in the position $r = r_0$ when the rotation time is $t = 0$, let us imagine that the radius OB lies along the horizontal axis OX, and let the axis OY be perpendicular to it. The center of the saw cylinder is defined as the coordinate origin [3].

We write the coordinate location of the mass of fluff on the sawtooth as follows:

$$x = R\cos\omega t + r\cos(\alpha - \omega t)$$
$$y = R\sin\omega t + r\sin(\alpha - \omega t) \quad (12)$$

To determine the kinetic energy of fluff of mass m, we can derive the equation of motion over time from equation (12) and is equal to:

$$T = \frac{m}{2}(\dot{x}^2 + \dot{y}^2) = \frac{m}{r}(R^2\omega^2 + r^2 + r^2\omega^2 + 2R\omega\dot{r}\sin\alpha - 2R\omega^2 rCos\alpha) \quad (13)$$

Using Lagrange's type II equation, the partial derivative is obtained from equation (13):

$$\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{r}}\right) - \frac{\partial T}{\partial r} = Q_r \quad (14)$$

From the equation (14), the generalized forces of the external forces affecting the fluff flow on the surface of the saw tooth are determined and the general and specific solutions of the inhomogeneous equation are calculated.

$$m\ddot{r} = m\omega^2(r - R\cos\alpha) + Q_r \quad (15)$$

where: Q_r – the generalized force is found by the following formula:

$$Q_r = \sum X_i \frac{\partial x}{\partial r} + \sum Y_i \frac{\partial y}{\partial r} \quad (16)$$

X_i, Y_i $- OX$ and OY the projection of external forces on the axes is equal to:

$Y_i = mg\sin(\alpha - \omega t)$ $X_i = 0$ we create an equation relating the gravity of the fluff, the frictional force of weight, and the Cariolis force.

$$F_{TP} = -f \cdot m \cdot g\cos(\alpha - \omega \cdot t) + f \cdot F_{кор} \quad (17)$$

Here, the coriolis force is generated when the fluff is separated from the saw tooth.

$$F_{кор} = -2 \cdot \omega_e \cdot \dot{r}_r \cdot \sin\alpha \quad (18)$$

Here, the angle α is the angle between the relative speed of the fluff and the suction force of the air under pressure P, the gravity of the fluff and the angle λ between the surface of the saw tooth is shown in Figure 3 [4].

$$P = S \cdot p\sin\lambda \quad (19)$$

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where: S - surface of contact of the pulp with the tooth,

λ - the angle between the force of gravity and the surface of the saw tooth.

$$\lambda = \arcsin\frac{R\sin\alpha}{\sqrt{R^2 + h_0^2 - 2Rh_0\cos\alpha}} \tag{20}$$

Taking these into account, the total bond strength of the fluff with the tooth is determined by the following formula:

$$Q_r = -mg\sin(\alpha - \omega t) + fmg\cos(\alpha - \omega t) + 2mfr\omega\cos\alpha + P\sin\lambda \; (\frac{\pi}{2} < \alpha < \pi) \tag{21}$$

The second-order inhomogeneous differential equation for determining the motion of fluff under the action of a cylinder saw tooth is:

$$\ddot{r} - \omega^2 \cdot r + 2\cdot f \cdot \dot{r}\omega \cdot \cos\alpha = -\omega^2 \cdot R \cdot \cos\alpha - g[\sin(\alpha - \omega t) - f\cos(\alpha - \omega t)] + (\frac{Q}{\rho\cdot\vartheta} - \vartheta_0)\cdot P \cdot \sin\lambda \tag{22}$$

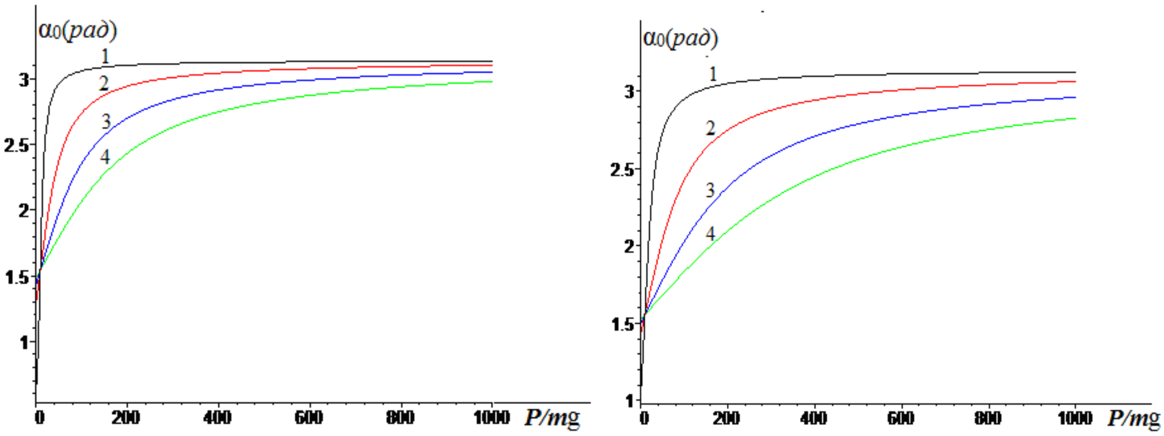

Fig 4. $\alpha_0 -$ **The effect of the angle of inclination of the saw tooth on the removal. of lint:** $1-\omega \approx 78.5c^{-1}$, $2-\omega \approx 104.67c^{-1}$, $3-\omega \approx 157c^{-1}$, $4-\omega \approx 314c^{-1}$,

Figure 4 shows the relationship obtained when calculating $f = 0.3$ $r_0 = 1$мм at different indicators of $R = 160$ мм , $R = 140$ мм angular velocity $\omega(c^{-1})$ for two different indicators of the radius R (m) of α_0 with respect to $\overline{P} = P/mg$.

Figure 4 shows the relationship obtained when calculating n versus (m) radius for two different indices of angular velocity.

From the graph, it is observed that as the air suction index increases, R rapidly increases at small values and becomes constant at short values. As the radius R increases, the growth intensity of α decreases. From the equation (22), the law of change of the air velocity supplied through the fan according to the pressure is determined. From this equation, it is possible to select rational values for the speed parameters and the saw tooth angle of the lint separator saw cylinder with an additional fan in the air pipe and the dimensions of the lint removal pipe.

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