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MODELING THE PROCESS OF SEPARATING COTTON PARTICLES FROM AIR IN THE WORKING CHAMBER OF A COTTON GIN

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Abstract: The article presents the results of the study of cotton particles movement in the separator working chamber located along the inlet of the vacuum valve. When studying the dynamics of cotton pieces movement in horizontal and vertical directions, it was found that cotton pieces entering the inlet spigot had time to get into the vacuum valve in about 0.4 seconds. The results also show that most of the cotton particles hit the front of the vacuum valve. The revealed regularities can be used in the design of new designs of cotton separators.

Keywords: cotton, separator, pneumatic conveying equipment, pipe, vacuum valve, separation process, air flow.

Introduction. The cotton separator is one of the main elements of the pneumatic transport equipment, which performs the function of separating the cotton from the air flow carrying it, removing it from the equipment and transferring it to the next process. In this direction, one of the important issues is to increase the efficiency of the equipment by preserving its initial quality indicators and reducing process energy consumption in the separator working chamber during the separation of the cotton piece from the air flow.

In the existing separators there is adhesion of cotton particles to the surface of the separator mesh, which leads to a decrease in productivity. Accordingly, the separator was designed according to the inlet of the vacuum valve, and the elimination of the existing shortcomings allowed to dramatically improve the efficiency of the separator.

Figure 1 shows the scheme of the improved design of the cotton separator, which consists of 1-inlet spigot, 2-mesh surfaces located on the side walls of the separation chamber, 3-shaft, 4-pulley, 5-axles with fixed couplings, 6-clamps, squeezing cotton stuck to the mesh surfaces, 7-tubes, sucking and pushing dust out of the air, 8-vacuum valve located perpendicular to the working chamber, 9-vacuum valve shaft, 10-blades, 11-elastic material attached to the edges of the blades, 12-belt, 13-reducer, 14-coupling, 15-shaft and bearings with axles mounted on them. This design is the object of study, and we will study the movement of cotton in this separator.

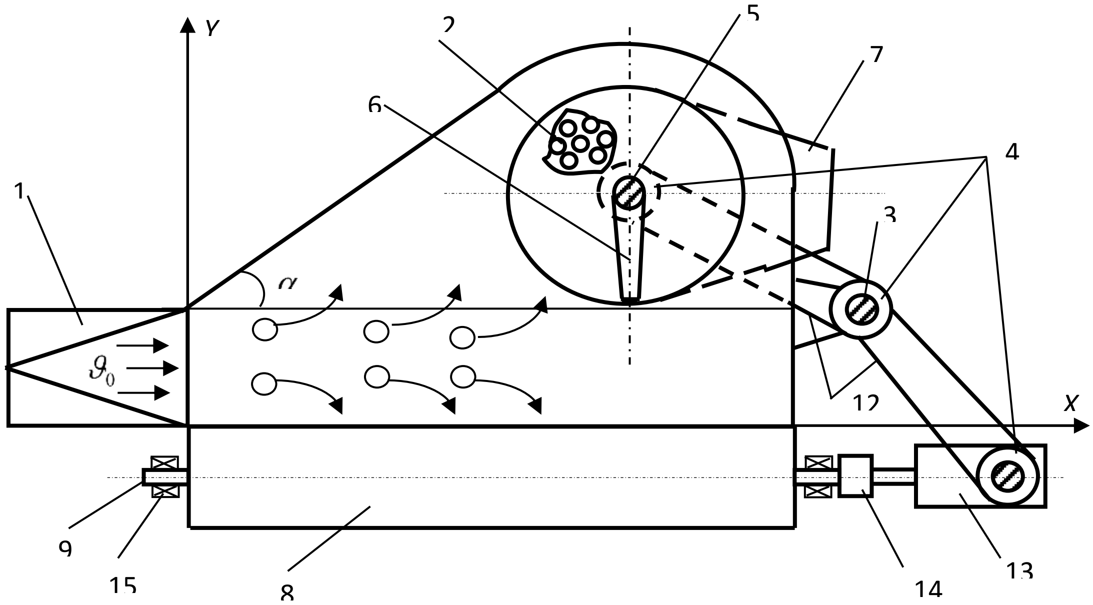


Figure 4.11. Improved separator design

2. Studying the laws of motion of cotton raw material in the separator chamber.

We consider the motion of a particles of cotton along with the air as two interconnected systems (Figure 2)

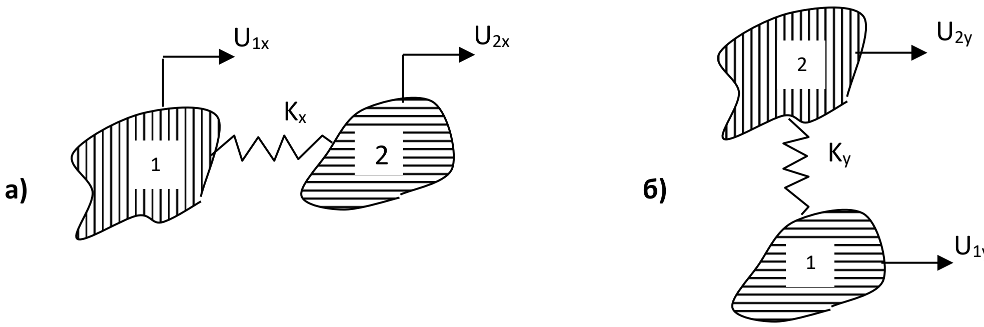


Figure 2. Movement of a cotton particle together with the airflow

In this case, the movement of cotton raw materials, connected together in equal sizes, under the influence of aerodynamic and gravitational forces, is considered. The air flow velocity is $V_0\,(м/c)$, and the displacement of cotton particles along the axes OX, OU, respectively, is $U_{1x}(t), U_{2x}(t), U_{1y}(t), U_{2y}(t)$.

$$\dot{U}_{1x}(t),\, \dot{U}_{2x}(t)$$

$$\dot{U}_{1y}(t),\, \dot{U}_{2y}(t)$$

The difference between the velocities of the cotton particles and the air flow velocity V_0 creates aerodynamic forces, which in turn create forces that move the cotton pieces -

$F_{1x}, F_{2x}, F_{1y}, F_{2y}$. Let the masses of the first and second cotton particles be - m_1, m_2 the coefficient of elasticity between them during the movement - K_x, K_y the forces of gravity $P_1 = m_1 g$, $P_2 = m_2 g -$, and the coefficient of proportionality of the resistance force under the influence of the speed of movement μ_x, μ_y − .

It is known that since cotton raw material particles do not have an axis of symmetry, they fall downward into a symmetrical flow zone under the action of gravity. Under the action of air resistance it rises again. The increase in cross-sectional air flow rate as a result of the worker entering the chamber reduces the absolute velocity of the cotton particles. As the velocity of cotton particles in horizontal and vertical directions relative to their flight velocity decreases, the air flow moves to the mesh surface of the separation chamber, and the cotton particles move to the vacuum valve.

In the new working chamber, placing the mesh air outlet surfaces at a certain distance above the flow direction along the vertical axis provides the following advantages:

1) This speeds up the separation of cotton particles from the air and increases the efficiency of the separator.

2) Reduces the likelihood of cotton particles sticking to the mesh surface.

Taking into account the cotton raw material and the forces acting on it, we formulate the differential equation of the law of motion in the air flow based on the D'Alembert principle.

STATE 1. m_1 *ва* $m_2 -$ Position the cotton particles with the mass in a horizontal direction. (Figure 2a).

In this case:

$$\begin{cases} m_1 \ddot{U}_{1x} + K_x (U_{1x} - U_{2x}) + 2\mu_x (\dot{U}_{1x} - \dot{U}_{2x}) = F_{1x} \\ m_2 \ddot{U}_{2x} + K_x (U_{2x} - U_{1x}) + 2\mu_x (\dot{U}_{2x} - \dot{U}_{1x}) = F_{2x} \\ m_1 \ddot{U}_{1y} + K_y (U_{1y} - U_{2y}) + 2\mu_y (\dot{U}_{1y} - \dot{U}_{2y}) = F_{1y} \\ m_2 \ddot{U}_{2y} + K_y (U_{2y} - U_{1y}) + 2\mu_y (\dot{U}_{2y} - \dot{U}_{1y}) = F_{2y} \end{cases} \tag{4.53}$$

(4.53) – The system of differential equations describes the laws of motion of cotton particles in the working chamber of the separator. The aerodynamic forces acting on the cotton particles of the air flow are as follows:

$$F_{1x} = C_1 (V_x - \dot{U}_{1x})^2, \qquad F_{2x} = C_2 (V_x - \dot{U}_{2x})^2$$

$$F_{1y} = C_1 (V_y - \dot{U}_{1y})^2, \qquad F_{2y} = C_2 (V_y - \dot{U}_{2y})^2$$

C_1, C_2 − aerodynamic drag coefficient.

The problem has the form of a Cauchy problem, which was solved on the computer by numerical methods in the MAPLE 2020 program under the following initial conditions.

STATE 2. $m_1\, ва\, m_2$ – Let the cotton mass pieces be in a vertical position at the entrance to the separator-working chamber (Figure 2b). In this case, the motion of cotton particles in the system of differential equations differs from the first case by elasticity coefficients and initial conditions. The mass of the first piece of cotton is added to the mass of the second piece of cotton, which participates in the differential equation.

So, in this case, the law of motion of cotton particles in the separator working chamber under the action of air flow will be as follows:

$$\begin{cases} \overline{m}_1 \ddot{U}_{1x} + \overline{K}_x (U_{1x} - U_{2x}) + 2\overline{\mu}_x (\dot{U}_{1x} - \dot{U}_{2x}) = F_{1x} \\ \overline{m}_2 \ddot{U}_{2x} + \overline{K}_x (U_{2x} - U_{1x}) + 2\overline{\mu}_x (\dot{U}_{2x} - \dot{U}_{1x}) = F_{2x} \\ \overline{m}_1 \ddot{U}_{1y} + \overline{K}_y (U_{1y} - U_{2y}) + 2\overline{\mu}_y (\dot{U}_{1y} - \dot{U}_{2y}) = F_{1y} \\ \overline{m}_2 \ddot{U}_{2y} + \overline{K}_y (U_{2y} - U_{1y}) + 2\overline{\mu}_y (\dot{U}_{2y} - \dot{U}_{1y}) = F_{2y} \end{cases} \tag{4.54}$$

3. **Analysis of the mathematical model**

The Cauchy problem posed in this case was solved numerically using the MAPLE-2020 program with initial conditions.

In both cases, the airflow velocities have values $V_0 = 15\ м/с$, $V_0 = 20\ м/с$, $V_0 = 25\ м/с$ and the corresponding cotton particle trajectories are presented graphically

Diagram 3a shows the trajectory of stationary motion of cotton particles 1 and 2 in horizontal position in the separator working chamber. As can be seen from the graphs, when changing the air flow rate between $15\ с/м\ ва\ 25\ с/м$, it can be seen that the cotton particles fall mainly into the first half of the vacuum valve. This process can also be observed by the fact that the velocity $V_{y1}(t)$ takes zero value in the range of 0.1÷0.3 m along the OX axis. The trajectory of the 2nd piece of cotton is also similar to the trajectory of the 1st particles of cotton, and we can observe that the vertical velocity becomes zero mainly in the range of 0.2÷0.35 m and moves towards the vacuum valve along the OX axis in the range of 0.3÷0.8 m.

Diagram 3b shows the pattern of change in the size of cotton particles in the horizontal and vertical directions with time. As can be seen from the graph, the cotton particles reach the vacuum valve in about 0.4 seconds.

Diagram 3b shows the patterns of movement of cotton particles 1 and 2 in the separator working chamber in the vertical position. As can be seen from the graphs, although the process of cotton particles getting into the vacuum valve is somewhat slower in time than in the horizontal position, it can be seen that more of them get into the front part of the vacuum valve.

Calculation of the efficiency of cotton particles falling into the vacuum valve chamber:

$$m_0 = m_1 + m_2 = 0{,}4 + 0{,}45 = 0{,}85\, г \text{ mass}$$

$t_0 = 0{,}25$ second fall speed

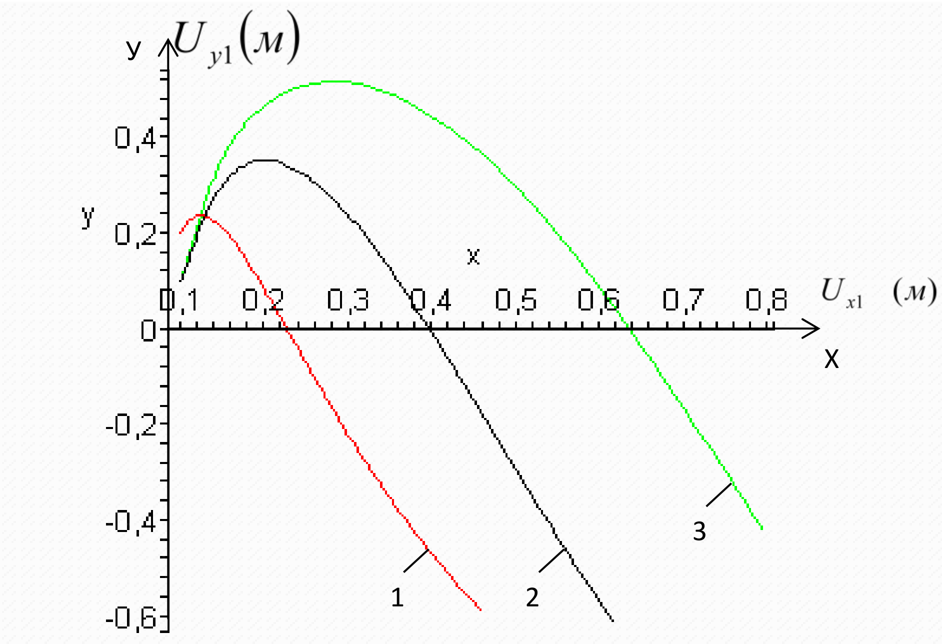
$t_1 = 1$ second $m_1 = 3{,}4\,gr$;

$t_2 = 60$ second $m_2 = 204\,gr$;

$t_3 = 1$ hour $m_3 = 1224\,0gr$.

Considering the entrance surface $S_0 = 0{,}16\,м^2$ to the separator working chamber, the working chamber has the potential to separate 19,584 tons of cotton from the air per hour.

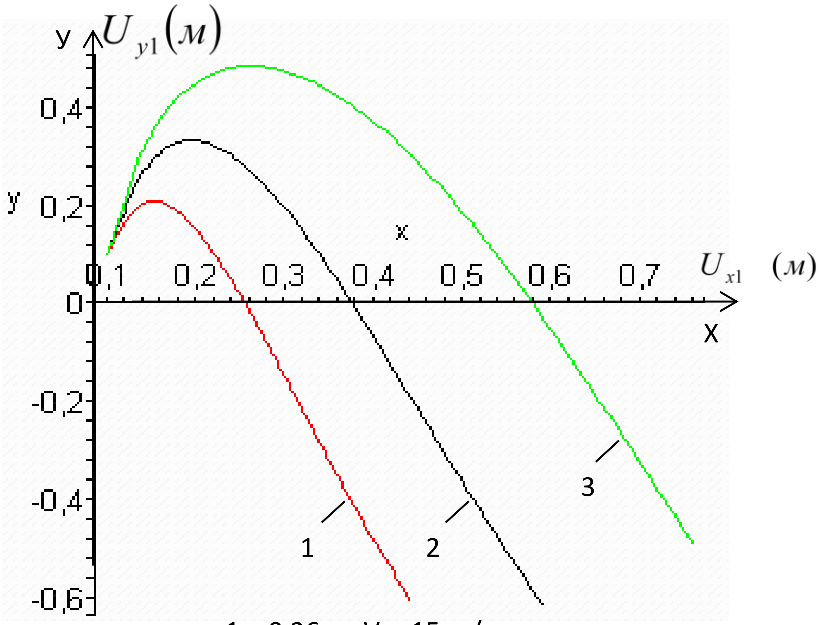
In addition, the fact that the velocity of cotton particles in the horizontal direction is several times less than their sliding velocity, and in the vertical direction their velocity becomes zero, reduces their impact on the back of the separator and completely eliminates the possibility of their adhesion to the surface of the mesh.



1 – 0,22 m V₀ =15 m/s;

2 – 0,4 m V₀ =20 ммs;

Figure 3a



1 – 0,26 m V_0 =15 m/s;

2 – 0,38 m V_0 =20 m/s;

Figure 3b

4. Conclusion

1. Study of the regularities of movement of cotton particles in the working chamber of the separator, where the inlet pipe is located along the vacuum valve, showed that the pieces of cotton, getting into the inlet pipe, after about 0.4 seconds get into the vacuum valve.

2. The bulk of the cotton mass is removed through the primary portion of the separator vacuum valve in accordance with the law.

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