ANALYSIS OF THE MOVEMENT OF COTTON THROUGH THE PIPE IN PNEUMOTRANSPORT

Nematjonov Shukrullo G'ulomjon o'g'li
Lecturer in International Digital University
E-mail: Nematjonov1995@bk.ru

ABSTRACT

The article analyzes the motion equations and trajectory of a piece of cotton in the pipeline of a pneumotransport device, in which the laws of changes in the movement of a piece of cotton under the influence of aerodynamic resistance, weight, inertia, impact and reaction forces are derived, and the change of quality indicators of cotton during movement is theoretically based.

Key words: cotton, pneumatic transport, aerodynamic resistance, air, pipe, movement, flow rate, impact.

INTRODUCTION

Currently, in the cotton ginning industry, extensive work is being carried out on the creation of high-efficiency techniques and technologies for the initial processing of cotton raw materials. Work is being carried out on the introduction of flexible technologies in the initial processing of cotton raw materials in cotton ginning enterprises. In particular, it is important to ensure the preservation of the quantity and quality of cotton raw materials prepared by cotton ginning enterprises, to reduce the consumption of raw materials and energy, and to create techniques and technologies.

The concentration of the mixture of air and cotton during the transportation of cotton by air has a significant effect on the nature of transportation. When the material moves in a straight line pipe with the help of air, the dimensions of the resistance forces with the inertial forces almost do not change. In this case, the transfer of cotton along the axis of the pneumatic transport equipment creates favorable conditions for the transportation process.

The lack of theoretical development of the selection of optimal conditions for the transfer of cotton to the pipeline raises the issue of theoretically studying the process of transferring cotton to the pipe of pneumatic transport equipment. The solution of this problem allows to determine the parameters that ensure the smooth progress of the air transportation process.

Transfer cotton to a pipe and study its movement inside.

A belt conveyor is used to transfer cotton to the pipe of pneumatic transport equipment (figure 1).

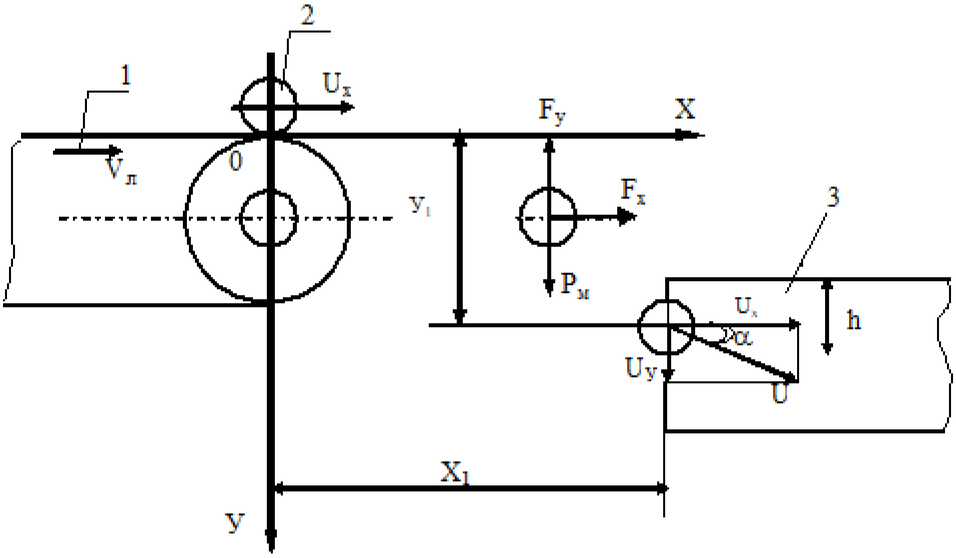

Figure 1. Transferring cotton to the pipe using a belt conveyor

1-horizontal ribbon cutting; 2- piece of cotton; 3- pipe.

First, we assume that the movement is in the plane and we place the coordinate head at the point where the contact of the tape with the piece of cotton is broken. Let's consider the movement of a piece of cotton along the XOY plane.

Aerodynamic and gravity forces act on the cotton ball ejected from the tape. The equation of motion will look like this:

$$\begin{cases} m\dfrac{dU_x}{dt} = -F_x \\ m\dfrac{dU_y}{dt} = -F_y + P_м \end{cases} \qquad (1)$$

where: m-particle mass, kg; Ux,Uy- velocity projections of the particle:

$F_x = k_п U_x$; $F_y = k_п U_y$, (2)

Here: F_x, F_y- aerodynamic forces against the movement of the particle along the coordinate axes; $P_м = mg$ - gravity; g- acceleration of free fall; $k_п$ is the coefficient of aerodynamic resistance of a piece of cotton.

Putting the expression of the acting forces and developing the system, we get the following:

$$\left.\begin{aligned} \frac{dU_x}{dt} &= -\frac{k_n}{m}U_x \\ \frac{dU_y}{dt} &= -\frac{k_n}{m}\left(U_y - \frac{mg}{k_n}\right) \end{aligned}\right\} \quad (3)$$

The solutions of equation (3) give the velocities of the cotton ball along the coordinate axes x, y. Integrating the solutions once over time, we get the resulting $y(t)$ and $x(t)$ - as a result of subtracting time from the solutions

$y = y(x)$ - law of change of the cotton ball's motion:

$$y = -\frac{m^2 g}{k_n^2} \cdot \left[\ln\left(1 - \frac{k_n \cdot x}{mU_{x_0}}\right) + \frac{k_n \cdot x}{mU_{x_0}} \right] \qquad (4)$$

According to this rule, we separate the cotton from the surface of the tape and build the trajectory of movement to the pipe (Fig. 2).

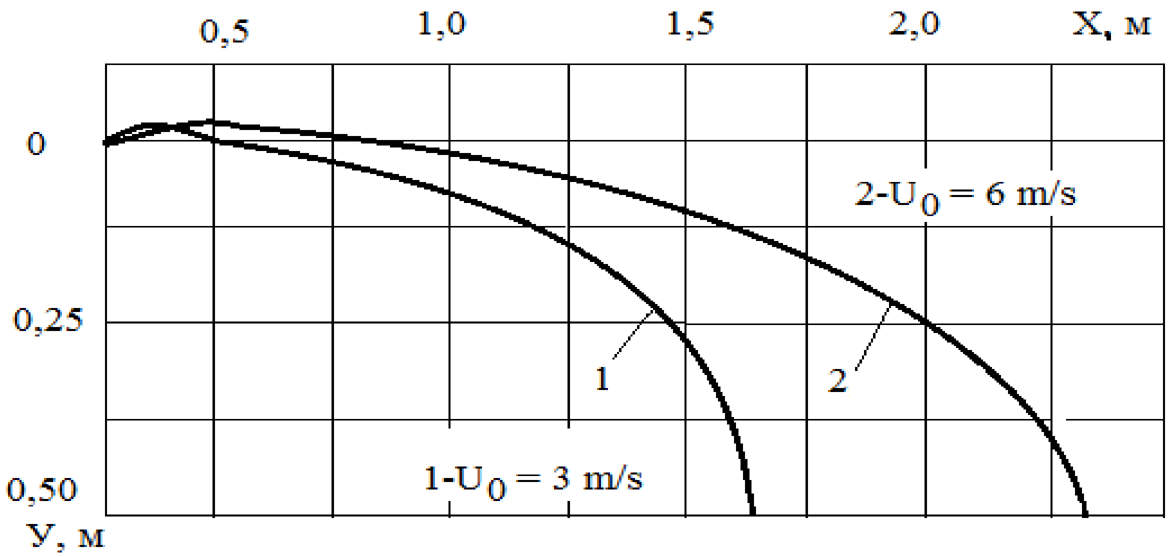

Figure 2. The trajectory of the cotton to the pipe.

Figure 2 shows the movement trajectory of a piece of cotton before it enters the pipe of the pneumatic transport equipment.

As can be seen from the graph, the fragment moves along an increasing trajectory after separation from the surface of the tape, where, at a small initial speed, the fragment arrives at the pipe with a small speed, and at a high speed - on the contrary.

To make it convenient while studying the movement of the cotton in the suction part of the pipe, we first put the coordinate at the beginning of the pipe. Let us assume that the particle is moving between two infinite walls:

y=0 and y=d.

Assume that the piece of cotton has an absolute velocity when it encounters the air stream, and that it is moving at a certain angle to the axis of the pipe. Then the equation of motion is:

$$\begin{cases} mx'' = -k(x' - V) \\ my'' = ky' - mg \end{cases} \qquad (5)$$

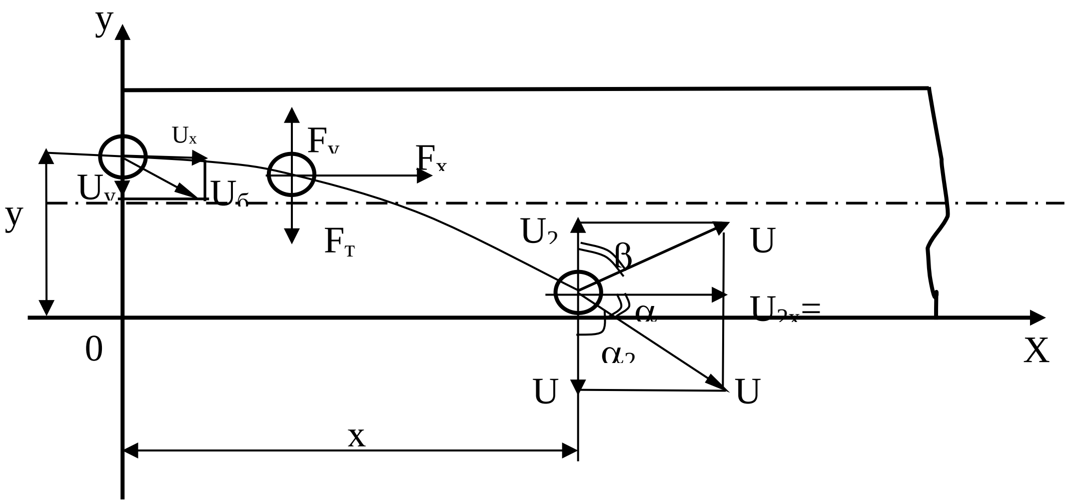

Figure 3. The movement of cotton in the pipe

Taking into account that $U_x = \frac{dx}{dt}$ and $U_y = \frac{dy}{dt}$, we integrate the system (5) under the condition t=0. The solution would be:

$$\begin{cases} x = \frac{m}{k}(U_H \cos\alpha - U)(1 - e^{-\frac{k}{m}}) + Vt \\ y = -\frac{m}{k}(U_H \sin\alpha - \frac{mg}{k})(1 - e^{\frac{k}{m}}) + \frac{mg}{k}t + y_1 \end{cases} \quad (6)$$

This system of equations determines the trajectory of cotton in the XOY plane.

At a certain distance (X), the particle collides with the inner wall of the pipe and is thrown up by the force of the impact.

From the circuit in Figure 3, we find the following equation:

$$tg\alpha = tg\left(\frac{\pi}{2} - \alpha_2\right) = ctg\alpha_2 \text{ or } tg\beta = \frac{ctg\alpha_2}{n} \quad (7)$$

where: n - recovery coefficient.

Based on analytical calculations, we determine the expression of the speed of the piece of cotton after the impact and its location along the coordinate axes (x,y):

$$\begin{cases} U_x == (U_{20x} - V)l - \frac{k}{m}(t - t_1) + V \\ U_y = \left(U_{20y} - \frac{mg}{k}\right)l\frac{k}{m}(t - t_1) + \frac{mg}{k} \end{cases} \quad (8)$$

$$\begin{cases} X = \frac{m}{k}(U_{20x} - V)\left(1 - l - \frac{k}{m}(t - t_2)\right) + V(t - t_2) \\ Y = \frac{m}{k}\left(U_{20y} - \frac{mg}{k}\right)\left(1 - l\frac{k}{m}(t - t_2)\right) + \frac{mg}{k}(t - t_2) \end{cases} \quad (9)$$

where: $U_{20x} = (U_n \cos\alpha_1 - V)\frac{k}{m}t_2 + V \; U_{20y} = U_{20x} x \cdot tg\beta$

Equations (8) and (9) determine the position of the particle at the first impact with the pipe wall. In this case, the particle reaches a critical point and falls down. If the magnitude of the vertical coordinate of the critical point is greater than the diameter of the pipe, then the particle will hit the upper wall. Its next state can be determined with sufficient accuracy by equations of the form (8) and (9). Only changes are made to the signs, taking into account the direction of the initial velocity after the impact.

As a result of subtracting time from the expression (9), y=f(x) - the equation of the trajectory of a piece of cotton according to the diameter and length of the pipe can be obtained, its graphical representation is shown in Fig. 4.

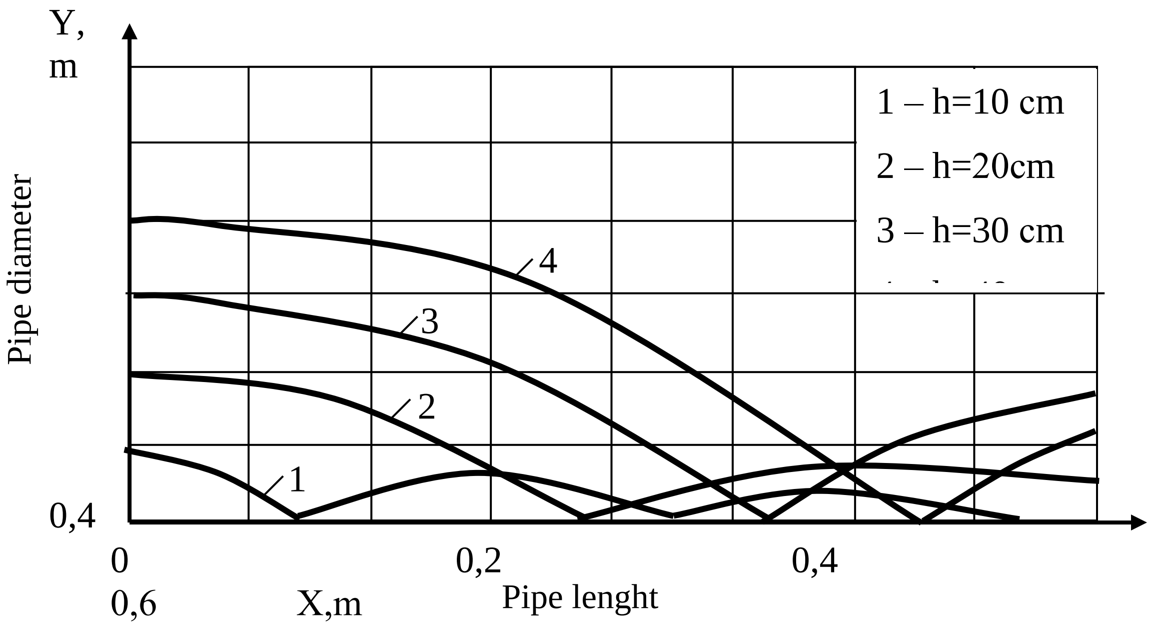

Figure 4. The trajectory of the movement of the particle in the pipe.

An interesting situation can be observed from the results, that is, during the movement of the cotton piece in the pipe, the impact of the cotton against the pipe wall occurs even if the turbulence of the flow, longitudinal, transverse and circulation forces are not taken into account. The higher the speed, the faster and more intense the impact. It has been found that this has a negative effect on the initial quality indicators of cotton.

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