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MATHEMATICAL MODELING OF THE CRUSHED WOOD PARTICLES MOVEMENT IN PNEUMATIC TRANSPORT SYSTEMS

Pneumatic transport systems (PTS) are widely used in various branches of industries. The transportation of crushed material in such systems is carried out due to the air flow. In the woodworking industry, there are technological processes that are often accompanied by the formation of dust and other small air pollutants. Studying the movement of particles in polluted air makes it possible to transport or separate such particles, while spending less energy. The mathematical model of the movement of dusty air containing separate solid particles (production waste) was worked out, and based on it solution will allow separating and capturing crushed wood particles and reducing the cost of consumed electricity for transportation.

Keywords: pneumatic transportation, air flow velocity, polluted air, frictional losses, separation.

Introduction

Transport pneumatic systems are used to remove air contaminated with small wood waste at industrial enterprises of the woodworking industry. The transportation of crushed material is carried out with the help of TPS. It is possible to transport crushed material along a complex trajectory, collect material from various loading devices, and protect the environment from pollution during transportation. simplicity of construction and operation, ease of management, the possibility of automation and remote control, are some of the characteristics of the TPS. They don't take up a lot of production space.

The main disadvantage of TPS is the high specific consumption of electricity, which is determined by the speed of the air flow in the pipeline, the need to separate the material from the air at the end of the transportation route [1, 2].

Methodology

The basic concepts in the theory of pneumatic transport are transportation speed, the speed of floating, and the starting speed of movement.

A reliable and stable movement of the material is achieved by the minimum speed of the air flow.

The speed of floating is the speed of the upward internal flow in a vertical pipe, at which the particle is in a soaring state.

The air speed averaged over the cross-section of a pneumatic transport pipeline is the start of the particle's movement..

When analyzing the movement of dust particles along the TPS pipeline, the following main sections should be distinguished:

- movement along a horizontal section;
- movement along the vertical section;
- movement in the elbow (ell).

During the analysis, we will study the value of the pressure decrease in the certain element of the transport pneumatic system, the nature of the movement of air flows and dust particles, and the value of the pressure decrease on this hydraulic resistance.

Movement along a vertical pipeline (**Figure 1**). It is assumed that a dust particle in a vertical pipeline will move if the value of the air flow speed exceeds the soaring speed of the particle. At the same time, the weight ***G*** of the particle will exceed the force ***F*** of capturing the particle by the flow.

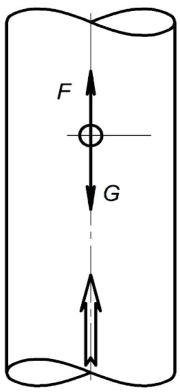

Figure 1. Movement of a particle in a vertical pipeline

The force ***F*** with which the flow acts on the particle is determined by the dependence:

$$F = C_F \cdot S \cdot \frac{\rho_n}{2} V^2 , \qquad (1)$$

where C_F – the resistance coefficient, which depends on the shape of the particle; S – the area of the projection of the particle on the plane that is perpendicular to the flow direction; ρ_n – air density; V - the speed of air flow.

Movement along a horizontal pipeline (**Figure 2).** In order for a particle to move in a horizontal pipeline, the force with which the air flow acts on it must be greater than the sum of all other forces acting on the particle. It is believed [2, 3] that reliable transportation is possible in the case when the flow rate in the pipeline is greater than the starting speed of movement of the particle.

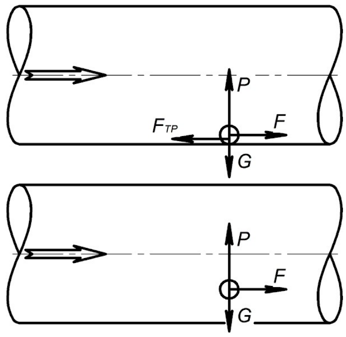

Figure 2. Movement of a particle in a horizontal pipeline

A particle lying at the bottom of the pipeline is affected by the force F of being captured by the flow, the force of gravity G, the force of friction F_{TP} and the lifting force P.

Movement in the ell of the pipeline. The movement of dust and air flow in the ell is the most complicated, so let's consider it in more detail. It is advisable [5] to use applied CFD packages.

We will analyze the flow of dusty air through a pipeline with a 90° ell. The diameter of the pipeline is 240 mm; the length of the section before the ell is 1500 mm, and after the ell – 3000 mm. The radius of the ell is 500 mm. Numerical analysis of the solution of the problem was carried out at the following parameter values: air density ρ_{Π}=1.3 kg/m^3, solid particle density ρ_P=700 kg/m^3; air flow temperature T_0 = 20°C; static pressure at the entrance to the pipeline is equal to atmospheric pressure; speed of the air flow at the exit from the pipeline – 20 m/s.

When the flow of air moves along a curved channel, the velocity of the flow particles decreases with an increase in the radius of curvature and, as a result, the pressure near the inner wall is lower than near the outer wall. It follows from this that at the beginning of the curvilinear flow near the inner wall there is a confusing section, and near the outer one - a diffusive section (**Figure 3**).

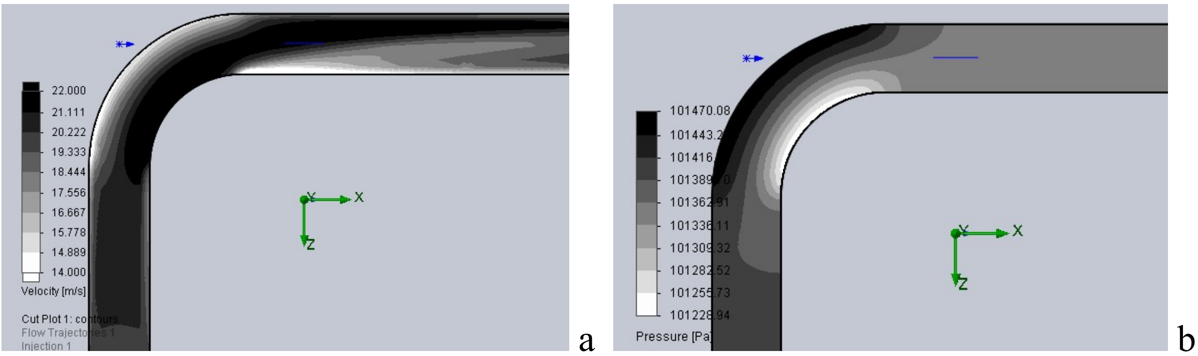

Figure 3. Distribution of air flow velocity (a) and air flow static pressure (b) in the ell

In the diffuser zone, the near-surface layer grows very intensively, it is unstable and can easily break away from the wall [4, 5]. This phenomenon is one of the main causes of air flow turbulence. It is observed in the diffuser zones of the curvilinear flow.

Results and discussion

These phenomena determine the nature of losses in a curvilinear flow, which consist of frictional losses; losses associated with the occurrence of paired vortices; and losses caused by the presence of local flow separations. The last ones have the largest relative value, and friction losses make up the smallest share of total losses.

When trying to improve transport pneumatic systems, we are dealing with the following contradiction, which must be resolved. For reliable transportation of crushed wood, it is necessary to increase the value of the air flow speed, which in turn leads to a sharp increase in the hydraulic resistance of the pipeline. A decrease in the value of the flow rate leads to a decrease in energy consumption, but at the same time to an increase in the danger of clogging the pipeline with the material being transported.

4. Conclusion

In accordance with the studies, the following design of the pneumatic pipeline parts should be proposed, which will achieve the following results:

1. Separation and trapping of large particles of chopped wood, which makes it possible to reduce the speed of transportation in the pipeline.
2. Elimination of the phenomenon of reducing the “live” cross-section of the ellipse, which will lead to a decrease in its hydraulic resistance.
3. Reducing the flow rate drop and static pressure in the section perpendicular to the pipeline axis outside the elliptic transition.
4. Reducing the concentration of crushed wood particles in the pipeline after the boathouse, which will reduce the cost of electricity for transportation.

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