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SCIENTIFIC JUSTIFICATION OF THE PROCESS OF SEPARATION OF GRAIN MATERIALS IN THE AERODYNAMIC SEPARATOR

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Abstract. *The article deals with the study of the separation of grain materials in pneumatic channels with an artificially formed distribution of air velocity in the cross-section of the channel, to determine the rational form and parameters of the material supply and the options for dividing the grain material into fractions.*

The patterns of grain movement were theoretically investigated and established in the form of mathematical models of the dynamics of solid particles in the air flow, which differ from the known ones in that they take into account the action of lateral forces, the concentration of the material, and the application of the power law and the artificially formed exponential law of air distribution made it possible to increase the difference (splitting) grain movement trajectory by 20%.

The solution of the system of nonlinear differential equations with initial conditions is performed in the MathCad software environment in the form of grain movement trajectories in the air stream, which allows you to calculate their movement trajectories, which differ by windage coefficients, and to determine the rational values of the parameters of pneumogravity and pneumoinertial separators.

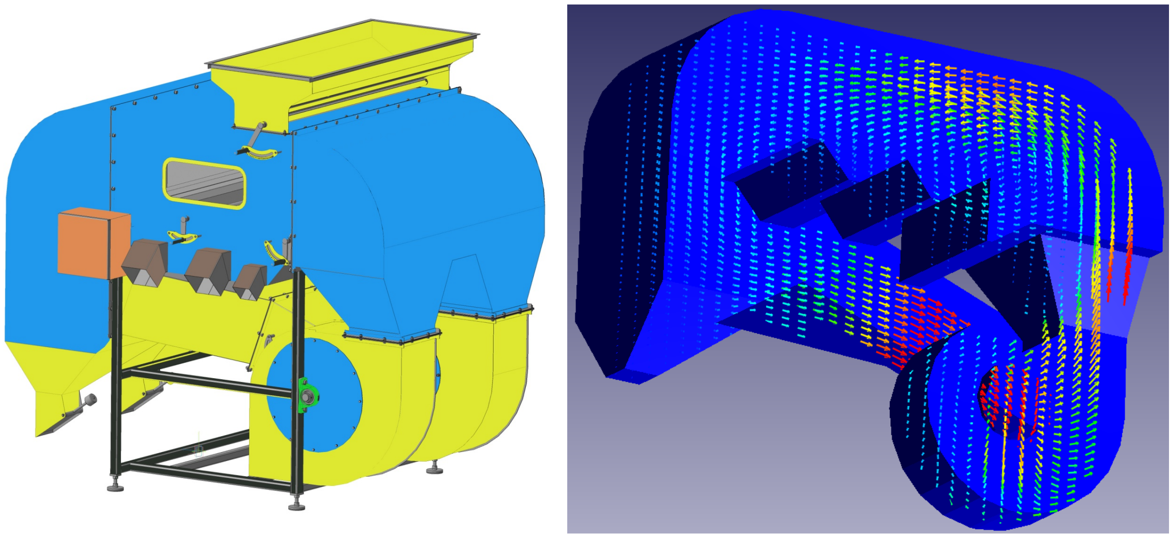
Using the obtained dependencies for the development of air separators, it is possible to determine the initial speed of input and the direction of entry of grains into the air flow, as well as determine the trajectories of material movement in air channels with the bottom discharge of material.

Key words: *air flow, grain, Zhukovsky and Magnus forces, trajectory, separation process, pneumatic separator.*

Introduction.

Sufficient attention has been paid to the study of the fractionation of grain materials in the aspiration channels of separators [1-4], but it should be noted that in most cases the grain material is considered as a monolayer of grains [2], which enters the pneumatic channels of the separator. Under these conditions, fractionation into separate fractions and subsequent removal of impurities from the grain material layer takes place along the length of the horizontal pneumatic separating channel [3-5], which significantly worsens the quality. Therefore, it became necessary to simulate the process of fractionation of grain materials in the aspiration channels of a new separator with a closed air cycle [6-8] and to investigate the change in the behavior of the movement of the air medium during the artificial loosening of grain materials along the length of the aspiration channel of the separator.

The results. On the basis, a combined separator of grain materials with a closed air cycle was developed (Fig. 1, a), mathematical modeling of the movement of the air environment during artificial loosening of grain materials along the length of the aspiration channel of the separator was carried out (Fig. 1, b).



a) b)

a) – 3-D model of the design of the combined separator;

b) – a model of air movement;

Figure 1 – Combined separator of granular materials with a closed air cycle SP-20 [8]

The separator is simple in structure, dust-free, self-cleaning and does not injure the grain material. Productivity at continuous loading of 20 t/h.

The combined separator of grain materials with a closed air cycle includes a frame, working and air channels, a fan, a loading hopper, a settling chamber, trays for the output of fractions of cleaned grain and air-separated waste, dampers, a confusor, the originality of the design [8] is that the working air channel made of a rectangular cross-section and under it there are trays with scaly channels inclined at a certain angle to the discharge direction, and the air inlet to the pneumatic channel and under the trays with a scaly channel is separated by a control valve.

The formation of a pneumatic channel in the form of a rectangular cross-section, under which there are trays with a scaly channel inclined at an angle to the discharge direction, ensures a uniform and accelerated movement of air in the working air channel, in the direction of its movement to the settling chamber. As a result of the artificially created physical phenomenon, effective fractionation of grain materials is achieved, as well as the separation of impurities from the grain mixture and its division into fractions according to aerodynamic properties. The slope of the scaly channel, at an angle significantly smaller than the angle of the natural slope, allows to efficiently transport the separated fractions for unloading from the combined separator through the trays with gentle grain movement and significantly reduce the height of the separator.

Installation of trays for fractions with the combined effect of the injection air stream, which evenly exits the working air channel from the fan, allows you to divide the grain mixture into several fractions: separation of metal and other foreign impurities (stones); grain (seeds) of the main crop; food grain; air-separated waste (light impurities), which helps to reduce the ingress of substandard grain into the main crop, and, accordingly, to increase the quality of food grain or seeds.

By studying the fractionation process of grain materials in a combined separator with a closed air cycle and the separation of grain material by density in the grain layer, a mechano-mathematical model (1) was compiled, which made it possible to simulate the process of air movement in the aspiration system of the combined grain material separator.

$$\begin{cases} \frac{d^2x(t)}{dt^2} = k_v\left[\upsilon(y) - \frac{dx(t)}{dt}\right]\sqrt{\left[\upsilon(y) - \frac{dx(t)}{dt}\right]^2 + \left(\frac{dy(t)}{dt}\right)^2} - \frac{[F_{ж(x)} + F_{м(\omega)x}]}{m} \cdot \frac{\frac{dy(t)}{dt}}{\sqrt{\left[\upsilon(y) - \frac{dx(t)}{dt}\right]^2 + \left(\frac{dy(t)}{dt}\right)^2}} \\ \frac{d^2y(t)}{dt^2} = g - k_v\left(\frac{dy(t)}{dt}\right)\sqrt{\left[\upsilon(y) - \frac{dx(t)}{dt}\right]^2 + \left(\frac{dy(t)}{dt}\right)^2} - \frac{[F_{ж(x)} + F_{м(\omega)x}]}{m} \cdot \frac{\upsilon(y) - \frac{dx(t)}{dt}}{\sqrt{\left[\upsilon(y) - \frac{dx(t)}{dt}\right]^2 + \left(\frac{dy(t)}{dt}\right)^2}}. \end{cases} \quad (1)$$

Where $\overline{G} = mg$ – gravity; $\bar{R} = -m \cdot k_V \cdot \bar{u}^2(t)$ – force of aerodynamic resistance; $\bar{F}_ж = \frac{4}{3}\pi\, \rho r^2\, qrad\, V(x)\bar{u}$ - the power of Zhukovsky; $\overline{F}_м(\omega) = \frac{16}{3}\pi\rho r^3 \cdot \omega \cdot \overline{u}$ – the power of Magnus; $\overline{u} = \bar{V}_П(x) - \bar{V}$ – relative velocity (flow velocity); I – moment of inertia; $m = \frac{\pi\, d_e^3}{6} \rho_3$ – grain mass; $d_e = 2r$ – equivalent grain diameter; ρ, ρ_3 – air density and grain substance, respectively; $\bar{V}$ – grain speed; $\bar{V}_\Pi(x)$ – air speed (distributed); k_V - coefficient of sailability (or "sailability"), which is determined from the ratio $k_V = \frac{g}{V_{вит}^2}$; $V_{вит}$ – the rate of germination of the grain; g – free acceleration.

The power distribution law is most widely used in the form of an expression [5-8]:

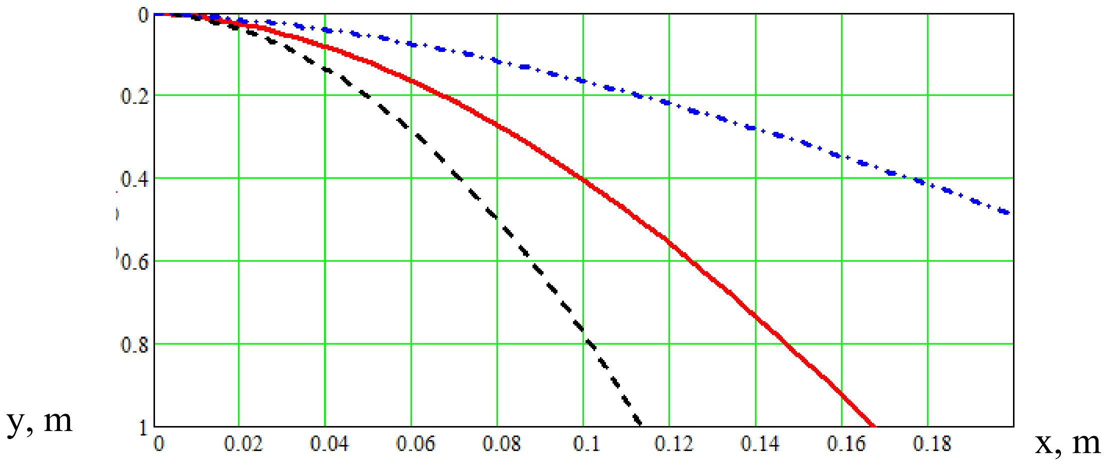
$$\vartheta(x) = \vartheta_{max} \cdot \left[\frac{x}{b}\right]^{1/n}, \qquad (2)$$

Where ϑ_{max} – time-varying air velocity in the center of the channel; b – half the distance between the channel walls; x – the distance from the considered point to the channel wall; n – a coefficient that depends on the Reynolds number Re [n=7-10 при Re=2,3($10^3 \ldots 10^5$)].

Initial conditions:

$$t = 0; x = 0; y = 0; \frac{dx(t)}{dt} = V_0 \cos \alpha_0 ; \frac{dy(t)}{dt} = V_0 \sin \alpha_0 ; \omega = \omega_0. \qquad (3)$$

The solution of the system of equations (1) under the initial conditions (3) was obtained numerically in the MathCad computer environment in the form of a grain movement trajectory [5, 6] with different values of the floating speed and, accordingly, the mass (Fig. 2).



1 – 3 in accordance k_V = 0,139; 0,184; 0,392

Figure 2 - The trajectory of movement of grains in a horizontal channel with an exponential distribution of air speed along the channel height

Conclusions.

According to the results of studies of the fractionation of grain materials [6-8] in a combined separator with a closed air cycle, the rational design and mode parameters of the separator were established, as well as the coordinates of the position of the dividing device, which led to the need to lower the level of the dividing line and, accordingly, increase the number grains of the main component in a full-fledged fraction.

Taking into account the conditions of the joint operation of pneumatic channels and the sedimentation chamber, a physical-mathematical model of the interaction of the components of grain material with air flows of a variable structure was also developed for the latter.

When mathematically modeling the movement of grains in vertical and horizontal channels and the variable nature of air speed, the presence of vortex components and the turbulent mode of air movement, the distribution of air speed in the cross section was not taken into account.

Thus, the improvement of the quality of grain cleaning from difficult-to-separate impurities, improvement of the sanitary working conditions of service personnel, reduction of energy consumption and the height of the separator [5-8] is achieved.

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