Mathematical model of the process of skalperation grain heap

Bogdanovich Sergey, Vladimír Kročko, Hristo Beloev

Abstract: *To describe the process of separation of the grain mixture in the drum scalperator asked to create a mathematical model of the process on the basis of the laws of dynamics of viscous liquid with regard to the influence of separation.*
Key words: *scalperator, cylindrical sieve, grain mass, vibration.*

Introduction

In the pile of grain that is served at the processing after harvesting , together with the grain, and there are large impurities: pieces of straw, ears, weeds, lumps of clod and pebbles. This negatively affects the results of the further processes of processing of grain: drying, primary and secondary treatment, calibration. It is recommended for removal of large admixtures of grain heap use machines hereinafter called skalperators, sieve holes which have a size much larger than the size of the grains, but smaller than the large impurities. Most widespread are the drum scalperators [1].

Feature of the process of skalperation is relatively easy passage of grain particles through apertures of a sieve. The problem with this process is in the rapid penetration of these particles to the surface of a sieve. This step in the process of skalperation is considered as a determinant. For a considerable increase in productivity of skalperators and improve the quality of the process of skalperation proposed to rotation movement cylindrical screens impose vibration.

Skalperator consists of a cylindrical sieve drum S_0, which revolves around a horizontal axis with a constant angular velocity Ω (Fig.1). The rotary movement of the drum overlap vibration. The mixture of grain is served inside, in the initial region of the drum (near Σ_1) and by the rotation and vibration impacts grain waking up and coarse impurities are moved to the right end Σ_2, forming a layer of variable cross-section with a free surface S_1.

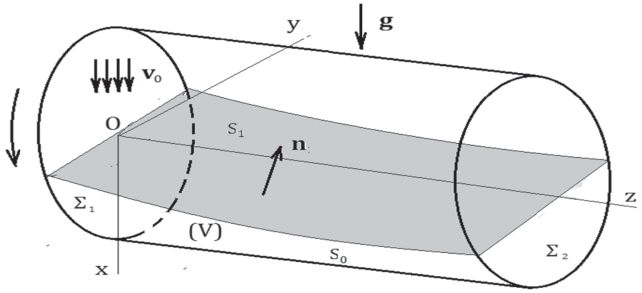

Fig.1. Settlement scheme of a skalperator

Mathematical modeling: Inside the drum skalpertor have the complex dynamic processes. We shall mention the main of them. In the future we will consider a regime of «fast» motion of granular media, which is provided by the influence of small vibration movements device. At a certain intensity of these impact, determined by the characteristic $j = a\omega^2$ (*a* - the amplitude of vibration oscillations, ω - their frequency), within the environment arise instant tensile forces that lead to a breach of contact between the grains. Occurs chaotic movement colliding between the particles, similar to the motion of atoms or molecules of the gas. This phenomenon leads to the fact that the environment in these conditions, subject to the laws of dynamics of viscous medium, rheological law of which, that same law of the Navier-Stokes and the phenomenological coefficients of which depends on the intensity of the vibration. So, the stress tensor in the Cartesian system of allelic worldview is:

$$\hat{\sigma} = -p\hat{\delta} + \left(\lambda - \frac{2}{3}\mu\right) div\,\vec{v} + 2\mu\hat{V}, \quad (1)$$

where λ, μ - bulk and shear viscosity coefficients, in this case reveal-related functions of the intensity of vibration , p - pressure, $\hat{\delta}$ - a single tenzor, $\vec{v} = \left(v_1(x_1,x_2,x_3), v_2(x_1,x_2,x_3), v_3(x_1,x_2,x_3)\right)$ - the velocity field of a continuous medium, $\hat{V}$ - tensor of deformation velocities equal to:

$$V_{ik} = \begin{pmatrix} \frac{\partial v_1}{\partial x_1} & \frac{1}{2}\left(\frac{\partial v_2}{\partial x_1} + \frac{\partial v_1}{\partial x_2}\right) & \frac{1}{2}\left(\frac{\partial v_3}{\partial x_1} + \frac{\partial v_1}{\partial x_3}\right) \\ \frac{1}{2}\left(\frac{\partial v_2}{\partial x_1} + \frac{\partial v_1}{\partial x_2}\right) & \frac{\partial v_2}{\partial x_2} & \frac{1}{2}\left(\frac{\partial v_3}{\partial x_2} + \frac{\partial v_2}{\partial x_3}\right) \\ \frac{1}{2}\left(\frac{\partial v_3}{\partial x_1} + \frac{\partial v_1}{\partial x_3}\right) & \frac{1}{2}\left(\frac{\partial v_3}{\partial x_2} + \frac{\partial v_2}{\partial x_3}\right) & \frac{\partial v_3}{\partial x_3} \end{pmatrix} \quad (2)$$

At low velocities of motion of continuous media can be considered that this movement is made with preservation of volume, as in the case of an incompressible fluid. Mathematical septic condition expression of incompressibility is written in the form:

$$div\,\vec{v} = 0. \quad (3)$$

Movement of fluid through a porous medium can be roughly described as a movement it through the curved cylindrical channels. Mathematical description of such a movement gives filtration theory. The basic law of filtration - Darcy's law - indicates the proportional dependence of the velocity of motion of the medium pressure gradient with the proportionality coefficient K_d [2]:

$$\vec{v} = K_d \nabla p$$

These considerations suggest that the rate of passage of a grain flow through the holes of the drum is proportional to the pressure drop in grain flow inside and outside of the sieve cloth cylinder :

$$v_r = K_d\left(p - p_a\right). \quad (4)$$

You must consider the impact of surface sieve flow in the form of friction, submitting to the law of the Coulomb friction:

$$T_k = f\,p \quad (5)$$

and strength of hydraulic resistance:

$$T_c = \lambda w_\tau, \quad (6)$$

where T_k, T_c - forces per unit area of the wall; f - dry sliding friction coefficient; p - pressure environment; λ - coefficient of hydraulic resistance, defined empirically; w_τ - relative tangent component of the speed of «liquid» particles of the internal surface of a sieve.

On the free surface are dynamic boundary conditions. As for over grain flow is absent, the pressure outside the scope of the grain mixture is equal to zero. Then the dynamic conditions meet the condition of absence of tension. Denote by $\vec{p}_n$ tension, according to the formulas of Cauchy, we obtain the following expression:

$$\vec{p}_n \equiv \sum_{i,k=1}^{3} n_k \sigma_{ki} \vec{e}_i \Bigg|_{S_1} = 0 , \qquad (7)$$

where $\vec{n} = n_k \vec{e}_k$ - the unit normal to the surface S_1, external to the volum of grain (on repeated indices according to the rules of tensor calculus here is the summation from 1 to 3), $\vec{e}_i\,(i = 1,2,3)$ - vector basis in some Cartesian coordinate system.

The kinematic condition:

$$\mathrm{v}_z = \frac{\partial F}{\partial t} + \frac{\partial F}{\partial x}\mathrm{v}_x + \frac{\partial F}{\partial y}\mathrm{v}_y . \qquad (8)$$

Assume condition: consumption of grain flow Q_1 and depth of filling $z = 0$ in are assigned values. Taken condition of the incompressibility environment gives the first equation model , having in the chosen coordinate system type:

$$\frac{\partial \mathrm{v}_x}{\partial x} + \frac{\partial \mathrm{v}_y}{\partial y} + \frac{\partial \mathrm{v}_z}{\partial z} = 0 ,. \qquad (9)$$

The following equation, called the vector nature, the equation of motion expressing the second law of mechanics of a continuous medium:

$$\rho \frac{d\vec{\mathrm{v}}}{dt} = div\,\hat{\sigma} + \rho \vec{g} , \qquad (10)$$

where ρ - the density of the medium (in this case the constant value); $\vec{g}$ - the intensity of the external forces acting on the environment (in this case equal to acceleration free fall), $\hat{\sigma}$ - stress tensor, which has components, determined by the ratio of (1).

Expressions (9) and (10) are a mathematical model of the process scalperation.

Conclusions

1. The mixture of grain in rotating drumskalperator superimposed vibrations obeys the laws of dynamics of viscous medium, rheological law which is similar to the law of the Navier-Stokes equations, and the phenomenological coefficients of which depends on the intensity of the vibration.

2. The process of separation of granular mixture in skalperator can be considered as a viscous fluid through a porous medium.

3. Identified correlation between the factors affecting the process of skalperator, allow you to create a mathematical model of this process.

References

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About the author

Assistant Bogdanovich Sergey, Department of theoretical mechanics and machine parts Kharkiv national technical University of agriculture named Petro Vasilenko, Kharkiv, Artioma st. 44, 61002, E-mail: bogdanovichserg@gmail.com

dr.h.c. prof. Ing.Vladimír Kročko, CSc., Department of Quality and Engineering Technologies, Faculty of Engineering, Slovak University of Agriculture in Nitra, Tr. A. Hlinku 2, 949 76 Nitra, Slovak Republic, e-mail: vladimir.krocko@uniag.sk

Prof. Hristo Beloev, DTSC, University of Ruse, 7017, 8 Studentska Str. Bulgaria

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