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THE MODEL OF MATERIAL MOVEMENT IN THE ROTOR ACCELERATOR OF THE CENTRIFUGAL IMPACT CRUSHER

The features of the use of grinding units produced by the SPA "Center" and possible approaches to their calculation are analyzed. The mathematical description of the motion of individual particles of the crushed material in the rotor accelerator of the centrifugal impact crusher is developed. The mathematical model of particle motion along a curved blade on a rotating flat disc, which allows to determine the trajectory of the particles, the magnitude and direction of the full speed at any point on the blade is presented. A graph of full speed and the relative velocity of the particles along the blade, as well as the separation angle, which determines the direction of full speed, the angular speed of the rotor are obtained. The change of the complete particle velocity depending on the position of the rotor is analyzed. It is shown that to change effectively the direction of emission of particles from the rotor can be possible only changing its design parameters and parameters of the crusher.

Introduction. Grinding machines of "Scientific and Production Association Center" are widely used both for grinding and crushing. [1] In this work we will focus on the aggregates for crushing materials; the size of the original product of these aggregates does not exceed 80 mm.

The operating principle of centrifugal impact crushers of "Scientific and Production Association Center" is based on the acceleration of the particles of the starting material to a high speed in the inter-blade rotor accelerator, followed by the impact on the reflective elements.

A characteristic feature of centrifugal impact crushers is that the material is fed into the center of the rotor in a fall from a certain height. Moreover, on the rotor surface it contacts the conical distributor and then falls into inter-blade space. These design and technological features significantly affect the motion parameters of the material in the rotor-accelerator. Obviously, both in theoretical and experimental studies we will have to separately consider the motion of the material along the cone and in the inter-blade space. The size of particles has a significant impact on the methodology of the research.

From the mechanics of the dispersion medium is known [2] that the array of particles of less than 10 m are considered to be loose medium and large particles – lumpy. Such approaches are guided by researchers of soil mechanics. Thus, when loading material for grinding sized from 10 to 80 mm medium can not be considered to be loose. The calculation in this case can be carried out as for a single particle, taking into account the interaction forces. Similar problems, but for other units [3], have already been solved, including the authors of this work [4].

Main part. The most important task of the analytical study of any centrifugal impact crusher is to determine the speed and direction of movement of the material at the exit of the rotor-accelerator. These settings affect the force of the impact damage. Naturally, the main acceleration particles obtain in the inter-blade area, but also important is the movement along the cone. Here they are redistributed, acquire initial direction and momentum.

The preliminary analysis of the motion of the material after contact with the cone showed that given strength of high-speed pressure, gravity and inertial force, the normal response over its entire surface is less than zero. This means that the pieces of material immediately bounce off a rapidly rotating cone distributor. This forms an oblique stroke. Knowing the initial velocity of a freely falling body and the coefficient of restitution, we can calculate the magnitude and direction of its motion after impact. This algorithm has been implemented by us to calculate the speed of the grinding material at the inlet of the inter-blade area.

Let us consider the motion of a piece of material in the inter-blade space of the rotor-accelerator. In contrast to the free movement on a flat rotating disk blades are present here, which restrict the movement of pieces. Therefore, one should consider the frictional force both over the disk and the blade. In the design of the "SPA Center" at the ends of the blades there are partitions, through which crushed material is retained on them. Thus, a self-lining is provided, i.e, the material moves over the layer of material, rather than metal, and thus reducing its wear.

Taking into account the above, we write the equation of the relative motion of a particle in a curved blade in a vector form.

$$m\vec{a}_d = \vec{F}_{1T} + \vec{F}_{2T} + \vec{F}_e + \vec{F}_c, \qquad (1)$$

where F_{1T} – the friction force of the particle over the rotor disc; F_{2T} – the friction force of the particle over the blade, or the material at self-lining; F_e – portable inertial force; F_c – Coriolis force.

Since the height of the rotor is small compared with the diameter, we assume that the motion occurs in a single plane and can be represented in a polar coordinate system 0rφ (Fig. 1).

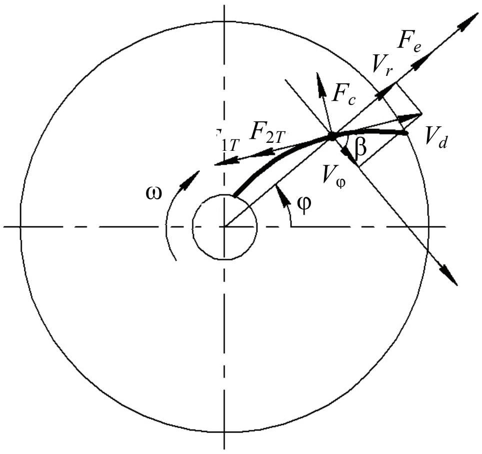

Fig. 1. Calculation scheme of particle motion over curved blades

The specific of the problem lies in the fact that the coordinates r and φ are rigidly bound by a blade profile. Therefore it is better to write the equation for a single coordinate r, and then express φ and its derivatives by r using the equation of the curve that describes the shape of the blade.

Thus, the equation of motion in the projection on the axis r will have the form

$$\frac{d^2r}{dt^2} - r\left(\frac{d\varphi}{dt}\right)^2 = -f_1 g\cos\left(\frac{\pi}{2} - \beta\right) -$$
$$- 2f_2\omega V_d\cos\left(\frac{\pi}{2} - \beta\right) + \omega^2 r + 2\omega V_d\cos\beta, \quad (2)$$

where ω – the angular speed of the rotor; f_1 and f_2 – the coefficients of friction, respectively over the material of the disc and blade; V_d – the relative velocity of the particle movement along the blade.

Expressing the cosines of the angles and relative speed through the differentials, we obtain

$$\frac{d^2r}{dt^2} - r\left(\frac{d\varphi}{dt}\right)^2 = -f_1 g\frac{\frac{dr}{dt}}{\sqrt{\left(\frac{dr}{dt}\right)^2 + \left(r\frac{d\varphi}{dt}\right)^2}} -$$
$$- 2f_2\omega\frac{dr}{dt} + \omega^2 r + 2\omega r\frac{d\varphi}{dt}. \quad (3)$$

The acceleration blades of the mills of the "SPA Center" are in the form of a logarithmic spiral, which is given by the equation $r = an$ in the polar coordinate system. Hence we can get

$$\varphi = \log_a r; \quad \dot{\varphi} = \frac{\dot{r}}{r\cdot\ln a}. \quad (4)$$

With regard to (4), equation (3) takes the form

$$\ddot{r} - \frac{\dot{r}^2}{r(\ln a)^2} = -f_1 g\frac{\dot{r}}{\sqrt{(\dot{r})^2 + \left(\frac{\dot{r}}{\ln a}\right)^2}} -$$
$$- 2f_2\omega\dot{r} + \omega^2 r + 2\omega\frac{\dot{r}}{\ln a}. \quad (5)$$

Equation (5) is calculated. This nonlinear differential equation of the second order, and it is solved by numerical methods using the package MathCad. The initial and boundary conditions for the solution of the equation are determined by the size of the rotor and linked to a specific type size of a crusher.

The solution of equation (5) allows us to construct the trajectory of the particles over the blade, to determine all components of the total velocity of the particle, its direction and magnitude. The calculation was performed for the crusher of the same size with a diameter of the rotor at the ends of the blades of 520 mm. Angular rotor speed was varied over the operating range: 30 to 100 rad/s. The model allowed us to calculate the velocity of a particle at any point of the rotor, determined by the current radius r. We were interested primarily in the speed at the extreme point of the rotor at the point in time of descent of a particle off the blade, i.e. $r = 0.52$ m.

Fig. 2 shows the dependence of the total and the relative velocity of the particle at the descent off the rotor on its angular velocity, and Fig. 3 – the dependence of the angle between a tangential to the rotor and the total particle velocity. The calculated dependences (Fig. 2) show that the particle velocity at the exit of the rotor varies linearly. Its value in the test range can be up to 100 m/s.

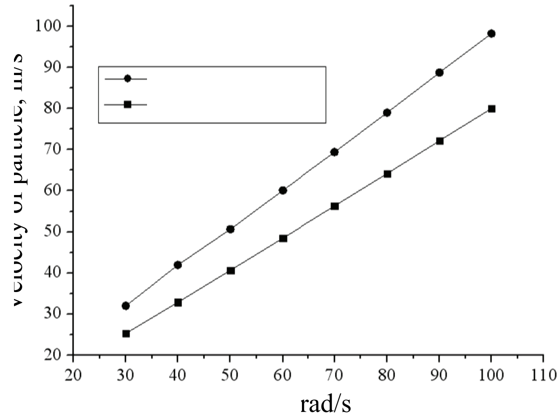

Fig. 2. The dependence of the speed of particle emission on the angular speed of the rotor

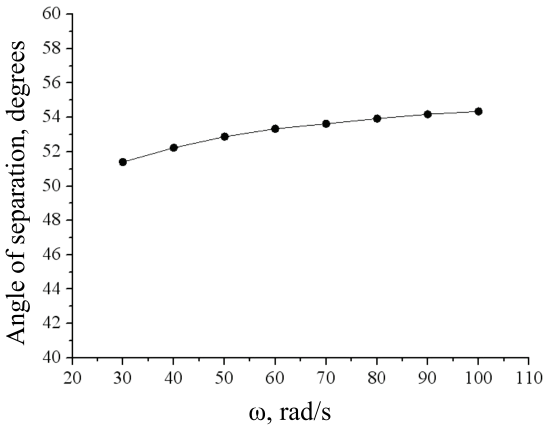

Fig. 3. The dependence of the angle of the particle separation on the angular velocity of the rotor

From the analysis of the graph shown in Fig. 3, it is seen that the angle of separation with increasing angular velocity varies only slightly within the three degrees. This is due to the fact that portable and relative particle velocity change proportionally, and their ratio and thus the separation angle remain practically constant. Thus, to effectively alter the angle of separation, and consequently the angle of attack (the angle of impact of the particles on a reflection surface) can be possible only changing the geometry of the crusher (the shape of the rotor blades and casing of reflective elements), which was confirmed earlier [4].

Fig. 4 shows the dependence of the relative velocity of the particle on its current location (along the blade) for three different angular speeds of the rotor.

As seen from the graph, the relative velocity of the particle from the center to the periphery of the rotor also increases linearly.

Conclusion. The resulting model can be used in the design and improvement of centrifugal impact crushers of any size. Knowing the speed and trajectory of the emitted particles from the rotor, the accelerator will assess the destructive abilities of impact, to choose the right shape of the blade and rationally redirect it toward the reflective surface of the body of the crusher.

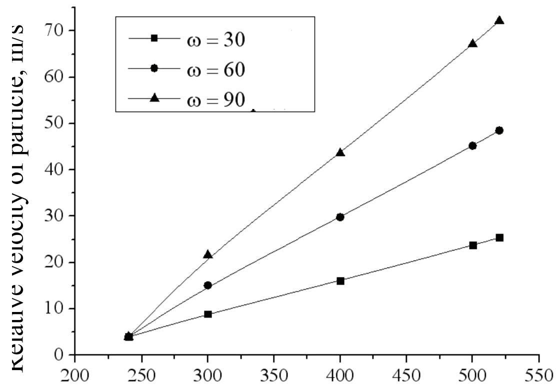

Fig. 4. The dependence of the relative velocity particles on the current radius of the rotor r

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