IOP Conference Series: Materials Science and Engineering

PAPER • OPEN ACCESS

Study of abrasive wear process of lining of grinding chamber of vortex-acoustic disperser

IOP Conf. Series: Materials Science and Engineering **327** (2018) 042077 doi:10.1088/1757-899X/327/4/042077

Study of abrasive wear process of lining of grinding chamber of vortex-acoustic disperser

D N Perelygin

Belgorod State Technological University named after V.G. Shoukhov, 46, Kostyukov St., Belgorod, 308012, Russia

E-mail: mehanikus@mail.ru

Abstract. The theoretical and experimental studies of the process of gas-abrasive wear of the lining of a vortex-acoustic disperser made it possible to establish the conditions and patterns of their occurrence and also to develop proposals for its reduction.

1. Introduction

The prossesses and technology of grinding materials throughout development were and remain the object of close attention of many scientists and specialists. Their theoretical and applied work is directed towards the further development of grinders, which make it possible to produce a floured product of the necessary granulometric composition and dispersion. Choice of a grinding unit most often depends on technological and energy indicators that meet the requirements of the customer.

At present, the most promising method of ultrafine grinding is the method of high-speed grinding of materials in jet mills using steam or gas as an energy carrier. The use of high speeds, up to several hundred meters per second in so-called annular jet mills makes it possible to increase not only the dispersion of the product obtained, but also the specific productivity of the grind and its efficiency. In addition, it becomes possible to use the advantages of high-speed selective grinding of polycomponent mixtures to produce products with specified properties.

At the present stage of the development of high-tech technologies, the following has particular relevance: obtaining highly dispersed composite mixtures with controlled physicochemical properties; production of a wide range of dry mixes for various purposes; active development of modern technologies for deep enrichment of metal-bearing rocks, etc.

With all the advantages of vortex mills, which are widely used for fine grinding of materials, they also have a number of disadvantages: relatively high specific energy consumption, relatively low specific productivity and increased contamination by foreign inclusions with a decrease in a particle size (less than 10 μm)
[1-4].

2. Materials and methods

The investigations were carried out on an experimental setup [1]. As an energy carrier, compressed air was used with a pressure of up to 0.4-0.6 MPa at a temperature of 20 ° C. The source of the energy carrier was a compressor of the PKS type with a capacity of 5 m^3 / min.

IOP Conf. Series: Materials Science and Engineering **327** (2018) 042077 doi:10.1088/1757-899X/327/4/042077

3. The study of the structure of the modified lead-tin-base bronze

Let the last disadvantage be discribed. A theoretical solution of the problem of calculating the amount of gas-abrasive wear despite a large number of studies in this field has not yet been obtained since the process of gas-abrasive wear depends on a large number of factors. Determining the numerical values of reliability indicators of equipment in industrial conditions is associated with a long test duration.

The wear amount of the working surface is determined by the number and size of particles removed from this surface and is a random value. The amount of wear during the time interval (0, t) was defined as the integral function of the wear rate [5]:

$$\eta(t) = \int_0^t \xi(t)dt,$$

where ξ (t) is rate of wear, as a random process, such that ξ (t)> 0, i.e. the wear process is irreversible and monotonous.

The speed of particles which is one of the components of technological medium in jet mills has the greatest impact on the rate of gas-abrasive wear of aggregate elements. Therefore, the study of the effect of this factor on the value of reliability indicators of structural materials was the most interesting.

Let us assume that two solid bodies (the particle and the surface of the chamber) are in contact with each other along the line [6-10]. The area of contact in this case is a narrow strip of width 2α (Fig. 1).

The distribution of pressure between the compressed bodies at their points of contact will be calculated as:

$$P_z(x) = const \cdot \sqrt{1 - \frac{x^2}{\alpha^2}}, \tag{1}$$

where x is coordinate along the width of the contact line, α – the contact line. The constant is determined from the condition that the integral over the area of contact $\int P_z(x)dx$ is equal to force P with which the bodies are squeezed. Then:

$$P_z(x) = \frac{2P}{\pi\alpha}\sqrt{1 - \frac{x^2}{\alpha^2}}. \tag{2}$$

For touching the bodies which are surfaces of the second order, the area of contact and deformation of bodies is determined by the formulas:

$$A = \frac{P}{\pi K}\int_0^\infty \frac{d\xi}{(\alpha^2+\xi)\sqrt{(\alpha^2+\xi)(\beta^2+\xi)\xi}}, \tag{3}$$

$$h = \frac{P}{\pi K}\int_0^\infty \frac{d\xi}{\sqrt{(\alpha^2+\xi)(\beta^2+\xi)\xi}}, \tag{4}$$

where K – effective Young's modulus:

$$\frac{1}{K} = \frac{3}{4}\left(\frac{1-\sigma^2}{E} + \frac{1-\sigma'^2}{E'}\right), \tag{5}$$

E, E' – Young’s modulus, σ, σ' – Poisson's ratios.

Equation (3) determines the semiaxis of the contact area for a given force (the value known for these bodies). After this, using relation (4), the relationship between the force and the resulting body convergence is determined.

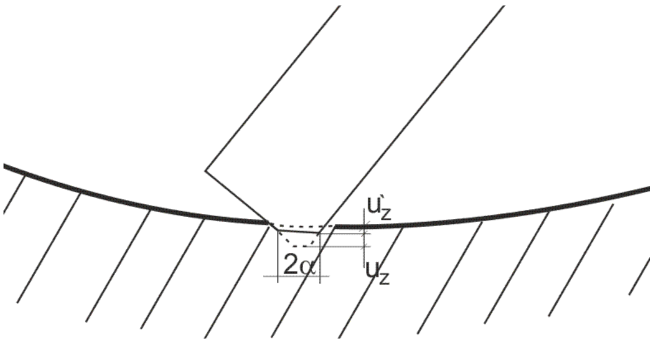


Figure 1. A scheme of interaction of a particle with a plane

Substituting (2) into (3) and performing the integration, one obtains:

$$A = \frac{8P}{3\pi\alpha^2 K}. \tag{6}$$

Since the radius of curvature of the chamber is equal to the radius of chamber R, and the radius of curvature of the line is equal to infinity, then:

$$A = \frac{1}{2R}. \tag{7}$$

Then the contact line is:

$$\alpha = \sqrt{\frac{16PR}{3\pi K}}. \tag{8}$$

Convergence h is expressed with force P by the relation:

$$h = P^{2/3}\left(\frac{1}{K^2 R}\right)^{1/3}. \tag{9}$$

Displacements u_z, u_z' under the influence of normal forces $P_z(x)$ are determined by expressions:

$$u_z = \frac{1-\sigma^2}{\pi E}\int \frac{P_z(x')}{r}dx', \tag{10}$$

$$u_z' = \frac{1-\sigma'^2}{\pi E'}\int \frac{P_z(x')}{r}dx', \tag{11}$$

where $r = \sqrt{x^2 + z^2}$.

In the case when force P is concentrated:

$$u_z = \frac{1-\sigma^2}{\pi E}\frac{P_z}{r}. \tag{12}$$

In expressions (10), (11), the integrals are elliptic. The analytic solution is represented as a sum of incomplete elliptic integrals of the first and second kind.

Stresses σ_{ik} arising in the material are determined by strain rate tensor u_{ik} :

$$\sigma_{ik} = K_1 u_{ll}\delta_{ll} + 2\mu\left(u_{ik} - \frac{1}{3}\delta_{ik}u_{ll}\right), \tag{13}$$

where K_1 – all-round compression module, μ – shear modulus. In this case, only normal stress σ_{33} is not zero.

$$u_{ik} = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & \dfrac{\partial u_z}{\partial z} \end{pmatrix}, \tag{14}$$

$$\sigma_{33} = \left(K_1 + \frac{4\mu}{3}\right)u_{33}. \tag{15}$$

Let us consider the plane problem of the collision of a rectangular particle with a surface. The velocity vector of the particle is directed at an angle to the surface. Let us suppose that the mutual displacements of the particle and the plane, as well as the forces at the contact, are connected by the static equations for the case of plastic contact.
The motion of a particle will be described by a system of equations:

$$m\ddot{x}_C = -Q, \tag{16}$$

$$m\ddot{y}_C = -P + G, \tag{17}$$

$$I_{Cz}\ddot{\varphi} = Q\frac{b}{2}\sin\alpha - P\frac{b}{2}\cos\alpha, \tag{18}$$

where Q is friction force, P is the force of normal pressure. Since the motion of a rigidly clamped body is considered, then x_C- the path traveled by the particle when sliding along the surface of the body - the depth of the indentation. Forces are determined according to:

$$P = ahp = ah3\sigma_T, \tag{19}$$

$$Q = fP = 3ahf\sigma_T. \tag{20}$$

where f coefficient of friction, h - penetration depth, σ_T - yield strength of the material.
Because of the transience of the impact, despite the large values of the acquired angular velocity, the angle of rotation of the particle will be small. Then the system of equations is written in the form:

$$\ddot{x}_C = -\frac{3ahf\sigma_T.}{m}, \tag{21}$$

$$\ddot{y}_C = -\frac{3ah\sigma_T}{m}. \tag{22}$$

$$\ddot{\varphi} = \frac{\frac{b}{2}(f\sin\alpha - \cos\alpha)3ah\sigma_T}{I_{Cz}}, \tag{23}$$

The problem is solved with the following boundary conditions:

$$x_C(0) = 0, \dot{x}_C(0) = V_0\cos\alpha, \tag{24}$$

$$y_C(0) = 0, \dot{y}_C(0) = V_0\sin\alpha, \tag{25}$$

$$\varphi(0) = 0, \dot{\varphi}(0) = 0.$$

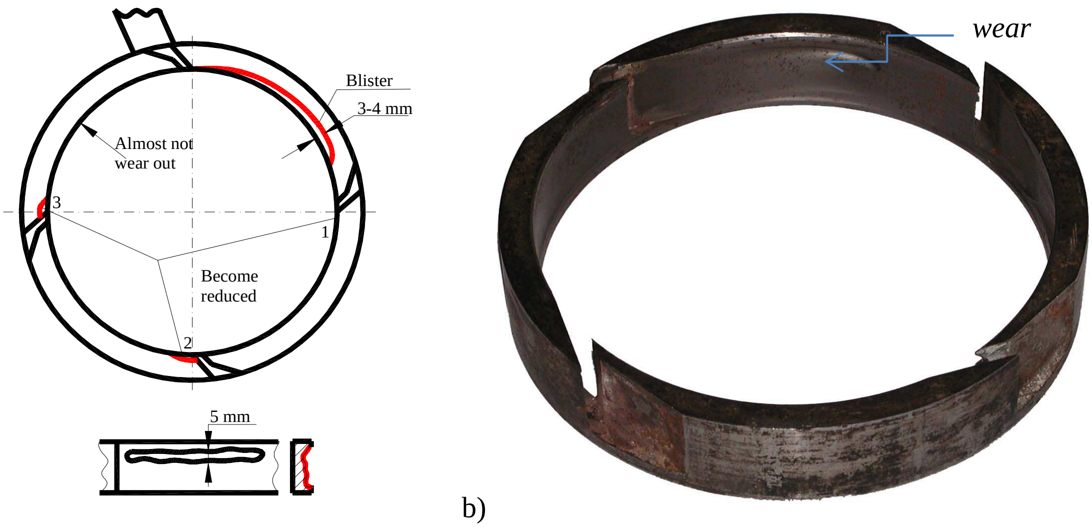
The solution of the problem was obtained numerically by the Runge-Kutta method of the 5th order.

Formulas (10), (11), (15) make it possible to calculate the deformation of the chamber and the normal contact stress arising on the surface of the lining of the vortex-acoustic dispersant. Numerical calculations have shown that for force $P = 3$ kN, $\alpha = 1{,}45\cdot10^{-4}$ m, $h = 3{,}19\cdot10^{-5}$, the deformation of the particle is 2.75 * 10-5 m, and the deformation of the chamber is 4.42 * 10-6 m.

During the experimental-industrial testing of the vortex-acoustic dispersant, investigations were carried out to identify the traces of abrasive wear of the lining of the vortex-acoustic disperser grinding chamber. Visual inspection for wear was carried out daily (after grinding 100 kg of material). The inner surface of the grinding chamber was ground, (shiny), there are no traces of the formation of gas-wear wear of the metal.

Fig. 2 shows the lining of the chamber for grinding a vortex-acoustic dispersant with traces of gas-abrasive wear.

After carrying out the whole series of experiments (about 800 kg), wear of lining elements was indicated. The inner surface of the ring underwent the greatest deterioration, which immediately follows the nozzle that feeds the energy carrier. On this site, along with the general wear along the width of the grinding chamber with a depth of about 0.5 mm, there is a narrow local wear in the upper part of the grinding chamber of a width and depth of about 3-4 mm in the form of a shell formed by abrasive wear with a two-component mixture directed from the supply nozzle . As the nozzle is removed from the feed nozzle, the wear on the width of the chamber decreases and the surface is almost not worn out before the outlet. There is also a pronounced wear on the surface of the resonators lying on the path of material and air passing (extreme exit surfaces) wear, which also decreases with distance from the supply hole.



a) b)

Figure 2. Lining of grinding chamber of vortex-acoustic dispersant: a - scheme of gas-abrasive wear lining; b - photo of lining

One of the criteria for the economic efficiency of using a vortex-acoustic disperser is the cost of repair and maintenance. The authors carried out studies to determine the specific wear of the grinding chamber.

The average specific wear of working elements can be represented by the following functional dependence:

$$I_{av} = f(v, Q, \sigma_{\mathrm{M}}, \sigma_{\mathrm{p}}, d_{av})$$

The working time of the working element before its replacement can be determined from the equation:

$$t = \frac{\eta_s * G_{gc}}{Q_{\sum R004} * I_{av}},$$

where η_s is a coefficient of stock for wear in the case of full production, η_s = 0.38; Ggc is the mass of the lining of the grinding chamber, kg.

4. Conclusion

Thus, based on the theoretical and experimental studies carried out, the authors established the process of gaseous wear of the vortex-acoustic disperser chopping chamber and proposed a dependence of the specific wear of the lining surface on the reduced dispersant productivity. The performed investigations make it possible to increase the efficiency of the process of grinding materials in vortex-acoustic dispersants and their operational reliability.

5. Acknowledgments

The article was prepared within the development program of the Flagship Regional University on the basis of Belgorod State Technological University named after V.G. Shoukhov, using equipment of High Technology Center at BSTU named after V.G. Shoukhov.

References

[1] Sevostyanov V S, Perelygin D N, Uralsky V I, Gorlov A S, Glagolev E S, Babaevsky A N 2014 Development and research of energy-saving grinding equipment for high-dispersion grinding of

materials. *Bulletin of BSTU. V.G. Shukhov* ***3*** 76-80
[2] Sevostyanov V S, Lesovik V S, Perelygin D N, Gorlov A S, Nechaev S P 2004 *RF patent No. 2226432. Vikhreakustic dispersant.*
[3] Gridchin A M, Sevostyanov V S, Lesovik V S, Gorlov A S, Fedorenko B Z 2005 *RF patent No. 2250138. Vortex-acoustic dispersant*
[4] Sevostyanov V S, Gridchin A M, Nechaev S P, Lesovik V S, Gorlov A S 2008 *RF patent No. 2317147 Vortex-acoustic dispersant-mixer (variants).*
[5] Mannapov R G 1977 *Research of aggregates of chemical industries working in the conditions of gas-abrasive wear, and development of measures to increase their reliability. Abstract diss. on Ph.D.* (MIHM)
[6] Kleis I R, Uumyhs H G 1986 *Wear resistance of elements of impact shredders.* (M.: Mechanical Engineering)
[7] Abramov Yu I 1987 Collision of solid dust particles with a barrier from an elastically plastic material. *Friction and Wear* **8(1)** 83-94
[8] Vinogradov V N, Sorokin G M, Albagachiev A L 1982 *Wearing a shock*. (Moscow: Mashinostroenie)
[9] Johnson K 1989 *Mechanics of Contact Interaction* (Trans. with English. Moscow: Mir)
[10] Mikhin I M 1974 *External friction of solids*. (M.: Nauka)