TIGHTING THE PIECES OF MATERIAL IN CENTRIFUGAL ROLLER MILLS

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ABSTRACT. The grinding bodies in the centrifugal roller mills are cylindrical rollers that roll on the inner cylindrical surface of the mill drum. Trapped between the roll and the drum, the ore particles are crushed by the large centrifugal forces. In this work, a mathematical relation is obtained between the dimensions of the drum, the rollers and the particles entering for grinding, so that the angle of capture is optimal. This allows maximum reduction factor (ratio) and high productivity to be achieved. A numerical example is also provided.

Keywords: centrifugal roller mill, angle of capture

ЗАХВАЩАНЕ НА МАТЕРИАЛА ПРИ ЦЕНТРОБЕЖНИТЕ РОЛКОВИ МЕЛНИЦИ

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РЕЗЮМЕ. Мелещите тела в центробежните ролкови мелници са цилиндрични ролки, които обтъркалват вътрешната цилиндрична повърхнина на барабана. Попаднали между ролката и барабана, частиците руда се натрошават благодарение на големите центробежни сили. В този труд е получена зависимост между размерите на барабана, ролките и постъпващите за смилане частици, така че ъгълът на захващане да е опимален. Така може да се постигне максимална степен на смилане и висока производителност. Приложен е и числен пример.

Ключови думи: не центробежна ролкова мелница, ъгъл на захващане

Introduction

The working bodies of the considered machines are the cylindrical steel rollers, which rotate at a high angular speed, press the ore pieces to the cylindrical drum and break them (Pulev 2013, Sezonov 2011, Chalashkanov 1978, Cvetkov 1988). Grinding is due to the large centrifugal forces. The main technological parameter is the gripping angle α, which directly affects the grinding intensity. When the angle is too small, the grinding rate is very low. At a large angle, the grinding rate increases, but the productivity decreases. The aim of this work is to determine the optimal gripping angle taking into account the dimensions of the drum, the rollers and the particles entering for grinding.

Analysis

The determination scheme is shown in Figure 1. The mill drum is represented by a circle of diameter D and center O. The roller with diameter d and center O_1 rolls without sliding on the inner cylindrical surface of the drum. The centrifugal force presses the roller tightly against the housing and eliminates the possibility of detachment or slipping. The ore piece has a regular shape with a diameter x and center O_2. The gripping angle is formed between the tangents to the ore piece at the points of contact with the drum and the roller. These tangents are perpendicular to the lines OO_2 and O_1O_2.

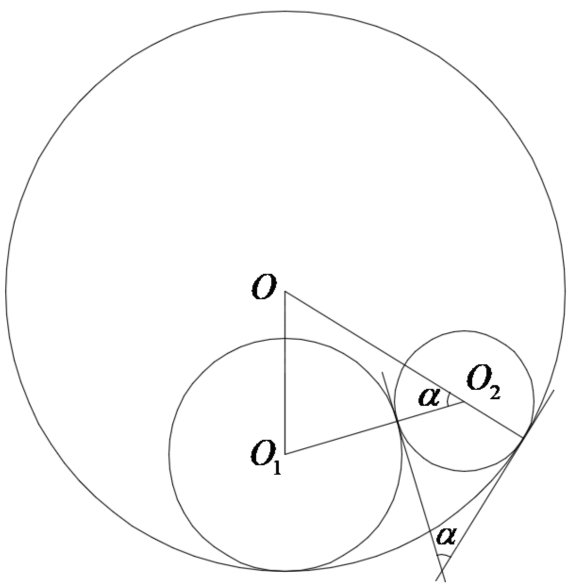

Fig. 1. The determination scheme

Therefore, the angle $\angle O_1O_2O = \alpha$ can be determined by a triangle with sides

$$OO_1 = \frac{D-d}{2}$$
$$OO_2 = \frac{D-x}{2}$$
$$O_1O_2 = \frac{d+x}{2}$$

By the law of cosines in triangle O_1O_2O

$$\cos\alpha = \frac{(D-x)^2 + (d+x)^2 - (D-d)^2}{2(D-x)(d+x)}. \quad (1)$$

With using trigonometric identity

$$tg\frac{\alpha}{2} = \sqrt{\frac{1-\cos\alpha}{1+\cos\alpha}} \quad (2)$$

after transformation from (1) and (2) is obtained

$$tg\frac{\alpha}{2} = \sqrt{\frac{-x^2+(D-d)x}{Dd}}. \quad (3)$$

The condition for tighting the ore particle is

$$\alpha \le 2\rho, \quad (4)$$

where ρ is the angle of friction, and $\mu = tg\rho$ is the coefficient of friction between the ore particle and the steel drum and roller. Condition (4) is equivalent to

$$tg\frac{\alpha}{2} \le tg\rho = \mu \ (5).$$

From (3) and (5) the inequality is obtained

$$\frac{-x^2+(D-d)x}{Dd} \le \mu^2$$

or

$$x^2-(D-d)x+\mu^2Dd \ge 0. \quad (6)$$

The roots of the quadratic equation corresponding to inequality (6) are

$$x_{1,2} = \frac{D-d \pm \sqrt{(D-d)^2-4\mu^2Dd}}{2},$$

which after transformation acquire the species

$$x_{1,2} = \frac{(D-d)\left(1 \pm \sqrt{1-\frac{4\mu^2Dd}{(D-d)^2}}\right)}{2}. \quad (7)$$

It is known that a function $f(t) = \sqrt{1-t}$ can be described by a Taylor series and at small values of the argument $|t| < 0{,}089$ can be represented as

$$\sqrt{1-t} \approx 1-\frac{1}{2}t. \quad (8)$$

Taking into account (8), formula (7) is transformed into

$$x_{1,2} = \frac{(D-d)\left(1 \pm \left(1-\frac{2\mu^2Dd}{(D-d)^2}\right)\right)}{2}.$$

Thus for the roots of the quadratic equation is obtained

$$x_1 = \frac{\mu^2Dd}{D-d},$$
$$x_2 = \frac{(D-d)^2-\mu^2Dd}{D-d}. \quad (9)$$

The solution of inequality (6) is

$$x \in (-\infty, x_1] \cup [x_2, +\infty) \quad (10)$$

The condition that the ore particle is smaller than the roll, ie.

$$x \in (0, d). \quad (11)$$

From (10) and (11) the final solution of inequality (6) is obtained

$$x \in (0, x_1]. \quad (12)$$

Therefore, optimal grip is obtained when the maximum size of the particles entering the grinding is determined by the formula

$$x_{max} = \frac{\mu^2Dd}{D-d}. \quad (13)$$

Therefore, the size of the ore particles depends on three circumstances

- the diameter of the drum, which cannot be substantially changed with a centrifugal roller mill operating;
- the coefficient of sliding friction, which depends on the material of the drum, rollers and ore particles;
- the diameter of the rollers.

The only way to ensure an optimal angle of capture is to select the dimensions of the rollers depending on the size of the ore particles. The diameter of the rollers can be determined by the formula

$$d = \frac{x_{max}D}{x_{max}+\mu^2D},$$

obtained after transformation of (13).

Numerical experiment and discussion

An example is a centrifugal roller mill with diameters of drum $D = 1{,}2\ m$ and roller $d = 0{,}2\ m$. The coefficient of friction between the pieces of ore and steel is $\mu = 0{,}3$. For the discriminant of (6) is obtained $(D-d)^2 - 4\mu^2 Dd = 0{,}9136 > 0$. The roots of (6) have the following values: $x_1 = 0{,}022$, $x_2 = 0{,}978$. The inequality $x_1 < d < x_2$ is satisfied, which proves that the interval (12) is defined correctly. Applying the derived formula (13) to the diameter of the particles fed for grinding is obtained $x_{\max} = 0{,}022\ m = 22\ mm$.

Figure 2 shows the dependence of x on d with a drum diameter $D = 1{,}2\ m$. It is obtained according to (13) and can be used by technologists in the operation of centrifugal roller mills. With the aid of Fig. 2, the diameter of the rollers can be selected according to the size of the ground particles so that the gripping angle is optimal.

The productivity of centrifugal roller mills and the degree of grinding directly depends on the correct determination of the diameter of the rollers according to the size of the ore particles. Therefore, the dependence obtained in this study (13) may be useful in mineral processing.

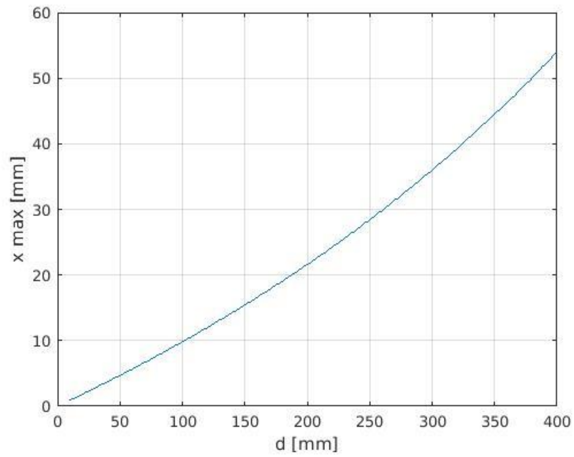

Fig. 2. Influence of the size of the ore particles on rollers diameter

References

Pulev, S., S. Sezonov. 2013. Opredelyane na centrobejnite sili pri edin extremen rejim na rabota na centrobejno rolkovite melnici. - Annual of the University of Mining and Geology “St. Ivan Rilski”, 56, Part 2, 151−154 (in Bulgarian with English abstract).

Sezonov S., M. Vulkov. 2011. Vuzmojnosti za usuvurshenstvane na centrobejno rolkovi melnici. Mashinostroene i mashinoznanie, 15, 25-28 (in Bulgarian)

Chalashkanov, M. 1978. Izsledvane na funkcionalnata vruzka mejdu osnovnite konstruktivno-tehnologichni parametric na centrobejno rolkova melnica pri smilane na polezni izkopaemi. Disertacia (in Bulgarian)

Cvetkov, H., 1988. Obogatitelni mashini. Tehnika, Sofia, 413 p. (in Bulgarian)