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Research Article

THE METHOD OF COMPUTING THE EFFORTS OF PRECONSOLIDATION OF MATERIALS IN A ROLL DEVICE

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Abstract.

The article deals with topical issues improving the reliability and durability in the roller press mill at the expense of uniform supply of crushed materials across the width of the rolls. A mathematical model of the motion of an anisotropic body in a roller device is developed. Analytically investigated the mechanism of distribution and preconsolidation of materials derived an equation for calculating the forces in the roller device. It is proved that the proposed device is designed to distribute and compact the material in width roll press roller grinder, creating a more equal deterioration of their working surfaces. An equation is derived for calculating the effort invested in the creation of the material layer preconsolidation. The analysis of the equation established that efforts preconsolidation materials depend, both on the geometric parameters of the rollers, their location in the bunker and the properties of the material being compacted. With increasing angle of inclination of the hopper walls α , and thus the thickness of the layer of material being compacted force decrease, and increase the radius of the sealing roller increases the sealing force. Materials article are devoted to increase of reliability in the roller press mill, at the expense uniform supply crushed materials on the width of the roll may be of interest to Russian and foreign organizations operating in the field of operation, design and manufacture of milling equipment.

Keywords: Reliability, roller press mill, roller unit preconsolidation stress.

Introduction: Today, the processes of grinding and fine grinding materials in the world are among the major operations carried out in different production technologies, spent about 10% of all the energy produced [1-2].

Therefore, the reduction of energy consumption for grinding of materials is very important. It is known [3-4] that the implementation of the milling process using a roller press mill (RPM) reduces specific energy consumption by 25-40% and increase productivity ball mill (BM) by 30-40%. This is achieved through a more efficient way of destruction of materials (crushing shift) implemented in RPM than shock in the first stage in the BM. For example: the specific energy consumption spent on pre-grinding materials in the RPM is 3-4 kWh / t, which corresponds to a cost equal to BM 7-10 kWh / t. These machines are widely used in mineral processing plants mining and cement industries. However, in recent decades due to the uneven wear of the working surfaces of the rolls on the pace of implementation of their width press roller assemblies decreased. One reason for this is to cause unequal distribution of feed material and the width of the roll, which leads to a more intense wear of the working surface in the center of the rolls. Therefore, throughout the period of operation of roller press mill attempts to develop technical solutions to improve the durability of the rolls [5-6].

The Main part. According to [7-10], increasing durability of working bodies roller press mill developed by scientists Belgorod State Technological University named after VG Shukhov design roller press mill with a roller device (Figure 1), which consists of two rollers, mounted on a frame, one of it is movable. Rotating rolls with capable of adjusting their peripheral speed is provided by individual drive. Above the rollers are located roller unit consisting of a bunker including inside the rollers are set in motion by an individual drive. Above the rollers is arranged mounted plate to guide the material into the area of their capture.Application of the device before feeding roller material to the rolls allows to preconsolidation PVI and evenly across the width of the charge rollers, causing equal deterioration their working surface. However, the amount of force preconsolidation has a significant impact not only on the energy performance of the grinding process, but also in the design of the unit and is largely determined by the position of the roller in the hopper. Therefore, in order to determine rational force required to create equal distribution across the width of the sealing material and a roller device, consider the calculation scheme shown in Figure. 2. The position of platen roller 1 unit radius with respect to the hopper 2 defines an offset of its center horizontally - and vertically -. The angle of inclination of the silo wall is denoted by the angle at which to begin sealing ma terial - by β .

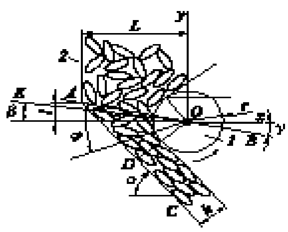

Figure 1: RPM with a roller device: roller unit 1, 2 – RPM. Figure 2: Sealing mechanism design scheme.

The thickness of the material layer h at the and (along the beam) can be calculated by the formula:

$$h = \sqrt{L^2 + l^2}\sin(\alpha - \gamma) - r, \quad (1)$$

Where the angle γ [gamma] (the angle of the line to the horizontal AOB) is the relation of $\operatorname{tg}\gamma = \frac{l}{L}$.

Compaction process begins with the ingress of particulate material to the line OE. Assuming that the force exerted by a roller directly proportional to the sealing material, determine the amount of compaction as you move the material. Equation of a line OE in polar coordinates ρ, φ [phi] (angle φ is measured from the line OA), has the form:

$$\rho\cos(\varphi - \theta) = p, \quad (2)$$

Where the parameters θ, p defined by the formulas,

$$\theta = \frac{\pi}{2} - \alpha + \gamma, \; p = h + r. \quad (3)$$

Changing the radial component according to the angle φ determined by the equation:

$$\Delta\rho(\varphi) = \rho(\beta) - \rho(\varphi), \quad (4)$$

где $\varphi \geq \beta$.

After a series of transformations, we obtain:

$$\Delta\rho(\varphi) = \frac{4(h+r)\cos\left(\alpha - \gamma + \frac{\varphi+\beta}{2}\right)\sin\left(\frac{\varphi-\beta}{2}\right)}{\left(\cos(\varphi-\beta) - \cos\left(2(\alpha-\gamma)+\varphi+\beta\right)\right)}. \quad (5)$$

In order to research the effect of value of the angle φ, at various offset center roller at vertically relative to the point of beginning of the slope of the hopper walls, on the magnitude of the compression of the layer of material construct the graphical dependence $\Delta\rho(\varphi)$ of the height l (exceeding height of angular point A above the center of the roll) if $\alpha = 50°$, $\beta = 17°$, L =55 cm, r =20 cm, taking calculated compaction ratio is equal to, respectively, 1,19; 1,24; 1,29 and 1,35 (figure 3).

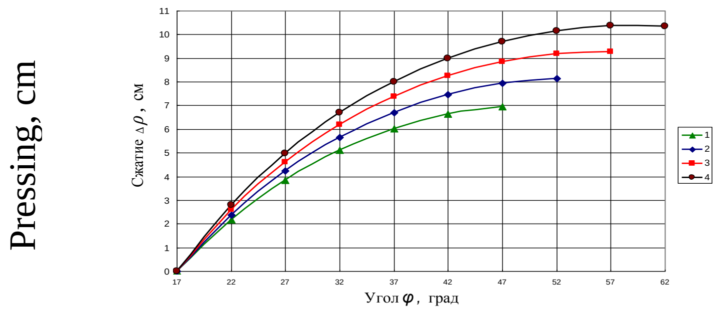

Figure 3: The magnitude of the compression of the material depending on the angle φ:

1 – l = 10 cm; 2 – l = 13 cm; 3 – l = 16 cm; 4 – l = 19 cm

As can be seen from the graphical dependence with increase of the angle of displacement of the roller center relative to the point of beginning of the slope of the hopper wall, amount of compression of the layer of material increases. However, in excess of this angle is more than 42-47^0 compression values slowly increase. It demonstrates beginning intensive slippage compacted material relative to the working surface of the rollers. Reduced central at vertical rollers leads to a slight increase in the compression of the material, the compression value increases with decreasing.

On the surface of the roller in the seal area distributed load acting on the part of compacted material q (q - is the force per unit area, has dimension N / m^2).

Then the total force which acts on the roll material is determined by the formula:

$$F = \iint_{(S)} q\,ds, \qquad (6)$$

Where S – area, to which is applied distributed load.

In step seal when no destruction of the material particles, the intensity of the distributed force directly proportional to reduce the radial component of $\Delta\rho$, in accordance with the scheme shown in (figure 4).

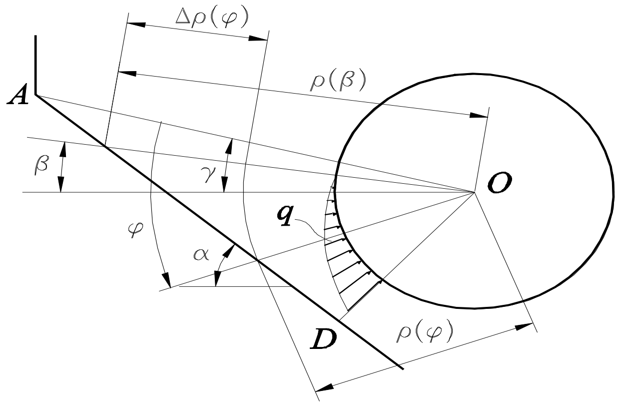

Figure 4: To the calculation of the intensity of a distributed load q

Thus, for calculating the value of the distributed load q can be written by the following formula:

$$q = \mu \Delta \rho\,, \tag{7}$$

Where μ [mu] – the proportionality coefficient depending on the characteristics of compacted material (particle size distribution, particle shape and deformability et al.), the dimension of this factor - N / m^3. The physical interpretation of the coefficient μ is as follows: it is the amount of force which must be applied to reduce the per unit volume of material.

Thus, assuming uniformly distributed load distribution along the roll axis, we obtain:

$$dF = \mu \Delta \rho \, ds\,, \tag{8}$$

Where ds – element of the roll surface, defined by the formula $ds = r\,d\varphi\; db$, db - the line element of length along the surface of the forming roll.

Thus, the formula to calculate the force of impact on the roll material is defined by the formula

$$F = \iint_{(S)} \mu \Delta \rho\, r\, d\varphi\, db == \mu r b (h+r) \int_{\beta}^{\varphi_{\max}} \left(\frac{h+r}{\sin(\alpha - \gamma + \beta)} - \frac{h+r}{\sin(\alpha - \gamma + \varphi)} \right) d\varphi, \tag{9}$$

Where b – roller width, $\varphi_{\max}$ – the maximum value of the angle φ.

As can be seen from the figure 2, $\varphi_{\max} = \angle AOD = \dfrac{\pi}{2} - \alpha + \gamma$.

To calculate the integral (9) we make the change $\xi = \alpha - \gamma + \varphi$, then

$$F = \mu r b (h+r) \left(\frac{\pi/2 - \psi}{\sin(\psi)} + \ln \operatorname{tg} \frac{\psi}{2} \right), \tag{10}$$

where $\psi = \alpha - \gamma + \beta$.

Since, as mentioned above, the parameter μ dependent on the properties of the material being compacted, its value is determined experimentally.

Figure 5 shows the experimentally obtained dependence of the seals k on the specific load q for the two materials - limestone and clinker. Analysis of the resulting graphic dependence revealed that with an increase in the specific sealing pressure increases the compression ratio of the material. Clinker with higher strength of the particles relative to the limestone, the seal is less intensive than for limestone. This suggests that for materials with high strength and coefficient of internal friction requires greater compaction effort.

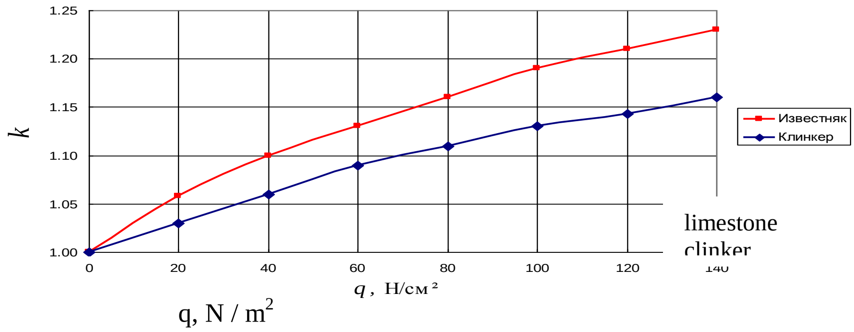

Figure 5: Dependence of the seals k on the specific load q

To use the results of experimental studies to determine the parameter μ formula for k be written as:

$$k = \frac{\rho(\beta) - r}{\rho(\varphi) - r}, \qquad (11)$$

or

$$k - 1 = \frac{\Delta \rho}{\rho(\varphi) - r}, \qquad (12)$$

The results of the experimental data presented in figure 5, into the form when the parameter k is an argument, and the specific load q - function (figure 6).

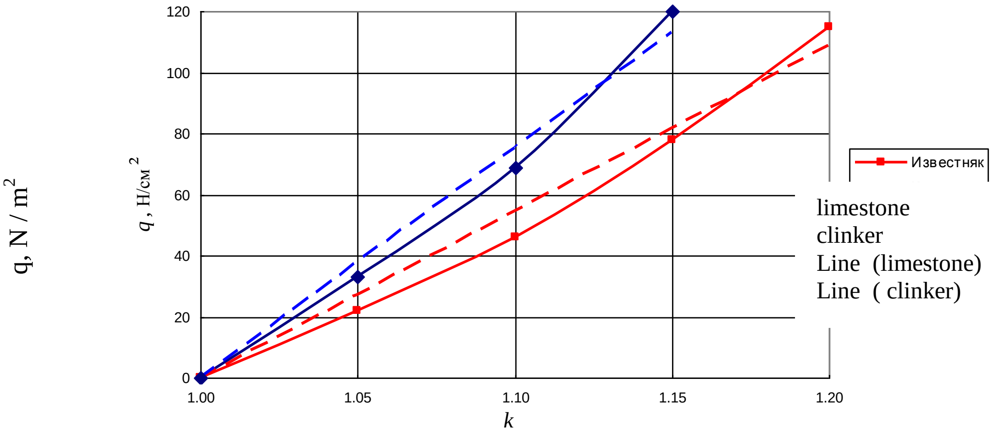

Figure 6: Dependence of the specific load q of compaction factor k

Approximated curves obtained q from k the linear dependency (Figure 6 shows a dotted line), we obtain the dependence of the form:

$$q = a(k - 1), \qquad (13)$$

where $a_{\lim} = 545$ N/cm², $a_{clin} = 754$ N/cm².

Finally, for q and μ find:

$$q = \frac{a}{\rho(\varphi) - r} \Delta \rho, \tag{14}$$

$$\mu = \frac{a}{\rho(\varphi) - r}, \tag{15}$$

In deriving (10) parameter μ is considered constant. Given that the change ρ while changing angle φ in the range of $\varphi = \beta$ up to $\varphi = \varphi_{\text{Max}}$ not long, μ can be calculated by the formula:

$$\mu = \frac{a}{\rho_{\text{av}} - r}, \tag{16}$$

where $$\rho_{\text{av}} = \frac{\rho(\beta) - (h + r)}{2}, \tag{17}$$

In Figure 7-8, by way of illustration shows the results of calculations according to the equation (10) to impact forces roller compacted material when the angle of inclination of the hopper walls α, radius of the roll r and shifting the center of roller vertically l for β=17°, l=5 cm, L=50 cm, r=20 cm, b=50 cm, a=545 N/cm^2 (limestone).

Analysis of the graphic dependences (Figure 7-8) revealed that with increasing inclination angle of the hopper walls, and therefore decrease the thickness of the layer of material being compacted, compacting force decrease, but increase the radius of the rollers results in an increase of these efforts. It demonstrates that increasing radius of the roller increase effective value of the capture and layer seal material.

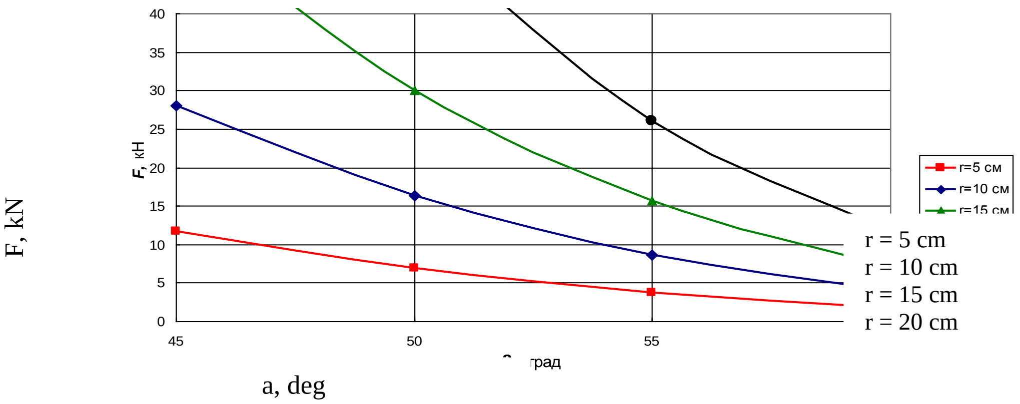

Figure 7: Dependence of force F on angle α for various values of r

Increasing the amount of the center axis of the platen vertically relative to the point of beginning of the slope of the hopper wall (Figure 2), leads to a decrease in the thickness of the layer of the sealing material, and, consequently, to the decrease in compaction effort.

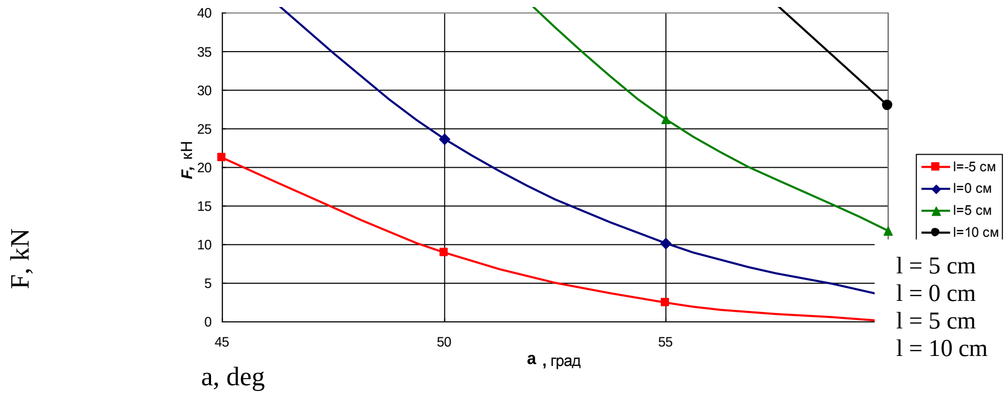

Figure 8: Dependence of force F on angle α for various values of l

Conclusion. Carried out theoretical researches have allowed to establish expression for calculating the maximum efforts of charge preconsolidation from the compaction rollers, depending on the construction of the bunker, the radius of rollers and their arrangement in the hopper.

Summary. Thus, our theoretical studies have established an analytical expression for the calculation of the maximum force preconsolidation charge by sealing rollers. According to equation (10) determines the maximum preconsolidation stress, which is calculated according to the power required for the implementation and design of preconsolidation roll device. An analysis of this equation and research constructed graphic dependences Figure 3-8 established that:

- the resulting equation allows to determine the maximum preconsolidation force F, which is calculated by the power needed for the implementation of the seal according to the properties of materials and design roller device.

- Material compaction force depends both on the geometric parameters of the rollers, their arrangement in the hopper and compacted material properties;

- With an increase in the specific sealing pressure the compression rate of the material is increased. Growth strength grinding material particles and its internal friction coefficient increases the sealing effort. This demonstrates that materials with a high internal friction coefficient and high strength are required compaction efforts.

- With increasing inclination angle of the hopper walls α, and therefore the layer thickness of the compacted material reduced sealing force, and increase the radius of the rollers, causes it to increase.

- Increasing the amount of the center roller at vertically relative to the beginning of the slope of the hopper walls, leads to the increasing value of the compression layer material. However, in excess of this angle is more than 42-47 compression values slowly increase. It demonstrates beginning intensive slippage compacted material relative to the working surface of the rollers.

- application roller device before applying the material to the rolls PVI allows to compact and distribute it equally across the width, which results in more uniform deterioration of their working surfaces and therefore the durability of the unit.

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