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Study of device for precompaction and uniform supply of materials to working bodies of aggregate

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Study of device for precompaction and uniform supply of materials to working bodies of aggregate

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Abstract. The article considers perspective ways of increase of reliability and durability of the press roller grinder due to the uniform supply of crushed materials across the width of the rolls. The mechanism of distribution and pre- compaction of materials in a roller arrangement has been analytically studied, an equation has been derived for calculating the effort expended. The materials of the article are devoted to increasing the reliability of the press roller grinder due to the uniform supply of grindable materials along the width of the rolls and may be of interest to Russian and foreign organizations that carry out their activities in the field of exploitation, designing and manufacturing of crushing and grinding equipment.

1. Introduction

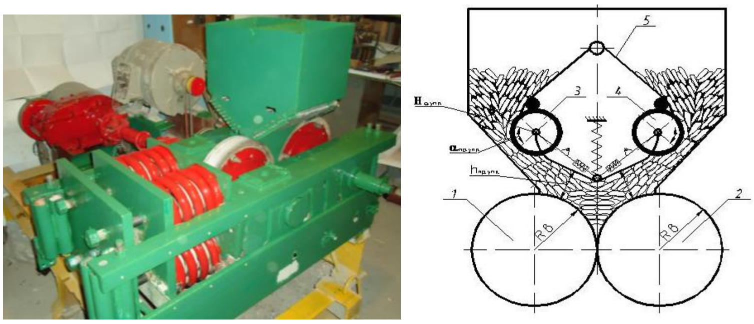
At present, such German companies as KRUPP Polysius AG, KHD Humboldt Wedag AG and Koppern are most fruitfully working on the creation of reliable high-pressure PRG designs. When creating their models of a press roller grinder, specialists of these firms pay the greatest attention to the development of the design of the working surfaces of rolls and the technology of their manufacture. They proposed various design versions of rolls, which make it possible to increase their service life. However, the use of the proposed solutions did not give a tangible result since the presence of a "wall effect" on the expiration of the material from the bunker device does not allow one to distribute the material evenly across the width.

2. The main part

The design of the PVI with a roller device (Figure 1), developed by scientists of BSTU named after V. G. Shukhov, allows one to obtain improving the durability of the working bodies according to [1-3] and consists of eccentrically mounted rollers 1, 2 on top of which there is a roller arrangement inside the hopper, consisting of two movable cheeks 5, in contact with rolls 3,4, connected by guides movable rods.

The use of the roller device before supplying the material to the rolls of the PRG allows it to be evenly distributed over the width of the rolls and pre-compacted, which makes it possible to achieve a more uniform wear on their working surface and thereby improve the durability of the rolls.

However, the magnitude of the material pre-compacted force, which depends in many respects on the properties of the material and the overall dimensions of the roller, and on its position in the bunker, has a significant influence not only on the energy parameters of the grinding process, but also on the design of the unit as a whole. Therefore, in order to determine the rational force of the rollers, required for uniform distribution over the width and compaction of the material in the roller arrangement, let us consider the design scheme shown in Figure 2.



a *b*

Figure 1. Press roller grinder with a roller device: a-photo of the unit, b - structural diagram

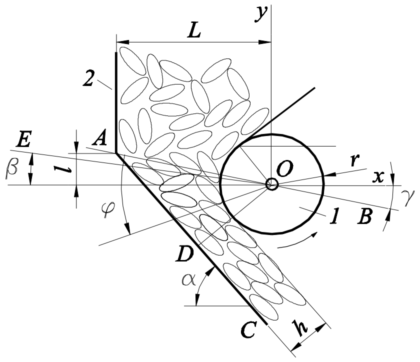


Figure 2. A calculation scheme of the compaction mechanism

The position of the roll in roller device *1* of radius r relative to bunker 2 will be set through the displacement of its center horizontally – *L*, and vertically – *l*. The angle of inclination of the bunker walls will be denoted by angle α at which compacting the material through β occurs.

The thickness of material layer *h* at the exit from the roller device (along the *OD* line) can be calculated from the formula:

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

where angle γ (angle of inclination of straight line *AO* to horizontal), let us find out from $\mathrm{tg}\,\gamma=\frac{l}{L}$.

The process of compaction of the material starts from the moment when its particles are captured by the roller (along the line *OE*), while the force of the roller action is directly proportional to the value of the compacting of the burden layer. The change in the compaction value as a function of angle φ is determined by equation:

$$\Delta\rho(\varphi)=\rho(\beta)-\rho(\varphi), \tag{2}$$

where $\varphi\geq\beta$.

Let us determine the amount of compaction of the material as it moves.

The equation of the straight line *OE* in polar coordinates ρ,φ (angle φ is measured from straight line *OA*) has the form:

$$\rho\cos(\varphi-\theta)=p, \tag{3}$$

where parameters θ, p are, relatively, equal to:

$$\theta=\frac{\pi}{2}-\alpha+\gamma\ ,\ p=h+r \tag{4}$$

After a number of transformations, let us obtain the equation for calculating the value of the material compaction, depending on its radius and location in the bunker:

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

Let us construct function $\Delta\rho(\varphi)$ dependences of height *l* at $\alpha=50°$, $\beta=17°$, *L* = 55 cm, *r* =200 mm, taking the estimated compaction ratio equal to 1.19; 1.24; 1.29 and 1.35 (Figure 3)

There is a specific load on the part of the compacted material influences on the surface of the roller in the zone of compacting q, N/m^2

Then the total force with which the roll affects the material is determined by the formula:

$$F = \iint\limits_{(S)} q\,ds\,, \tag{6}$$

where S is the area to which the distributed load is applied.

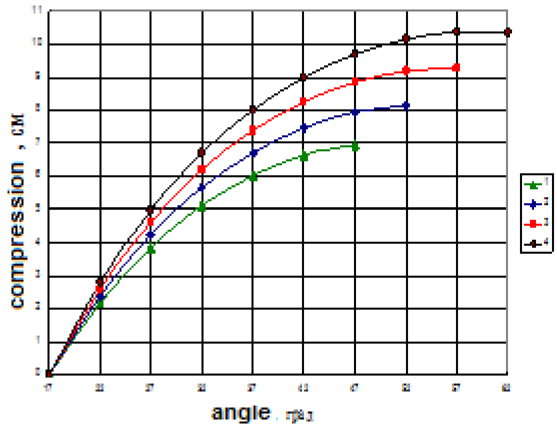


Figure 3. The amount of compression of the material depending on the angle φ:
1 – *l*=10 cm; *2* – *l*=13 cm; *3* – *l*=16 cm; *4* – *l*=19 cm

At the compaction stage, when there is no destruction of the material particles, the intensity of the distributed force is directly proportional to the reduction in radial component $\Delta\rho$ (Figure 4).

Thus, intensity q can be written in the form of:

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

where μ – coefficient of proportionality, depending on the characteristics of the compacted material (mesh-size distribution, shape, etc.). The physical interpretation of the coefficient μ is as follows: the magnitude of the force that should be applied for compaction per unit volume of material.

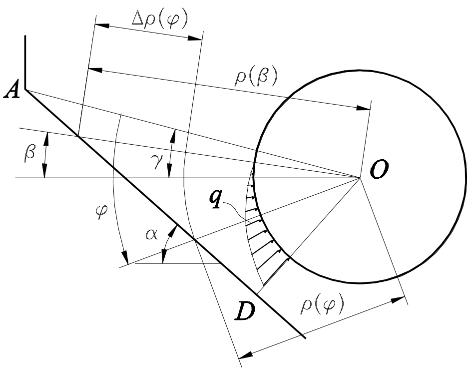


Figure 4. Calculation of the intensity of distributed load q

Considering that the distributed load is uniform along the roll axis, one obtains:

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

where *ds* – element of the roll surface is determined by formula $ds = r\,d\varphi\,db$, *db* – linear element of length along the generatrix of the roll surface.

Thus, the force of the action of the roller on the material can be determined from 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* – roll width, φ_{max} – maximum value of angle φ.

As follows from Figure 2, $\varphi_{max} = \angle AOD = \frac{\pi}{2} - \alpha + \gamma$. To calculate integral (9), let us make the substitution $\xi = \alpha - \gamma + \varphi$, then one obtains:

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

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

Since, as it was already noted above, the value of parameter μ depends on the properties of the material to be compacted, its value was determined experimentally

Figure 5 shows the experimentally obtained dependence of specific load *q* on compaction factor *k*, for two materials - limestone and clinker.

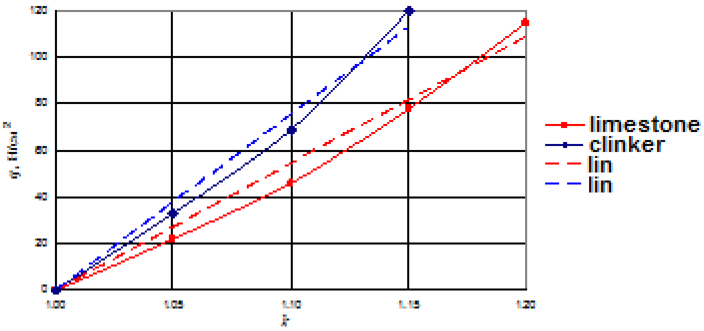


Figure 5. Dependence of compaction factor *k* on specific load *q*

To use the results of experimental studies for the purpose of determining parameter μ, the formula for determining the coefficient of compaction is written in the form:

$$k = \frac{\rho(\beta) - r}{\rho(\varphi) - r}. \tag{11}$$

or

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

Having approximated the obtained dependency graphs *q* against *k* by linear curves (are shown in Figure 5 by dashed lines), we obtain the dependences of the form

$$q = a(k-1), \tag{13}$$

where $a_{lim} = 545$ N/cm^2, $a_{clin} = 754$ N/cm^2.

Finally, to determine q and μ, let us find out:

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

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

In the derivation of formula (10), parameter μ was considered as constant. Considering that compaction ρ, for brittle materials without their destruction, with a change in angle φ from $\varphi = \beta$ to $\varphi = \varphi_{ìàõ}$ is not large, then μ can be calculated according to the formula:

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

where

$$\rho_{ñð} = \frac{\rho(\beta) - (h + r)}{2}. \tag{17}$$

The analysis of the graphic dependences in Figures 6 and 7 constructed according to equation (10), the influence of the impact roller to the compacted material with a change in the angle of inclination of the bunker wall, the radius of the roll and the displacement of the center of the roll along vertical l at $\beta = 17^o$, $l = 5$ cm, $L = 50$ cm, $r = 20$ cm, $b = 50$ cm, $a = 545$ N/cm^2 (material - limestone) allowed us to find out that the magnitude of the material's pre-compacting force depends both on its properties and overall dimensions of the roller, and on its position in the bunker.

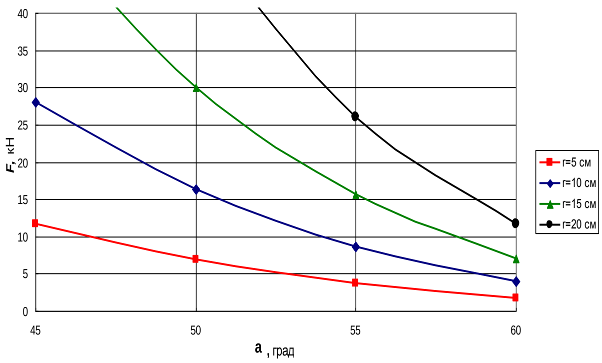


Figure 6. The dependence of force F on corner α for different values of r

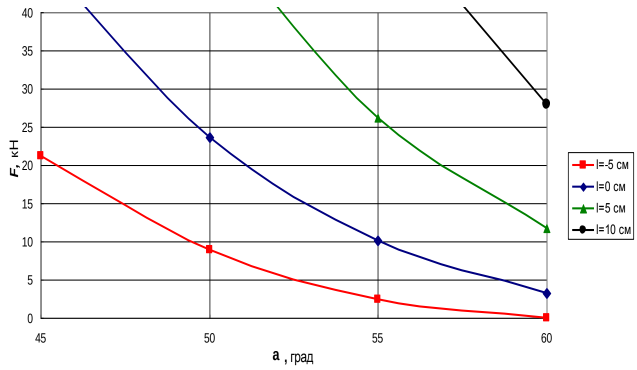


Figure 7. The dependence of force F on corner α for different values of l

It is established that an increase in the angle of inclination of the bunker wall and the radius of roller r entails an increase in the values of the compaction force of the material. By changing the position of the roller in the hopper along the vertical, it is possible to change the pre-compacting forces of the material supplied to the rolls of the PRG.

3. Conclusion

Thus, the conducted theoretical studies made it possible to establish that the magnitude of the pre-compacting force depends on the material properties, the overall dimensions of the roller and its position in the bunker has a significant influence not only on the energy parameters of the grinding process, but also on the structural design of the aggregate as a whole. An expression is derived for calculating the maximum pre-compacting force of the charge from the side of the compacting rollers, depending on the design of the bunker, the radius of the rollers and their location in the receiving bunker. According to equation (10), depending on the required compaction factor of materials, it is possible to determine the value of the pre-compacting force, which calculates the power required to perform pre-compacting.

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