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# Enhancing wear resistance of working bodies of grinder through lining crushed material

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**Abstract.** The article presents the analysis of directions of increasing wear resistance of working surfaces of rolls. A technical solution developed at the level of the invention is proposed, which is simple to implement in production conditions and which makes it possible to protect the roll surface from heavy wear due to surfacing of wear-resistant mesh material, cells of which are filling with grinding material in the process of work. Retaining them enables one to protect the roll surface from wear. The paper dwells on conditions of pressing materials in cells of eccentric rolls on the working surface with a grid of rectangular shape. The paper presents an equation for calculation of the cell dimension that provides the lining of the working surface by a mill material with respect to its properties. The article presents results of comparative studies on the grinding process of a press roller grinder (PRG) between rolls with and without a fusion-bonded mesh. It is clarified that the lining of rolls working surface slightly reduces the quality of the grinding, since the material thickness in the cell is small and has a finely divided and compacted structure with high strength.

## 1. Introduction

Materials used in the cement production have an abrasive structure, and its grinding between rolls of the press roller grinder (PRG) leads to intensive wear of working parts that reduces the efficiency of their using.

At present such German companies as KRUPP Polysius AG, KHD Humboldt Wedag AG and Koppern [1-6] are most fruitfully working on the creation of reliable high-pressure PRG designs. In the process of creating the PRG model, the greatest attention of these organizations is paid to reduction of operating costs and improvement of the reliability of units. In this case, main directions are development of the design of roll working surfaces and the technology of their manufacture. They propose the following structural rolls design to increase service life:

- rolls with cast tires made of wear-resistant metal, which are used at not high working pressures of grinding and temperatures. Their service life, depending on the abrasive material, ranges from 1500 to 15 thousand hours [7,8];
- steel rolls with welded or melted layers of wear-resistant metal. The layer thickness reaches up to 10-12 mm. Re-welding can be performed on the roll without dismantling it from the unit. The service life of such rolls is up to 17 thousand hours;
- solid rollers are used in high pressure grinding; the thickness of the metal wear layer reaches up to 160 mm, and the service life is up to 40 thousand hours.

For small working pressures, segmented roller designs have been developed. The reliability of the operation of such roll depends on specific pressures in the working zone and temperature of the raw material, the service life of segment rolls reaches 9,000 hours.

The roller, consisting of a shaft with a bandage attached to it, is characterized by low capital costs, easy mounting of the bandage and optimal selection of materials, since requirements for the shaft and band materials are different.

Produced by the company Seibel brothers [9,10], PRG has changeable roll bandages made of wear-resistant material (Nihard) to increase the unit service life.

## 2. The main part

The practice of applying PVI shows that the roll working conditions have a significant influence on the roll working capacity. For example, the high temperature of the starting material may pose a significant danger to rollers with bandages. Therefore, in addition to the widely accepted design of the roll with a bandage, the technology of obtaining a solid casting roll is developed. Such technology for making rolls provides for the protection of the base material with a wear layer or use of heat treatment. Depending on the specific requirements, the roll surface can be profiled to improve the ability to grasp the material in the work area. The average hardness of the roll surface is from 57 to 60 HRC with a high content of carbides. The technology of overlaying the surface layer improves the wear resistance of rolls. Such rollers are preferably used in the case of variations of starting material temperature.

Alternative solid surfacing of the surface layer is the solution on the surface of rolls according to a scheme protrusions or profiling of its surface. In this case, the means to combat rolls wear are not a corresponding increase in the thickness of the protective layer.

Using press roll grinder with eccentric or conical rolls makes it possible to create intensive shearing deformation of the grindable batch between the rollers. This leads to reduce the specific power consumption, but this entails to an increased wear on their working surfaces. Therefore, there is a need to develop technical solutions for protecting roll surface from intense wear to increase their service life.

One of the most simply technical solutions is protecting rolls surface from heavy wear using a carrier made of wear-resistant mesh material, which elements are filled with a grinding material to protect rolls surface from wear.

To ensure the lining of the roll surface, the mesh surfacing must be done so that the crushed material is pressed into the cells at the moment of grinding and, after the stress is removed, does not leave them and thereby forms a layer of material (pressed in cells) that protects the rolls working surface from intense wear.

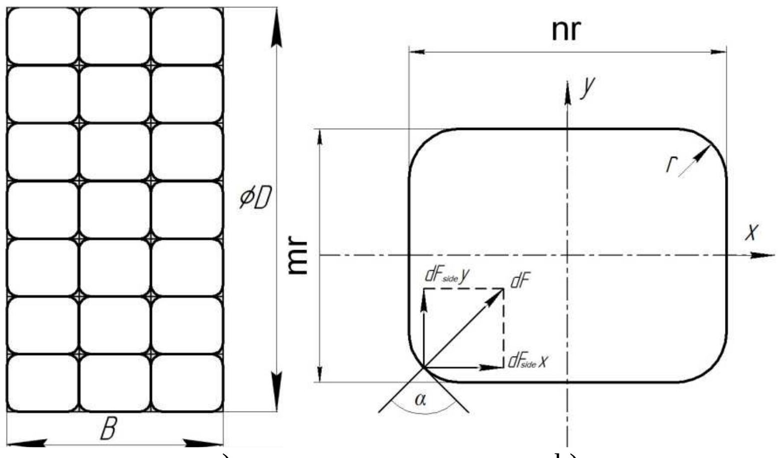
From the foregoing, it follows that the conditions for working surface of lining rolls depend to a large extent on the geometric profile and dimensions of the cells, as well as on the properties of materials, in particular, the friction coefficient.

Conditions for material pressing in cells of eccentric rolls on the working surface with a rectangular grid are reported in Figure 1.

The compressed material after passing the zone of maximum pressure is subjected to sudden removal of grinding forces that causes its elastic expansion. Depending on the cell shape and magnitude of material elastic expansion forces, it can exit or jam in a cell on roll working surfaces.

Cells with rounded corners are formed along radius r (Figure 1b, 2) by padding grid surfaces of the rolls due to the wall effect in the cell corners. Let us suppose that force F, arising from the forces of elastic expansion, is in the cell equal to the whole of its side surface $S_{side}$. Then the force acting on an infinitesimally small area of the cell side surface with perimeter length $l_b$ and height $r$ is equal to:

$$dF = F\ dS_{side} = F\ r \cdot d\alpha \cdot l_b\ . \qquad (1)$$




*a*) b)

**Figure 1.** The working surface of the bandage roll with weld mesh: a – general view, b – view from cells.

The magnitude of the force acting on the entire lateral surface of the cell is:

$$dF_{side} = cr \cdot d\alpha(2nr + 2mr) \times F\, d\alpha \;. \tag{2}$$

where *n* and *m* - the numbers of a multiple of fillet radius *r*, accordingly, the height, width and length of the cell.

Force $dF_{side}$ is decomposed into vertical $dF_{side}(z)$ and horizontal $dF_{side}(x)$ and $dF_{side}(y)$ components. Horizontal forces $dF_{side}(x)$ and $dF_{side}(y)$ are mutually compensated, as oppositely directed in the cell.

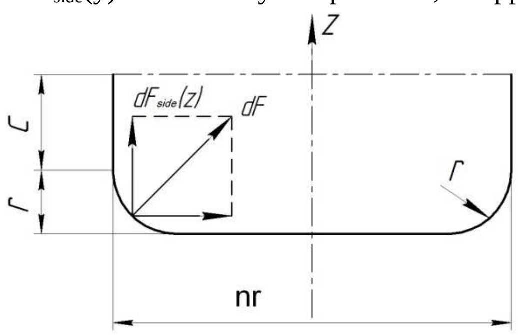



**Figure 2.** The scheme for determining the shape and size of the cell.

Vertical components give total force $\Sigma F_{side.z}$ equal to:

$$\Sigma F_{side.z} = \int dF_{side}(z) \cdot \cos\alpha = 2r^2 d\alpha(n+m)F \times \int \cos\alpha d\alpha \;. \tag{3}$$

Integrating expression (3), the following expression is obtained:

$$\Sigma F_{side.z} = 2r^2(n+m)F_z \cdot \sin\alpha \;. \tag{4}$$

The force acting on an infinitesimally small area of the spherical surface at the cell corners is:

$$\Sigma F_{sf} = rd\alpha \cdot r\cos\alpha \cdot dF \tag{5}$$

Projections of forces on the “x" and "y" axes are mutually compensated, and the projection on the "z" axis is equal to:

$$\Sigma F_{sfz} = dF_{sf} \cos \alpha \quad (6)$$

The total force per axis "z", which comes to the entire spherical surface, consisting of angled hemispheres of radius r, is determined by expression:

$$\Sigma F_{sfz} = r^2 F \int_0^{2\pi} d\xi \int_0^{\frac{\pi}{2}} \sin\alpha \cos\alpha d\alpha \quad (7)$$

Integrating the expression in these limits, one obtains:

$$\Sigma F_{sfz} = \pi r^2 F \quad (8)$$

The force acting according to norms of the cell surface area, $S_s$, is equal to:

$$F_n = S_s F \quad \text{or} \quad \mathrm{F_n = (nr \cdot mr) \cdot F = F \cdot mn \ \ r^2} \quad (9)$$

Then the total force, which provides the output from the pressed charge from the cell, is:

$$\sum \overline{F} = \sum F_{side} + \sum F_{sfz} + P_n \quad (10)$$

or

$$\sum \overline{F} = 2r^2(n+m)F \cdot \sin\alpha + \pi r^2 F + F \cdot mn \ r^2 . \quad (11)$$

The exit of the pressed charge from the cell is prevented by the frictional force of the material on its side surface. The lateral surface consists of a spherical part in corners of the cell, a rounded surface between them and a parallel surface along the perimeter of height "c".

The total projection of forces acting on infinitely small portions of the lateral surface along the radius of the cell rounding on the *z* axis is:

$$F_{tr.b} = \int fdF_{side} \sin\alpha = -f\, 2r^2(n+m) \cdot F \cdot \cos\alpha \ . \quad (12)$$

The total projection of forces acting on infinitely small parallel sections of the lateral surface of the cell with a height "c" on the z axis is:

$$F_{tr.b} = \int fdF_{side} = -frc(n+m) \cdot F \ . \quad (13)$$

The total projection of the frictional forces acting on infinitely small parts of the spherical surface in the cell corners on the "z" axis is equal to:

$$F_{tr.sf} = fdF_{sf.z} \sin\alpha = f\pi r^2 F \ . \quad (14)$$

The total force that holds the pressed batch in the cells is:

$$\sum F_{tr} = \sum F_{tr.b} + \sum F_{tr.sor} \quad (15)$$

or

$$\sum F_{tr} = f(2r^2(n+m)F \cdot \cos\alpha + frc(n+m) \cdot F + f\pi r^2 F \ . \quad (16)$$

Conditions for crimping the crushed material into cells on the working surface of rolls will be ensured in case $\sum F_{tr} \geq \sum F$ , then:

$$2r^2(n+m)F \cdot \sin\alpha + F \cdot mn \ r^2 + \pi r^2 F \leq f(2r^2(n+m)F \cdot \cos\alpha + \ldots$$

$$+ f\pi r^2 F + frc(n+m)F \quad . \tag{17}$$

After carrying out transformations, one obtains:

$$f \geq \frac{2r^2(n+m)F\cdot\sin\alpha + F\cdot nmr^2 + \pi r^2 F}{2r^2(n+m)F\cdot\cos\alpha + \pi r^2 F + rc\cdot(n+m)\cdot F} \quad . \tag{18}$$

After making abbreviations, one obtains:

$$f \geq \frac{2r((n+m)\cdot\sin\alpha + nm/2 + \pi/2)}{2r(n+m)\cdot\cos\alpha + \pi r + c(n+m)} \quad . \tag{19}$$

Proceeding from the above-mentioned conditions, which ensure the "lining" of the working surface of eccentric rolls, let us further consider the square cell variant, for n = 1, m = 1, c = 3 mm, r = 1, a = $45^0$;

$$f \geq \frac{2r((n+m)\cdot\sin\alpha + nm/2 + \pi/2)}{2r(n+m)\cdot\cos\alpha + \pi r + c(n+m)} = \frac{4\cdot\sin\alpha + 4.14}{4\cdot\cos\alpha + 13.14} = 0.4 \; . \tag{20}$$

From obtained equation (19), it follows that at a value of angle *a* less than $45^0$, the lining of the working surface by the material to be crushed can be performed, while the height of the side surface "C" must be at least 3 mm. Pressing in the cell will be carried out by materials under investigation with a calculated coefficient of external friction less than 0.37.

The practical application of a reticulated surface with cell sizes satisfying above-mentioned conditions will make it possible to reduce the working surface wear of rolls and thereby increase the roll service life.

Experimental studies, carried out in the grinding of cement production materials (clinker, limestone, marl and others), have confirmed theoretical assumptions that roll application to the cell surface provides not only the best conditions for grinding materials, their delivery to the force zone with less slippage, but also pressing in them small particles of the material to be crushed (Figure 3).

*a*) *b*)

**Figure 3.** Rolls PRG with welded mesh on their working surface: a - before the grinding process; b - after grinding

The roll surface with cells filled with small particles of the material has a hardness that is lower than original metal. This leads to the appearance of elastoplastic deformations in the processing of pressure materials.

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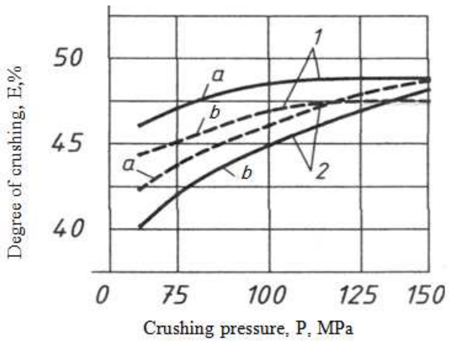


**Figure 4.** A graph of the dependence of the crushing degree on the crushing pressure:
a – not lined rolls; b-lined; 1-limestone organogenic; 2- clinker

This phenomenon has little effect on the grinding process, since the material thickness in the cell is small and has a finely divided compacted structure with high strength. In addition, during processing materials with pressure in the PRG, the material is ground in its layer under the action of forces and various strengths of its grains.

Comparative studies carried out on the grinding process in PRG with weld lining mesh and without it have confirmed the assumptions that using a lining mesh makes it possible to protect the roll surface from intensive wear, while negatively affecting the quality of the grinding of materials (Figure 4).

As can be seen from the graph, differences between obtained values are small, while the roll service life, as shown by industrial tests carried out with the grinding of abrasive materials, will increase almost 1.5 times.

## 3. Conclusion

Thus, the technical solution developed at the level of the invention makes it possible to protect the roll surface from heavy wear due to surfacing from the wear-resistant mesh material, whose cells are filled with grinding material during work and, while retaining them, and to protect the roll surface from wear. As a result of consideration of material pressing conditions in the roll cells on the working surface, which are applied to a rectangular grid, an equation is obtained that makes it possible to calculate dimensions of its cell providing the lining of the working surface with a material to be grinded, taking into account its properties.

Comparative studies on the grinding process in the PRG with the weld lining grid and without it identify the slight reduction of the grinding quality by the fettle of roll working surface, because the material thickness in the cell is small and has a finely divided compacted structure with high strength.

## 4. Acknowledgement

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