Simulation of the stress-strain state of the combined rolls plates in the form of a Reuleaux Triangle Profile roller grinder

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Abstract. This paper aims to provide specialists with the main principles of work and stress-strain state of the combined rolls plates in the form of Reuleaux Triangle Profile (RT-profile). The paper is devoted to the problem of the flow pattern of force in the material cutting zone, the kinematic-geometric characteristics, the working principles of the combined rolls and the stress-strain state of the rolls while material grinding. The additional effect of rolling is implemented in the grinder with combined rolls in a form of Reuleaux Triangle Profile while moving crushed material in at least two coordinates of the gap, also the effect of crushing and cutting is realized in the field of a cross gap between combined rolls plates, due to crushing efficiency increases (will increase). Reuleaux Triangle profile of combined rolls plates provides even load distribution.

1. Introduction
The materials grinding is an important stage in the technological processes of materials recycling in different fields such as agriculture, metallurgy, heat power, coal and mining industry [1-3]. The development of new grinding methods and material destruction equipment can improve the quality and physico-mechanical properties of the crushed material such as powders, granules preforms for composite manufacturing. Due to the rolls design it is possible to achieve various methods of material destruction: compression, stretching and abrasion [4-6]. Using rolls in the form of Reuleaux Triangle profile allows achieving a combination of different grinding mechanisms [7]. This article describes the analysis of the material destruction in built-up construction of roll grinder. The paper is given a research of plates stress-strain state of combined rolls under load.

2. Analysis of the forces in the grinding area
Completely reversing load is realized in the grinding area between the rollers in the form of RT-profile. Figure 1 shows vectors and directions of forces. The grinding area is shifted about spin axis of rolls; when RT-profile rotates. Owing to this effect, crushed material is mixed, and forces act on this material from different points and directions and with different intensity. In this way various methods of material destruction work together: compression, stretching, abrasion, impingement attack, constantly changing the forces directions operating on the material, change of numerical values and force vectors [8, 9].
Figure 1. System of forces implemented in grinding area between rollers

The grinder design with combine rollers is implemented as follows: plates in a form of Reuleaux Triangle Profile are located on the shaft with an 120° offset relative to each other. Figure 2 shows the material cutting areas.
During cutting, the guillotine working principle is realized (with knives rotation) with non-linear distribution load [10]. Figure 3 shows directions of effort in the cutting zone along the radius of roll Reuleaux Triangle Profile.

During roll rotation, the point of forces application shifts tangentially to the curve formed by the opposite edges of Reuleaux Triangle Profile. Furthermore, due to this design of the rolls, additional destructive forces arise in the transverse gap between the plates, such as crushing and cutting. Moreover, this rolls design allows grinding not only fragile materials, but also plastic, such as machining swarf of non-ferrous metals and alloys. The main forces during cutting are concentrated on the side faces of the plates closer to the larger radius of the Reuleaux Triangle Profile. The concentration of such forces can provoke increased tenseness and deformations in these areas.

3. Analysis of the stress-strain state of the plate
The analysis of the plate stress-strain state is modeled in SolidWorks Simulation. During the simulation, the Finite Element Method was used and diagrams were obtained for the loads distribution and the stress-strain state of the plate. To study the stress-strain state, one of the working surfaces of the disk was divided into three segments, which describe three main areas of forces distribution. As it is seen from Figure 4 there are the stress diagrams in rolls for the material grinding. As a result of Reuleaux Triangle Profile rotation the working pressure area relative to the axis of roll rotation is shifted. Therefore, the forces operate on the roll surface nonuniformly.
4. **Conclusion**

After conducted studies of roll work, it is possible to conclude that using plates in the form of Reuleaux Triangle Profile increases the technical and economic performance of the crushing process.

The analysis of the forces, operating in the grinding area, showed an effective combination of various material destruction methods such as abrasion, crushing and cutting, reversing loads. In conclusion, analysis of the stress-strain state of the plates showed low rates and operating characteristics of impact forces on the working bodies of the grinder.

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