Destruction mechanisms of materials grinding in a crusher with plates in a form of Reuleaux Triangle profile

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Abstract. The article presents studies of the materials destruction mechanisms according to a new kinematic crushing scheme, which is implemented in a roll crusher with stacked plates in the form of Reuleaux Triangle Profile. The paper is devoted to give the substantiation of the kinematic and force factors acting on the material in the crushing zone. It is considered a combination of various destruction mechanisms with a new grinding scheme and an increase in the intensity and efficiency of the grinding process. It is substantiated the necessity of implementing a new crushing scheme in the form of a crusher with stacked plates in the form of Reuleaux Triangle Profile.

1. Introduction
The materials grinding is an important stage in the technological processes of materials converting in the different fields such as agriculture, metallurgy, heat power, coal and mining industry. The quality and physical and mechanical properties of crushed material determine the final technical and economic product’s indicators. A variety of grinding schemes have been developed to implement the material’s destruction mechanisms. Equipment manufactured according to such schemes has a great number of characteristics: type of destructive effect, intensity of grinding, reliability, manufacturability and others. However, while the equipment has high performance characteristics of one, other parameters remain at a sufficiently low level [1-5].

As a result of the analysis of the known structures, it is proposed a new kinematic diagram of the crushing process, which is based on the usage of rolls in a form of Reuleaux Triangle Profile, and also the geometric and power characteristics of a new design of the roll crusher are investigated [6-7].

2. Kinematic crushing scheme
In a crusher with rolls in the form of Reuleaux Triangle Profile, the material is moved horizontally and vertically. Thus, the effect of material rolling in the crushing zone is realized (figure 1).
Such displacements occur due to a change in the radius of the curved surface of Reuleaux Triangle Profile from the minimum \( r \) to the maximum \( R \). Because of this effect, the probability of jamming large pieces of material in the slotted gap is reduced, due to the pieces rejection from the contact area by multidirectional forces. As the rollers rotate, the size of the slotted gap changes.

At the moment of increasing the gap, the material is captured and further abraded and crushed (figure 2).

With the minimum slotted gap formed by the minimum radius \( r \) of one roll and the maximum \( R \) of the other roll, the maximum capture angle \( \alpha \) acts in the crushing zone (figure 2a). When the rolls rotate, the slotted gap gradually increases, the abrasion (due to the different peripheral speed of the rolls) and compression forces act on the material (figure 2b).

The capture angle in this position allows the pieces of material to be pulled into the slotted gap, while too large pieces rise to the surface of the volume of crushed material.

With further rotation and the increase in the slotted gap, the material is crushed and abraded, while large pieces are also crushed (figure 2c). Crushed material falls freely under the influence of gravity through the unloaded slotted gap. In this position, the crushing mechanism is similar to a jaw crusher.
In the position of the rolls shown in figure 2d, the slotted gap reaches a minimum, a large radius R crushes large pieces of material and cuts off its parts.

The described scheme of influence on the material significantly increases the possibility of crushing the material in comparison with classical roller crushers, where the size of the pieces of crushed material is limited by the diameter of the rolls.

The implementation of the crushing scheme with constant slotted gap allows to crush small pieces of material. Such gap contributes to a finer crushing of the material and an increase in the uniformity of the particle size distribution of the crushed raw materials. To maintain the constant slotted gap during the rotation of the rolls, a special profile is provided in the crusher design. This solution allows the spring-loaded shaft to be displaced, while the operability of the spring-loaded mechanism remains.

It was created an animation model for visual confirmation of the nature of the change in the slotted gap and the dynamics of the work of a pair of rolls (figure 3).

![Figure 3. Change of the slotted gap on the animation model.](image)

On separate animation frames, it can be seen the change in size (from the minimum $a_{\text{min}}$ value to the maximum $a_{\text{max}}$) and the position of the slotted gap at different positions of the rolls (figure 4).

![Figure 4. Changing the position of the slotted gap on the animation model.](image)

Due to the change in the position of the slotted gap and different angular velocities, the material rolling mechanism is implemented, and in the case of large pieces of material hit with an insufficient capture angle, the pieces are thrown out of the crushing zone.
3. **Diagram of forces in the crushing zone**
In the grinding zone between the rolls in the form of Reuleaux Triangle Profile, a cyclic alternating load is realized. When the rolls in the form of Reuleaux Triangle Profile rotate, the vectors and numerical values of the forces change relative to the axis of rolls rotation (figure 5).

![Diagram of forces in the crushing zone](image)

**Figure 5.** Scheme of forces in the crushing zone at different positions of the plates.

The load application points on the material are changed at different positions of the crusher plates. The combination of the described kinematic and force effects gives additional mixing of crushed material and various mechanisms of material destruction act jointly: compression, tension, abrasion, impact and constant change in the direction of forces acting on the material, change in numerical values, force vectors.
4. Cutting forces between plates
The design of the rolls, made in the form of inlaid plates in the form of the Reuleaux Triangle Profile, makes it possible to implement a guillotine mechanism (with rotation of the knives) with a nonlinear load distribution (figure 6).

![Figure 6. Material cutting zones.](image)

When the rolls rotate, the edges of the adjacent plates are intersected. The force application point is displaced tangentially to the curve formed by the opposite faces of the Reuleaux Triangle Profile (figure 7).

![Figure 7. System of forces when cutting materials.](image)

Such mechanism allows to destroy fragile materials by splitting. The most important cutting effect is for grinding ductile materials, the processing of which presents certain difficulties [10-11].

5. Conclusion
The proposed scheme of material grinding combines various mechanisms of destruction: compression, abrasion, crushing, cutting under alternating loads. The possibility of crushing large pieces of material is realized by changing the size and position of the slotted gap and the capture angle. For fine grinding and grinding of ductile materials, it is possible to maintain the size of the slotted gap by cyclic displacement of the spring-loaded shaft. Due to the guillotine effect, shredding of ductile materials is possible.

All the aggregate characteristics of the grinding scheme, implemented by type-setting plates in the form of the Reuleaux Triangle Profile, make it possible to increase the grinding intensity. The proposed
prefabricated structure, built according to this scheme, is more efficient in terms of manufacturability, maintainability and grinding efficiency.

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