INNOVATION IN METALLURGICAL INDUSTRIAL AND LABORATORY EQUIPMENT, TECHNOLOGIES AND MATERIALS
ИННОВАЦИИ В МЕТАЛЛУРГИЧЕСКОМ ПРОМЫШЛЕННОМ И ЛАБОРАТОРНОМ ОБОРУДОВАНИИ, ТЕХНОЛОГИЯХ И МАТЕРИАЛАХ

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Short Report
Краткое сообщение

IMPROVING THE EFFICIENCY OF RAW MATERIAL PREPARATION FOR METALLURGICAL PROCESSING

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Abstract. In the metallurgical industry, approximately 40 % of the energy spent on raw material preparation for further processing accounts for the processes of brittle materials destruction in crushing machines. From the analysis of operation of crushing machines, differing in the method of creating stresses in a destructible piece of brittle material, it follows that the best, from the point of view of energy efficiency, is the one in which tangential stresses (shear deformation) are generated in the processed material. The authors describe the design of a crushing machine which ensures that during the crushing process only tangential stresses arise in the piece, causing shear deformations.

Keywords: metallurgical processes, raw material preparation, crusher, energy efficiency, brittle material, shear

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ПОВЫШЕНИЕ ЭФФЕКТИВНОСТИ ПОДГОТОВКИ СЫРЬЯ ДЛЯ МЕТАЛЛУРГИЧЕСКИХ ПЕРЕДЕЛОВ

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Аннотация. В металлургической промышленности примерно 40 % энергии, затрачиваемой на подготовку сырья для дальнейшего передела, приходится на процессы разрушения хрупких материалов. Измельчение осуществляется на дробильных машинах. Из проведенного анализа работы дробильных машин, отличающихся по способу создания в разрушаемом куске хрупкого материала напряжений, следует, что оптимальным, с точки зрения энергоэффективности, является способ дробления, при котором в перерабатываемом материале путем генерации возникают касательные напряжения (деформация сдвига). Авторы приводят описание конструкции дробильной машины, обеспечивающей в процессе дробления в куске возникновение только касательных напряжений, вызывающих сдвиговые деформации.

Ключевые слова: металлургические процессы, подготовка сырья, дробилка, энергоэффективность, хрупкий материал, сдвиг

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The rapid growth in the production of metallurgical products necessitates an increase in the volume of mineral raw materials prepared for metallurgical processes. Typically, the primary reserve for improving the performance of metallurgical units is enhancing the quality of raw material preparation. Therefore, mineral processing is one of the key stages in preparing mineral resources for further use.

The productivity of metallurgical units depends on the quality of charge materials, including their particle size distribution. Therefore, charge preparation is a priority for boosting productivity and improving the quality of finished products in the metallurgical industry at its current stage of development. For example, to produce high-quality coke, coal undergoes preliminary preparation, while iron ores are processed into pellets used in blast furnace iron smelting. Loose fluxes containing limestone are essential in the preparation of sinter and in the smelting process in steelmaking furnaces (converters, electric arc furnaces). The initial stages of mineral raw material preparation for smelting include crushing to achieve the required particle size for further processing [1].

In the metallurgical industry, approximately 40 % of the energy spent on raw material preparation for further processing is dedicated to the destruction of brittle materials in crushing machines. This makes energy conservation a pressing concern. Additionally, the demand for processed (size-reduced) raw materials is increasing by about 7 % annually [2; 3], as metallurgical processes require lump materials of specific sizes, which are achieved through the use of crushing equipment. One of the key indicators of the crushing process is its energy efficiency. Crushers that operate based on compression, such as roll crushers [4], cone crushers [5], and high-performance jaw crushers [6], are commonly used for brittle materials. However, it is well known that compression-based crushing is the most energy-intensive method [7].

To reduce energy consumption in the crushing of brittle materials, it is essential to create conditions in which only tangential stresses act within the material, leading to shear deformations. In this case, the strength of the processed material is minimized, reaching a value that is half of what it would be under normal stresses that occur during compression.

In this study, a design of a jaw crusher (see Figure) is proposed, which ensures that the forces acting on the crushed piece are distributed in such a way that only tangential stresses are generated, causing shear deformations [8]. The developed crusher design consists of the crusher's bed (*1*), to which a support hinge (*2*) is attached on the lower plate, and a movable jaw (*3*) is installed. The jaw is driven by a crank-connecting rod mechanism, allowing it to perform a swinging motion around the vertical axis. In the upper crossbar of the crusher's bed (*1*), there is a loading spout (*6*) for feeding lump material into the crushing zone. The size of the discharge opening of the spout corresponds to the size of the crushed piece (*7*), and the spout's axis aligns with the vertical axis of the support hinge (*2*). To ensure the crusher remains operational during use, it is necessary to meet the condition that the upper edge of the movable jaw does not touch the lower edge of the discharge opening of the loading spout during the swinging motion.

The operation proceeds as follows: pieces of material to be crushed are fed one by one into the crushing zone through the loading spout under the influence of gravity. The crushing zone is formed by the surface of the movable jaw and the lower edge of the spout's opening. When a piece enters the crushing zone, it contacts one side along line *B* with the edge of the loading spout and the other side along line *A* with the movable jaw.

As the movable jaw moves, it presses the crushed piece against the lower edge of the spout's discharge opening, causing forces to act upon it. One of these forces, com-

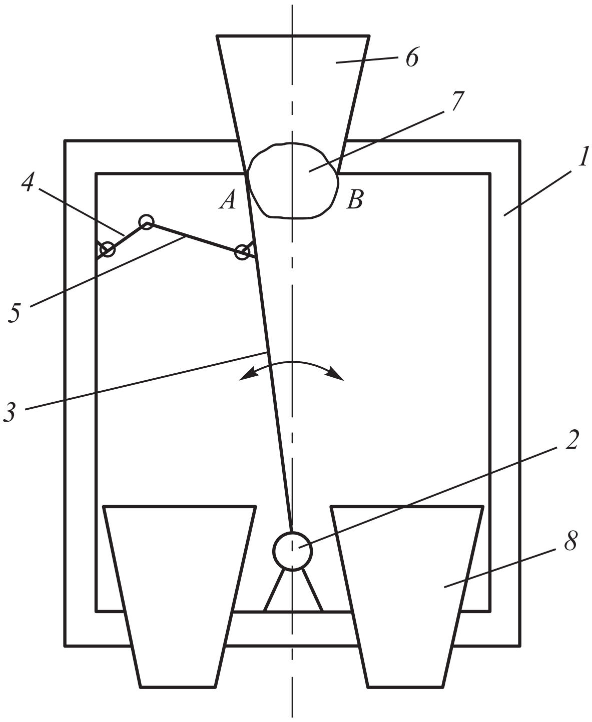

Diagram of a jaw crushing machine operating in shear:
1 – crusher's bed; *2* – support hinge; *3* – movable jaw;
4 – crank; *5* –connecting rod; *6* – loading spout; *7* – crushed piece;
8 – unloading spout

Схема щековой дробильной машины, работающей на сдвиг:
1 – станина дробилки; *2* – опорный шарнир; *3* – подвижная щека;
4 – кривошип; *5* – шатун; *6* – загрузочная течка;
7 – дробимый кусок; *8* – разгрузочная течка

ing from the upper edge of the movable jaw, is directed tangentially to the trajectory of point *A*'s movement. The other force, from the lower edge of the spout, is directed horizontally away from point *B*, passing through the lower edge of the spout. With this force distribution acting on the crushed piece, only tangential stresses arise due to the opposing directions of the force vectors in the same plane. In this case, the fracture of the brittle material occurs as a result of shear deformation generated in the piece.

After the initial fracture, the detached part of the material is ejected toward the discharge spout, while the remaining part is removed from the crushing zone as the movable jaw changes its direction. During the reverse stroke of the movable jaw, the crushing process is repeated.

In the jaw crusher under consideration, the fragmentation of the brittle piece is achieved due to the generation of tangential stresses and the formation of shear deformations. The energy consumption for crushing is reduced by nearly half compared to jaw crushers operating on compression.

CONCLUSIONS

An analysis of the operation of crushing machines (which use various methods to generate stresses in the crushed piece of brittle material) shows that the most energy-efficient method is one where fragmentation of the original piece is achieved by generating tangential stresses in the processed material, resulting in shear deformation.

A crushing machine design has been developed that ensures only tangential stresses, causing shear deformations, occur in the crushed piece during operation. This design reduces energy consumption for crushing by nearly half compared to crushers that operate based on compression.

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A. G. Nikitin – formation of the basic concept, formulation of conclusions, scientific guidance.

I. A. Bazhenov – development of the crusher design, writing the text.

N. M. Kurochkin – revision of the text, correction of conclusions, discussion of results.

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