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FEATURES OF MATERIAL MOVEMENT IN A VERTICAL CHAMBER OF A VIBRATORY JAW CRUSHER WHEN PRODUCING A FINE-GRAINED PRODUCT

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Abstract. Currently, vibrating jaw crushers show a fairly high efficiency of the technological process. An extensive amount of research carried out at the Dnipro University of Technology made it possible for the first time to substantiate the possibility of using a vibratory jaw crusher with a vertically located chamber and a pendulum suspension of the jaws as an independent grinding unit for the production of powder materials.

The high-frequency impact nature of the load on the material implemented in vibrating jaw crushers made it possible to reduce the energy consumption and metal consumption of the plant, to increase the degree of crushing, which can reach the value i > 100. However, the specifics of the process of interaction of the material with the surface of the jaws in the vertical working chamber and the features of its unloading remain unknown.

The refinement of this process was carried out by an experimental method on a laboratory sample of a vibratory jaw crusher ВЩД-130 using high-speed photography. The crusher includes the main elements: a body mounted on elastic elements, crushing jaws, articulated with the body by means of axes. The side surfaces of the crushing chamber are limited by transparent glass walls rigidly connected to the crusher body. The vertical movement of the jaws was determined by the readings of the vernier. The starting material was pieces larger than 40 mm and large bulk material with a grain size of 10…15 mm.

An analysis of the nature of the movement of material throughout the crushing chamber showed the need to consider the chamber of a vibratory jaw crusher as two interconnected zones: crushing and grinding. Further studies were carried out for each zone.The productivity of the crushing zone is determined by a known method. It is necessary to create a rational profile of the working surface of the jaws on the basis of additional studies.

Studies of the grinding zone made it possible to obtain a physical picture of the interaction of the material with the jaws over the period. In the lowest position, at the initial moment of unloading, the speed of the finished product is practically zero. When determining the productivity of the grinding zone, it is advisable not to take into account the unloading of the material at the initial speed.

Keywords: vibratory jaw crusher crusher, crushing chamber, process, amplitude, zone, crushing.

1. Introduction

Successful implementation of many production processes in a number of industries is impossible without preliminary fine grinding of materials. At the same time, the grinding operation is the most expensive [1, 2] in the overall processor chain of mineral processing due to the consumption of a significant amount of electricity, the loss of a large volume of high-quality metal due to wear of grinding media and lining plates.

The main grinding unit, despite the low efficiency, is a drum ball mill and the possibility of replacing it with more efficient equipment in large-capacity production is not foreseen.

Small-tonnage production with a capacity of several tons per hour allows the use of more efficient equipment - horizontal and vertical vibratory mills [3, 4], which have become widespread. However, their high metal consumption and consumption of grinding media, limited (5...10 mm) size of the initial feed show the need to improve existing grinding methods and develop new grinders that combine crushing and grinding operations in one design.

A large amount of research carried out at the Dnipropetrovsk Mining Institute (now the Dnipro University of Technology) made it possible for the first time to substantiate the possibility of using a vibratory jaw crusher with a vertically located

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chamber and a pendulum suspension of the jaws as an independent grinding unit for the production of powder materials, as well as in production processes that require special technological regimes [5].

The scope of vibratory jaw crushers in the technological process is diverse. They can be used as a separate unit, as well as in the technological chain, where the performance of the crusher must be strictly linked to the parameters of the subsequent equipment [6, 7].

The research and development of vibratory jaw crushers are is carried out according to three basic schemes:

- crusher with rectilinear jaw movement;
- a crusher with a pendulum movement of the jaws and a lower suspension axis;
- a crusher with a pendulum movement of the jaws and an upper suspension axis.

When studying a vibratory jaw crusher with a pendulum movement of the jaws and a lower suspension axis [8], the assumption of absolute symmetry of the structure was made, which made it possible to consider the design scheme with one movable jaw. The parameters of jaw movement in the idle mode are determined, and the calculated value of the jaw oscillation amplitude in the crushed product unloading zone is supposed to be used when determining the crusher performance. Experimental studies of the influence of the vibration frequency of the jaws on the performance of the crusher showed a high operating frequency (30...32 Hz), fineness of the finished product (3...12 mm) and a low degree of crushing (10...15). Such technological indicators slightly differ from those of jaw crushers. Placement of a directional inertial drive on each jaw in combination with a rigid frame fixing eliminates the vertical vibrations of the crusher, ensuring the monotonous movement of the material towards the discharge slot during the crushing process. A similar motion model has been quite thoroughly studied [9] in jaw crushers. The advantage of the considered design is the elimination of the rigid kinematic connection of the movement of the jaws, which increases the reliability of the crusher, however, the high vibration frequency of the jaws adversely affects the strength of its elements. The results presented in the paper do not show the prospects of creating vibratory jaw crushers with a lower suspension axis for the production of fine-grained materials.

Experimental studies of such crushers are given in [10, 11]. In the vibratory jaw crusher KW 40/1 with an initial fraction of 0–50 mm, ceramic waste, dolomite, diabase, quartzite were processed. The crushed product contained 60–90% of the 0–2 mm fraction. Crushing of rock crystal at a frequency of 18 Hz oscillation of the jaws ensured the release of 95% of the material with a particle size of less than 5 mm.

A vibratory jaw crusher with reciprocating jaws in a horizontal plane [12] is considered as a three-mass resonant system. Based on the design scheme with a disturbing directional force, a system of differential equations was compiled that describes the movement of the jaws in the horizontal plane. The amplitude-frequency characteristics are constructed and the rational values of the main dynamic parameters are determined. At the same time, the behavior of the material in the crushing chamber, without proper justification, is considered taking into account the vertical movement of the crusher.

Similar results were obtained when considering a similar design scheme with a single-shaft vibration exciter [13]. Graphical dependences of the vertical amplitude of vibrations of the crusher body on the stiffness of shock absorbers are presented. The article does not take into account the rotational vibrations of the body that occur when installing a single-shaft vibration exciter and affect the dynamics of the crusher.

The destruction of lumpy material in a vibrating jaw crusher with a pendulum movement of the jaws and an upper suspension axis is considered in [14]. The crushing chamber has zonal vertical separation, the properties of the material are described by a phenomenological model, in each zone the material is destroyed in 10 cycles of force loading. The amplitudes of jaw oscillations in time, as well as the distribution of forces along the length of the jaw, are obtained. The accepted assumption about the absence of vertical vibrations of the jaw significantly distorts the behavior of the material in the crushing chamber.

A significant number of publications are devoted to the study of the material crushing process, however, the interaction of material and jaws with a pendulum motion in a vibratory jaw crusher has not been fully investigated.

To clarify the available analytical dependencies and determine the further improvement of the technological process for obtaining fine-grained and powder materials of the required size and shape, an accurate understanding of the nature of the movement of the material in the crushing chamber, which can be obtained on the basis of experimental data, is essential.

2. Methods

The studies were carried out by an experimental method on a laboratory sample of a vibratory jaw crusher ВЩД-130 using high-speed photography. During the research, the crusher had the following parameters:

- receiving window size, mm 130×60;
- unloading window size, mm 130×10;
- crushing chamber height, mm 320;
- capture angle, rad 0.384;
- height of the parallel zone, mm 90;
- jaw oscillation frequency, Hz 17.

The general view of the crusher is shown in Fig.1.

The crusher [5] includes a body 1 mounted on elastic elements 2, crushing jaws 3, articulated with the body by means of axes 4. Each jaw is equipped with a vibration exciter 5 and lining plates 6 having parallel working surfaces 7. On one end surface of the lining plates there is a measuring scale 8 with a division value of 1 mm.The side surfaces of the crushing chamber are limited by transparent glass walls 9, rigidly connected to the crusher body, which made it possible to film the behavior of the material in the crushing chamber under force loading. The vertical movement of the jaws was determined from the readings of the vernier, which consisted of a measuring scale 10 fixed on the movable body of the crusher and a plate 11 fixed on the support frame.

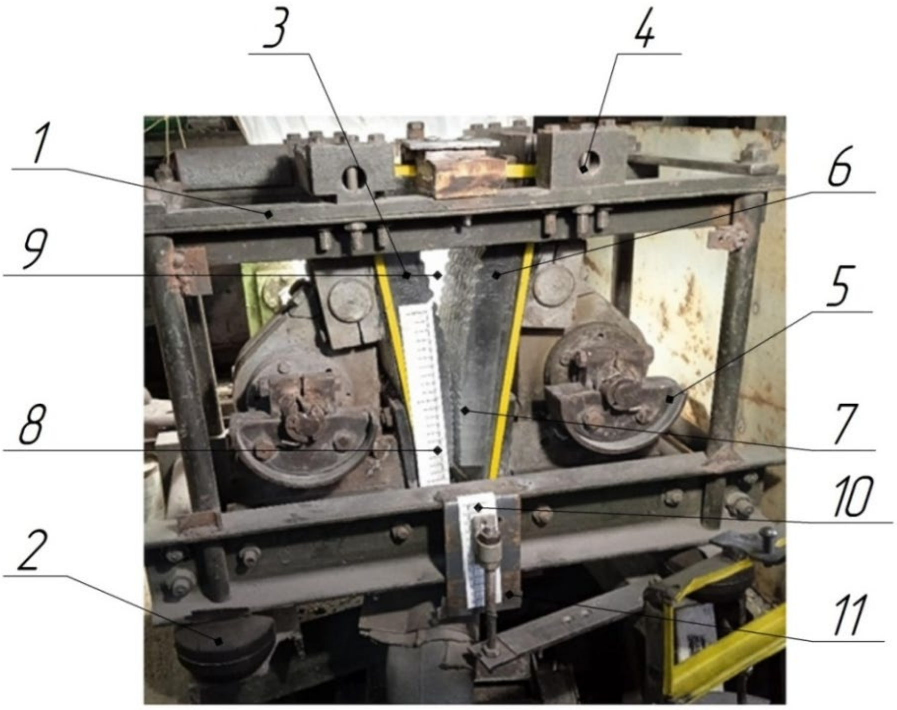


Figure 1 – Vibratory jaw crusher ВЩД-130

Depending on the direction of rotation of the unbalance shafts, it is possible to implement two modes of operation of the crusher: direct-flow and counter-flow. Their main difference lies in the vertical movement of the body in the direction of unloading the material in direct-flow mode and oncoming movement in counter-flow mode. In this paper, the direct-flow mode of operation of the crusher is considered.

3. Results and discussion

The inertial principle of the impact of the vibration exciter on the crushing jaws allows to ensure the normal operation of the crusher with direct contact of the working surfaces of the jaws (pos. 7, Fig. 1) at the moment of their closest approach, which is the determining factor for using the crusher as an independent crushing unit. In this case, the working chamber can be conditionally represented as two adjacent zones. The upper part of the working chamber (Fig. 2) forms the crushing zone, the lower part - the grinding zone.

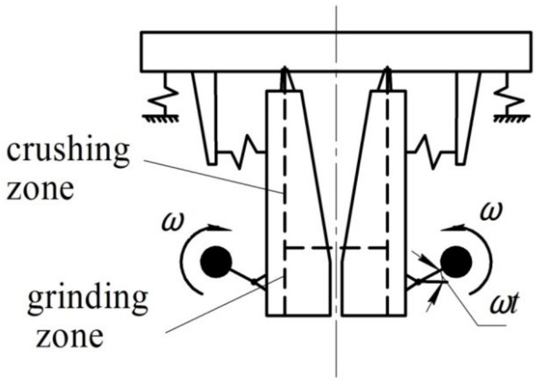


Figure 2 – Structural scheme of a vibratory jaw crusher

When the material is fed into the crushing zone, the piece moves to the unloading window along a zigzag trajectory, successively contacting the opposite surfaces of the jaws until a stable position is formed (Fig. 3, a) destructive relative deformation of the piece. For several periods, moving down, the piece enters the section of the working chamber of the crusher, where the amplitude of the vibrations of the jaws is sufficient to complete the crushing process (Fig. 3, c). The material crushed to the size corresponding to fine crushing is the initial product of the grinding zone. To increase the efficiency of the crusher, the lining plates must be designed with a special profile of the working surface.

a b c

Figure 3 – Filling the working chamber with material

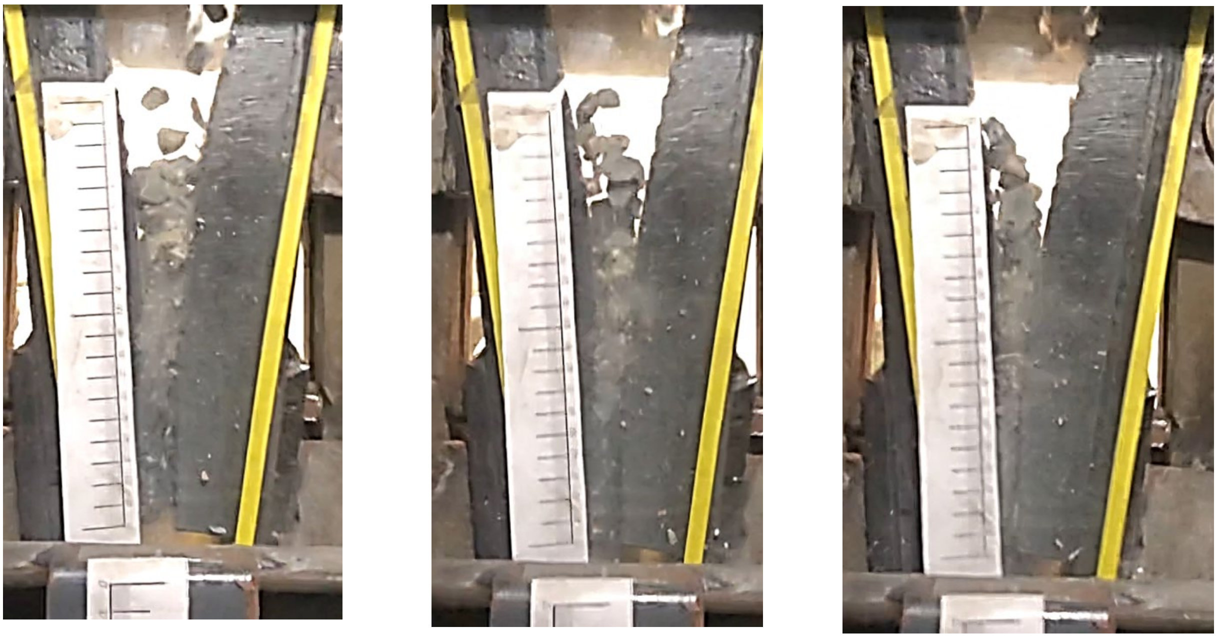
The productivity of the crushing zone is determined according to the well-known theory [15], which is based on the total path moved by the material during the gap opening, which includes the path:

- passed by the material under the influence of gravity,
- with the speed reported by the crusher to the material at the moment of opening the gap,
- moving the crusher vertically.

Bulk material, freely passing the crushing zone (Fig. 3,c), directly enters the grinding. The productivity of the crushing zone corresponds to the theoretical substantiation of this process, however, it requires justification and clarification in the grinding zone.

The well-known theoretical description of the process of material movement [3] and the definition of productivity [11], which is characteristic of the crushing zone, requires justification and clarification for the grinding zone.

When considering the process in the grinding zone, we take the equilibrium position of the crusher ($\omega t = 0$) as the reference point, at which the jaws are maximally separated and the crusher moves upwards at maximum speed (Fig. 4, a). After passing the equilibrium position, the speed of the crusher and the convergence of the jaws begin to decrease. In the extreme upper position ($\omega t = \pi/2$), the speed of the body is 0, the speed of the jaws is maximum.



a - $\omega t = 0$ b - $\omega t = \pi/2$ c - $\omega t = 3/2\pi$

Figure 4 – Material movement in the grinding zone

Under the action of the restoring forces of the elastic elements, the crusher begins to move down with acceleration while the jaws converge. Predominantly, in the first place, the material located in the lower part of the crushing chamber, where the amplitude of the vibrations of the jaws is maximum, is subjected to clamping. There is a compaction and destruction of the material in the layer. In the upper part of the crushing chamber, free-lying material in the area of the accelerated movement of the crusher can temporarily loosen (Fig. 4, b). The speed of its movement is less than the speed of the crusher.

In the equilibrium position ($\omega t = \pi$), the transition from the maximum speed of the material movement to the mode of deceleration and a decrease in the force effect on the material from the side of the jaws begins. The crushed material is in a clamped state and continues to move downwards with the crusher.

Approaching the lower extreme position ($\omega t = 3/2\pi$), the speed of the crusher and the material decreases to zero. The material is not unloaded (Fig. 4, c) due to the fact that the density of the material decreases, it fills the formed space and the friction force is sufficient to keep it in the crushing chamber in the lowest position, as well as at the beginning of the crusher movement upwards.

With further spreading of the jaws, the unloading of the material under the action of gravity begins with a zero initial speed, while maintaining the relative movement of the material and the jaws by the magnitude of the amplitude value of the vibrations of the crusher body.

4. Conclusions

The conducted studies have shown that when obtaining fine-grained and powder materials, the working chamber of a vibratory jaw crusher must be considered as two interconnected zones: crushing and grinding. Each of the zones requires its own design specifics. In the crushing zone, the profile of the working surface of the lining plates should ensure the preparation of the starting material for grinding with the smallest possible fineness. In the grinding zone, it is necessary to increase productivity to the level of the crushing zone by creating special unloading devices. The performance of the crushing zone is determined according to known methods. When determining the productivity of the grinding zone, it is advisable not to take into account the unloading of the material at the initial speed.

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ОСОБЛИВОСТІ ПЕРЕМІЩЕННЯ МАТЕРІАЛУ У ВЕРТИКАЛЬНІЙ КАМЕРІ ВІБРАЦІЙНОЇ ЩОКОВОЇ ДРОБАРКИ ПРИ ОТРИМАННІ ДРІБНОЗЕРНИСТОГО ПРОДУКТУ

Федоскіна О.В.

Анотація. В даний час досить високу ефективність ведення технологічного процесу показують вібраційні щокові дробарки. Проведений у Національному технічному університеті «Дніпровська політехніка» великий обсяг досліджень дозволив уперше обґрунтувати можливість застосування вібраційної щокової дробарки з вертикально розташованою камерою та маятниковим підвісом щік як самостійного подрібнювального агрегату для отримання порошкових матеріалів. Реалізований в них високочастотний ударний характер навантаження на матеріал дозволив знизити енергоспоживання і металоємність установки, підвищити ступінь дроблення, яка може досягати величину і >100.

Уточнення цього процесу проводилося експериментальним методом на лабораторному зразку вібраційної щокової дробарки ВЩД-130 з використанням швидкісної зйомки. Дробарка включає основні елементи: корпус, встановлений на пружних елементах, щоки, що дроблять, шарнірно зчленовані з корпусом за допомогою осей. Бічні поверхні камери дроблення обмежені прозорими скляними стінками, що жорстко пов'язані з корпусом дробарки. Вертикальне переміщення щік визначалося за показаннями ноніуса. Вихідний матеріал приймався у вигляді шматків крупністю більше 40мм і сипкий 10...15мм.

Аналіз характеру руху матеріалу по всій камері дроблення показав необхідність камеру вібраційної щокової дробарки розглядати як дві взаємопов'язані зони: дроблення та подрібнення. Подальші дослідження проводилися для кожної зони. Продуктивність зони дроблення визначається згідно з відомою методикою. Необхідно створення раціонального профілю робочої поверхні щік виходячи з додаткових досліджень.

Дослідження зони подрібнення дозволили отримати фізичну картину взаємодії матеріалу з щоками протягом періоду. У крайньому нижньому положенні, в початковий момент розвантаження швидкість готового продукту практично має нульове значення. При визначенні продуктивності зони подрібнення доцільно не враховувати розвантаження матеріалу з початковою швидкістю.

Ключові слова: вібраційна щокова дробарка, камера дроблення, процес, амплітуда, зона, подрібнення.