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# INNOVATIVE TECHNOLOGY FOR OBTAINING FINE-GRAIN AND POWDER MATERIAL


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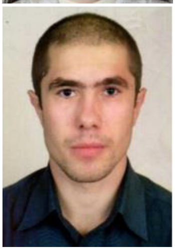

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**Abstract**

The production of fine-grained materials is associated with a high consumption of electricity and is mainly carried out in several stages of processing. The last stage - grinding is the most expensive. This necessitates the creation of new economical machines and technologies. A large 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 vibrating 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, as well as in production processes requiring special technological modes. The development of this direction is the creation of a vibroimpact grinder with an inclined working chamber, which provides regulation of the magnitude of the force effect on the material over a wide range. The purpose of the work is to substantiate the need for research and development of new design solutions for vibrating jaw crusher units, modular installations of a production line based on small-sized vibration equipment. The paper indicates the reason for the relatively low productivity of the vibrating jaw crusher and recommends ways to improve it. The possibility of redistributing the percentage of narrow classes of material in the finished product by changing the vibration frequency of the crushing jaws is shown. The analysis carried out shows the possibility of a significant increase in the efficiency of grinding materials in the development of new design solutions for the parallel zone. The features of the developed new class of vibrating jaw crushers with a complex jaw movement, which ensures the process of grinding the material along the entire length of the working chamber, are considered. The creation by a separate module of an innovative technological line for the production of fine-grained and powder materials with a horizontal layout of small-sized vibration equipment is justified.

## Introduction

At present, along with large-capacity production, the number of enterprises is increasing, the need for which to obtain fine-grained and powder materials is limited from several tons to tens of kilograms per hour.

This necessitates the creation of highly efficient small-sized installations that provide a complete technological process for the processing of minerals, including the preparation of the starting material, the crushing and grinding operation, and the separation of the commercial product. In this process chain, the crushing and grinding operation is the most expensive due to the consumption of a significant amount of electricity [1], the high cost of repairs, and the replacement of rapidly wearing elements of crushing parts. One of the reasons is the use by enterprises of obsolete equipment with a low degree of crushing and a multi-stage technological process.

A large 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 vibrating jaw crusher with a vertically located chamber and a pendulum suspension of the jaws as an independent grinding unit for obtaining powder materials, as well as in production processes, requiring special technological regimes [2,3].

The design scheme of the vibrating jaw crusher in general (fig. 1) is an oscillatory system in which the jaws 1, movably articulated with the body 2 through the axes of the suspension 3, reported high-frequency vibrations. The rotary oscillatory movement of the jaws, as well as the vertical movement of the body, are generated by the forces of inertia of the rotating unbalanced masses of single-shaft vibration exciters 4.

The inertial principle of the action 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 at the moment of their closest approach, which is the determining factor in the use of the crusher as an independent crushing unit.

The high-frequency impact nature of loading of the material implemented in them made it possible to reduce the energy consumption and metal consumption of the installation, and to increase the degree of crushing [4].

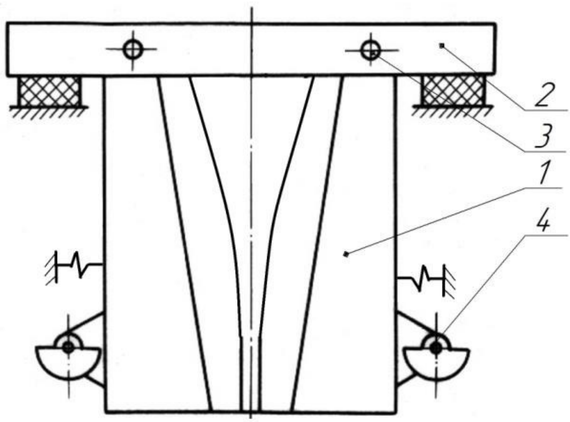


**Fig. 1.** Structural scheme of a vibrating jaw crusher with a vertical crushing chamber: *1* - jaw; *2* - body; *3* - suspension axis; *4* - vibration exciter

Table 1 shows the characteristics of the crushers parameters: PALLA type vibrating mill, ball drum mill with continuous screening and vibrating jaw crusher.

Table 1

Comparative characteristics of grinder parameters

| Options | Chopper type | | | | |
|---|---|---|---|---|---|
| | PALLA 20U | PALLA 35U | Drum mill | VSHCHD -220 | VSHCHD - 220 |
| Size of the original pro-duct, mm | 0-5 | 0-5 | 0-50 | 0-50 | 0-50 |
| Final product size, mm | 0-0,2 | 0-0,2 | 0-0,2 | 0-0,2 | 0-0,2 |
| Material for recycling | Medium hard | Medium hard | Ferro-chrome | Ferro-chrome | Ferro-silicium |
| Finished product capacity *Q*, т/ч | 0,05 | 0,65 | 0,06 | 0,24 | 0,6 |
| Installation weight, kg | 600 | 2900 | 1845 | 600 | 600 |
| Specific electricity consumption, *W/Q*, kWh/t | 80 | 28,5 | 55 | 32 | 13,5 |
| Grinding degree | 15 | 15 | 65 | 65 | 65 |
| Dimensions, mm | - | - | 1245 | 580 | 580 |
| | - | - | 1320 | 720 | 720 |
| | - | - | 2255 | 1040 | 1040 |
| Efficiency *Qi,* t/h | 0,75 | 9,8 | 3,99 | 16 | 40 |
| Electricity consumption related to efficiency *W/Qi*, kWh/t | 5,35 | 1,86 | 0,78 | 0,48 | 0,2 |

The vibro-impact method of grinding material was further developed in the development of a new crusher design with an inclined crushing chamber, which provides control over the magnitude of the force effect on the material over a wide range [5].

In general, the crusher (see Fig. 2) includes a lower crushing jaw 1 mounted on the shock absorber 5.

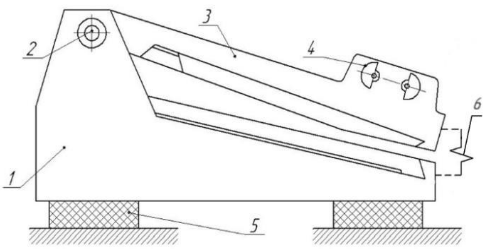


**Fig. 2.** Structural scheme of a vibratory jaw crusher with an inclined crushing chamber: *1* - lower jaw; *2* - jaw suspension axis; *3* - upper jaw; *4* - vibration exciter; *5* - shock absorber; *6* - elastic element

The upper jaw 3 is installed in the racks of the lower cheek by means of the suspension axis 2 relative to which it can perform rotational vibrations. In a given neutral position, the upper jaw is held by elastic elements 6. The vibrations of the jaws are generated by a two-shaft inertial vibration exciter 4.

The operation of vibratory crushers has shown that there are a number of units and elements, the improvement of which will increase the efficiency of the technological process. The purpose of the work is to substantiate the need for research and development of new design solutions for vibrating jaw crusher units, modular installations of a production line based on small-sized vibration equipment.

**The productivity of the crusher** in obtaining a fine-grained and powder product is one of its main disadvantages and requires a significant increase. This is mainly due to the small width of the unloading gap and the small volume of the prism of the unloaded material. One of the simplest ways to increase productivity in the required size class is to change the vibration frequency of the jaws [4].

For example, Fig. 3 shows the results of ferrosilicon crushing on the VSHD-220 crusher (here 220 is the jaw width).

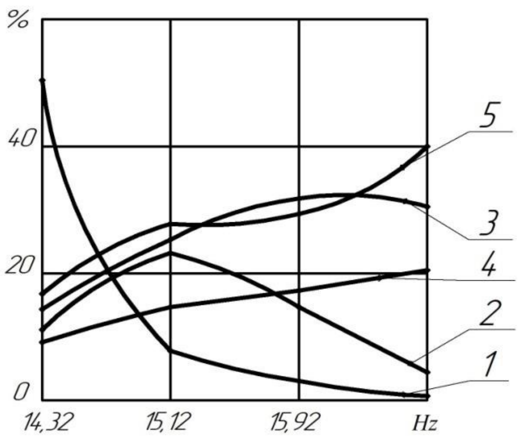


**Fig. 3.** Dependence of the output of crushed ferrosilicon on the vibration frequency of the jawsб mm: *1* - class + 5; *2* - class 3-5; *3* - class 1 - 3; *4* - class - 0,28 - 1; *5* - class -0,28

Pieces of 40-50 mm were taken as the starting material. The width of the unloading gap was 2 mm. The material was fed into the crusher by a vibrating feeder with a capacity of 1200 kg/h. If we take a fraction of -0,28 mm as a finished product, then at a frequency of 90 rad/s, the productivity will be 216 kg/h, but at a frequency of 110 rad/s, the productivity will reach 480 kg/h. The nature of curve 5 (see Fig. 3) predetermines, with a subsequent increase in the frequency of oscillation of the jaws, a sharp increase in productivity for a given fineness class, however, there are already difficulties with the strength and reliability of the construction and its elements.

It seems natural to increase the length of the discharge gap, but this parameter has its limitations and depends on the overall layout of the crusher.

A significant increase in productivity is achieved by creating devices that ensure the removal of the finished product from the working chamber as it is formed. One of the design schemes [6] of this type of vibratory crushers is shown in Fig. 4.

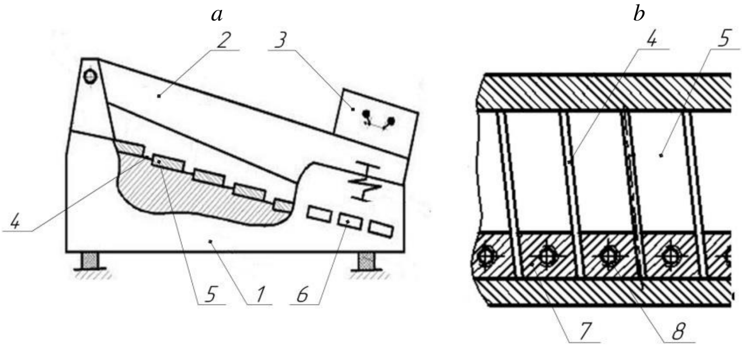


**Fig. 4.** Crusher with discharge gaps: *a* - general view, *b* - working surface of the lower jaw, 1 - lower jaw; 2 - upper jaw; *3* - vibration exciter; *4* - gaps; *5* - lining plate; *6* - unloading window; 7 - wedges; *8* - tightening bolts

The process of removing the finished product is as follows. The material entering the crushing chamber moves to the unloading slot of the crusher along the working surface of the lower jaw 1 and is subjected to high-frequency shock loading from the upper jaw 2, which oscillates under the action of the vibration exciter 3.

The interaction of a piece of material with the upper jaw leads to the appearance of material fractions of the required size. This class of material falls under the action of gravitational forces on the working surface of the lower jaw and, moving along with large pieces in the direction of the crusher discharge slot, enters the gaps 4. The width of the gaps is taken equal to the maximum fineness of the finished product and is set by the appropriate setting of the lining plates 5. The minimum gap width can be fractions of a millimeter. The lining plates are placed on the massive surface of the lower jaw and are fixed by tightening the wedges 7 by means of the bolts 8. The finished product, which has fallen into the gaps, moves along the inclined surface to the unloading windows 6. The stepped arrangement of lining plates along the length of the crushing chamber contributes to the loosening of the material in the process of its transition from the upper stage to the lower one, which also increases the efficiency of removing finished fractions from the crushing zone.

Parallel zone. In jaw crushers, the particle size distribution of the crushed product is determined by the size of the dropping material prism and may have a significant amount of excess grains. The reduction is achieved by installing lining plates with a parallel zone in the unloading window. The height of the parallel zone is taken from the condition under which the time of passage of the zone by a piece of crushed material is greater than the time of one revolution of the eccentric shaft. When this condition is met, each piece, at least once, will be clamped in a parallel zone during the unloading of the material. With the width of the unloading window, which is determined by tens of millimeters, there are no special requirements for the manufacture and installation of lining plates, which practically perform the function of a calibrator for the upper size of the crushed product.

A feature of the design of vibro-jaw crushers for obtaining fine-grained and powder material is the obligatory presence of a parallel zone. In this section of the crushing chamber, the formation of a qualitative composition of the finished product is mainly carried out.

Fig. 5 shows the results of crushing the sinter charge with an initial size of 3-15 mm. [7]. The height of the parallel zone was 25 mm (solid line) and 50 mm (dashed line).

An analysis of the granulometric composition of the crushed product shows that the height of the parallel zone is one of the control parameters that allows you to adjust the composition of the crushed product, redistributing its content in narrow size classes. For example, with a jaw oscillation frequency of 115 rad/s, by changing the height of the parallel zone, you can get 40% or 50% of a product of the -0,56 mm class.

The graphical dependence shows the presence of the boundary value of the height of the parallel zone, at which an increase in the vibration frequency of the jaws has practically no effect on the granulometric composition of the crushed product. So, in particular, for a height of 25 mm. it is not advisable to take the operating frequency of vibrations of the jaws more than 120 rad/s.

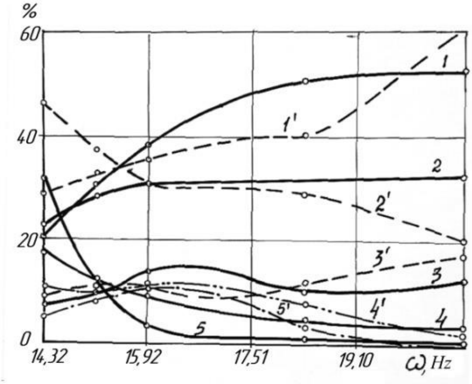


**Fig. 5.** The influence of the height of the parallel zone on the granulometric composition of the crushed product: 1 class-0,56 mm; 2 class 1-2 mm; 3 class 0,56-1 mm; 4 class 2-3 mm; 5 class +3 mm

Upon receipt of fine-grained and powder materials in a parallel zone, final grinding is carried out in a layer whose thickness depends on the strength of the material and can be only a few millimeters.

In connection with this feature, for the effective operation of the parallel zone, the initial setting of the parallelism of the working surfaces of the jaws is essential.

Several options are possible:

- parallelism is established with closed jaws;

- parallelism is established when the jaws are in the equilibrium position;

- parallelism is established at the maximum width of the unloading slot.

The first option is not rational, since when the jaw is retracted, a reverse grip angle is formed, which is also preserved when interacting with the material layer in any position of the jaw.

Setting at the maximum slot width ensures parallelism only at the time of loading. The material compression process takes place with a right grip angle, which reduces the grinding effect at the beginning of the parallel zone, especially at the minimum layer thickness. It is advisable to establish parallelism in the position of balance of the jaws , which ensures the force loading of the material over the entire surface of the parallel zone at the moment of the highest speed of the cheek. Parallelism must be maintained when adjusting the width of the unloading slot and the height of the parallel zone. This is achieved by constructive solutions, examples of which are shown in Fig. 6 [8].

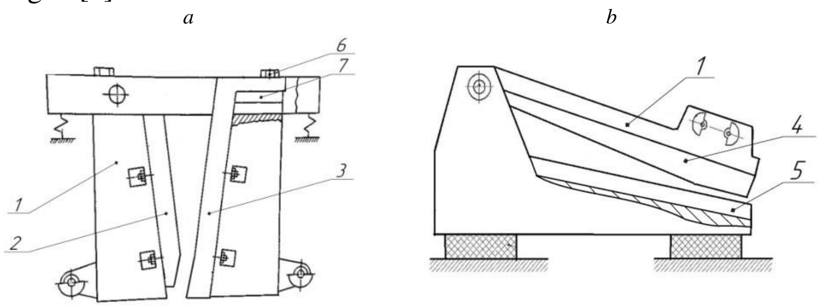


**Fig. 6.** Devices for regulating the parallel zone and the width of the unloading slot: *a* - vertical chamber; *b* - inclined camera; *1* - jaw; *2*,*3*,*4*,*5* - movable plates; 6 - attachment point; *7* – plates

Parameter adjustment is performed as follows. With a rigidly fixed plate 2 (see Fig. 6*a*), the maximum height of the parallel zone will be when the end surface of the plate 3 is located at or below the end surface of the plate 2. The required height of the parallel zone is set by shifting the plate 3 upwards and fixing it with a set of plates 7. After that, a rigid screed is performed plates with a cheek by means of the fastening unit 6. Similarly, the height of the parallel zone is adjusted in the crusher with an inclined crushing chamber. Plate 5 is in a rigidly fixed state (see Fig. 6*b*), plate 4 is installed with subsequent fixation in the position required by the technological regulations.

Adjustment of the width of the unloading slot while maintaining the height of the parallel zone is carried out by simultaneously shifting two plates (2-3, 4-5, Fig. 6). The joint adjustment of the slot width and the height of the parallel zone is carried out by shifting the plate 2 with a vertical location of the crushing chamber and plate 5 with an inclined location of the crushing chamber.

The analysis carried out shows the possibility of increasing the efficiency of grinding materials in the development of new design solutions for the parallel zone.

Crusher with complex jaw movement. A common disadvantage of jaw crushers with a pendulum jaw suspension is the absence of a linear jaw oscillation amplitude in the region of the suspension axis. This leads to a shift from the jaw suspension axis of the initial breaking load on the material, an increase in the length of the crushing chamber, dimensions and metal consumption of the crusher.

Developed in Dnipro University of Technology a new class of vibrating jaw crushers with a complex jaw movement [9] provides the process of grinding the material along the entire length of the working chamber (see Fig. 7).

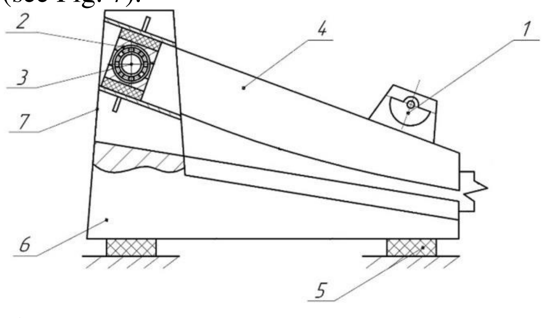


**Fig.7.** Crusher with a complex movement of the jaw:
*1* - vibration exciter; *2* - bearing support; *3* - suspension axis; *4* - upper jaw; *5* - elastic elements; *6* - lower jaw; *7* - receiving window

A feature of the crusher is the use of a single-shaft inertial vibration exciter 1, which generates a disturbing force with a rotating vector and the installation of bearing supports 2 suspension axes 3 of the upper jaws 4 in the elastic elements 5, which makes it possible for the suspension axis to move relative to the lower jaw 6 in any direction considered in the plane of the drawing . The amount of movement of the suspension axis is determined by the rigidity of the elastic elements, which is much greater in the direction perpendicular to the working surface of the upper jaw than in the longitudinal direction. This proportionality forms the trajectory of the upper jaw in the form of an ellipse with the direction of the major axis along the working surface of the upper jaw. Under the action of the disturbing force of a single-shaft inertial vibration exciter, the upper and lower jaws oscillate. Due to the difference in masses, the amplitude of oscillations of the upper jaw is higher than the amplitude of vibrations of the lower jaw. The source material entering the receiving window 7 of the crusher moves to the discharge slot along the lower cheek and, at the moment of contact with the working surface of the upper jaw, is subjected to high-frequency force loading. At the same time, a new technological process (principle) of the interaction of the upper jaw with the material is implemented. In the region of the cheek suspension axis, where the magnitude of the amplitude of the rotational oscillations of the jaw is insufficient to create compressive destructive deformations in the piece of material, the destruction of the piece of material is carried out by means of shear deformations created by the displacement of the upper jaw.

With further movement of the piece and reaching the area where the amplitude of the rotational vibrations of the jaw is sufficient to create a destructive compression deformation in the piece, a different character of the interaction of the upper jaw with the material takes place, in which the material receives a combined force loading according to the principle "compression + shear", which significantly increases the efficiency of the grinding process.

The innovative technological line for the production of fine-grained and powder materials is represented by a set of units that provide preliminary drying of the source material, crushing and grinding operation and isolation of the finished product.

The creation of a vibrating jaw crusher with an inclined crushing chamber allows you to move from the traditional vertical layout of equipment to its horizontal placement (see Fig. 8), which greatly simplifies installation and maintenance, significantly reduces the material consumption of the line.

The production line works as follows.

From the hopper - feeder 1, the material is fed with a given capacity to the vibrating conveyor of the drying plant. Two types of vibroconveyor have been developed: for lumpy and bulk materials. A feature of the vibroconveyor for lumpy materials is the possibility of drying material with a wide granulometric composition, including grain fractions from fractions to tens of millimeters. The material supplied for drying, under the action of a directed vibration disturbance, moves along the lattice stepped surface and is blown through the slots with hot air [10]. Conveyor length up to 6m, capacity up to 5t/h.

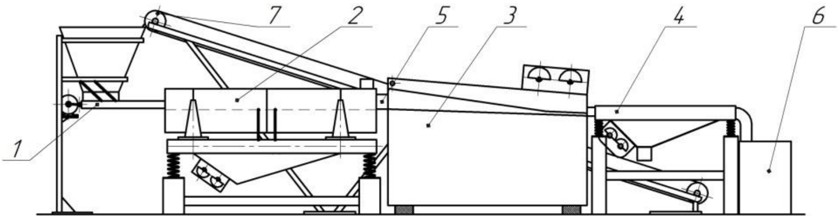


**Fig. 8.** Scheme of an innovative technological line for the production of fine-grained and powder materials: *1* - hopper - feeder; *2* - vibrating dryer; *3* - vibrating jaw crusher; *4* - screen; *5* - docking elements

A more compact design of the vibratory conveyor for bulk materials with a particle size of up to 15 mm. The created complex profile of the working surface made it possible to set the movement of the material with intensive mixing, which increased the drying efficiency and increased the time the material was under high-temperature exposure [11]. Tests of a laboratory sample of the vibroconveyor showed the possibility of reducing the length of the vibroconveyor, compared with the usual perforated profile of the working surface, by several times with the same technological indicators.

Not all materials require pre-drying. In its absence, the raw material is fed into the working chamber of the crusher directly from the feed hopper.

The vibratory crusher accepts material up to 100 mm in size and carries out its grinding to a micron condition. The separation of the finished product is carried out on a screen with a complex profile of the working surface. Reducing the dimensions of the destructive and classifying equipment in height makes it quite easy to organize a closed cycle with a minimum amount of transport equipment.

**Conclusions**

The innovative technology of grinding materials based on vibrating jaw crushers has great potential for further development for fine destruction of materials, including strong and abrasive ones.

The most significant way to increase the productivity of a vibrating jaw crusher when producing finely divided materials is to remove the finished product from the working chamber as it is formed.

The development of new solutions for creating a parallel zone is a great reserve for improving the efficiency of grinding in vibrating jaw crushers.

The created small-sized structures are the basis for the development of modular installations of technological lines: feeder - vibrating dryer - vibrating crusher - vibrating screen; feeder - vibro crusher - vibrating screen - conveyor for closing the grinding (crushing) cycle. The capacity of such modular plants is up to 5t/h, length up to 10 m.

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