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IMPROVINGTHE EFFICIENCY OF THE IMPACT CRUSHER WITH INCLINED WORKING CHAMBER

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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 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 vibration shock grinder with an inclined working chamber, which provides adjustment of the magnitude of the force effect on the material within a wide range.

A vibrating grinder with an inclined working chamber includes the main elements: a passive jaw located on shock absorbers, an active jaw pivotally mounted in the body and connected to it by means of elastic links, and a two-shaft inertial vibration exciter.

On the basis of the given design scheme for the movement of material to the discharge slot, the reduction in volume and throughput in each cross section of the working chamber is determined. When the boundary values are reached, the material pressing mode starts followed by jaw opening, reduce of chamber efficiency and vibrating shock grinder productivity.

Having the smallest throughput of all sections of the chamber, the parallel zone determines the throughput of the grinder, as well as the performance of its feeder.

The possibility of increasing the throughput by increasing the angle of inclination of the parallel zone and matching the speeds of material movement in different parts of the working chamber is considered. Based on the studies carried out, a chamber profile was developed in the form of a multifaceted working surface of the passive jaw and a stepped surface of the active jaw. Analytical expressions are given for calculating the parameters of the profile of the inclined working chamber of a vibration shock grinder.

Keywords: vibrating grinder, working chamber, throughput, jaw, oscillation amplitude.

Introduction. In the general line of the technological process of mineral processing, the grinding operation is the most expensive due to the consumption of a significant amount of electricity [1]. One of the reasons is the use of obsolete technology by enterprises. Thus, the jaw crusher, the creation of which dates back to the middle of the 19th century, is widely used in industry. Despite a significant number of design changes, the use of a kinematic drive does not significantly intensify the crushing process based on crushing a piece of material.

The location of the inertial drive on the jaws allowed to significantly increase the vibration frequency of the jaws (1000 - 1500 rev/min) and implement the vibration shock method of material destruction. Currently, the vibrating jaw crusher is effectively used for crushing hard and abrasive materials [2].

Methods. Numerous researches carried out at the Dnipropetrovsk Mining Institute (now the Dnipro University of Technology) allowed 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 that require special technological modes [3]. The high-frequency shock nature of the material load implemented in them made it possible to reduce the energy and metal consumption of the installation, and to increase the grade of crushing.

The operating experience of a crusher with a vertically located crushing chamber showed limited possibilities for controlling the disintegration process, which led to the search for new design schemes. One of such solutions is a vibrating shock grinder with an inclined working chamber, which provides a wide range of adjustment of the magnitude of the force effect on the material [4].

Results and discussion. The goal is to determine rational parameters for the curvilinear profile of the working chamber of the vibrating shock grinder.

Theoretical part. In general terms, the grinder (Fig. 1) includes a passive (lower) jaw 1 installed on elastic elements 5 and simultaneously performing the function of the body.

The active jaw 3 is installed in the racks of the passive jaw with the help of the suspension axis 2, relative to which it can perform rotational vibrations. In a given neutral position, the active jaw is held by elastic elements 6. Vibrations of the jaws are generated by a two-shaft inertial vibration exciter 4. Synchronous antiphase rotation of the unbalanced shafts is provided by an external or internal gear transmission. The working surfaces of the jaws are coated with wear-resistant plates 7.

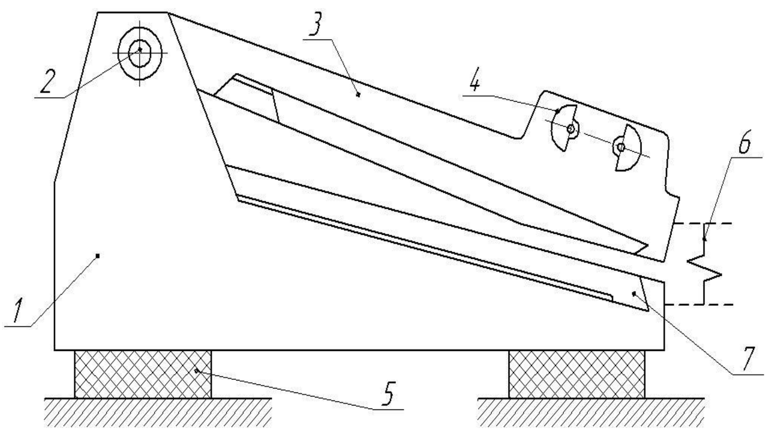


Figure 1 – Structural diagram of the vibrating shock grinder

The material that enters the loading area of the working chamber has a density corresponding to its bulk density, and the material loosening coefficient has a maximum value. The filling factor of the loading zone is less than unity, since the dimensions of the material entering the grinder are limited by the height of the loading opening, the working surfaces of the jaws are parallel, and the amplitude of the oscillations of the upper jaw is minimal. Therefore, the material tends to a state that is determined by its angle of repose. The absence of clamping of the material from the side of the jaws determines the same flow velocity along the entire length of the loading zone, which will be:

$$v_{cp} = \frac{\omega S}{2\pi},$$

where ω - jaw oscillation frequency, s^{-1}; S - path of movement of particles for the period, m.

Then, the throughput capacity of the grinder in the loading area ($П_{зз}$) is:

$$П_{зз} = 3600bh_{зо}v_{cp}\gamma_з k_з ,$$

where b - is the width of the working chamber, m; $h_{зо}$ - is the height of the loading zone, m; v_{cp}- is the speed of the material, m/s; $\gamma_з$ - material density in the loading zone, t/m^3; $k_з$- is filling factor of the loading area.

In the grinding zone (Fig. 2), the interaction of the material with the jaws begins, the partial destruction of material pieces of a size limiting for a given section of the chamber, and the filling of voids in the material layer with destroyed fine fractions.

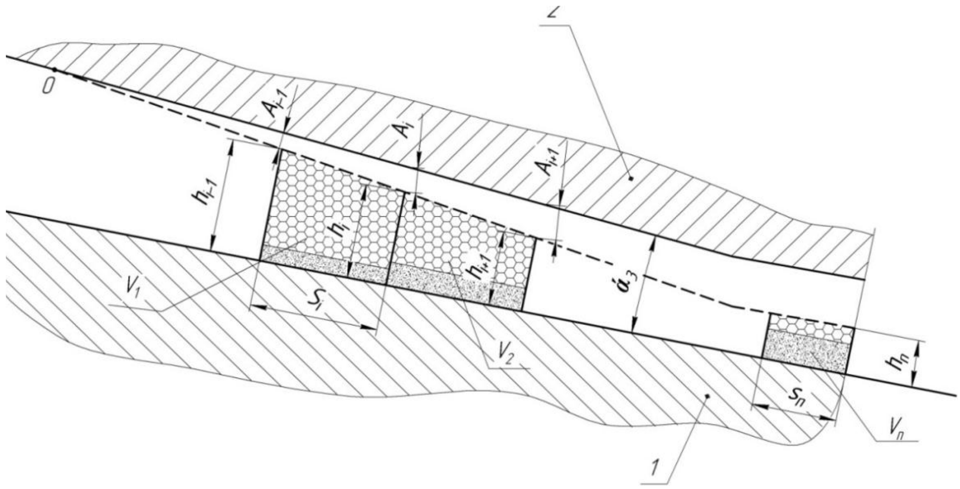


Figure 2 – Calculation scheme for filling the working chamber of the grinder with material

The diagram shows: 1 –is passive jaw; 2 - active jaw; O - is jaw suspension axis; $\alpha_з$ – is capture angle; A_I - is vibration amplitude of the active jaw in the cross section of the working chamber; h_i - is the height of the chamber in the i-th section at the lowest position of the active jaw; $h_п$ -is the height of the chamber in the parallel zone at the lower position of the active jaw, V_1 ... V_n -is the volume of the chamber, which is filled with material per one period of vibration of the jaw; S_j–I s the distance that the particle passes, with taking into account the clamping, to the discharge window during the oscillation period of the jaw.

As the layer moves to the discharge window of the crusher, its loosening coefficient decreases and the filling factor of the section of the working chamber increases.

Throughput of the i-th cross section in the grinding zone:

$$П_i = h_i bS_j \gamma_i k_i ,$$

where γ_{i-1} -is the density of the material in the i-1-st section; $k_{зi-1}$- is filling factor in the i-1- st section.

Throughput i + 1st cross section in the grinding zone is:

$$П_{i+1} = h_{i+1}bS_j\gamma_{i+1}k_{зi+1},$$

The height $h_{i+1}$of the chamber is:

$$h_{i+1} = h_i - S_j \tan\alpha_з - A_{i+1} + A_i = h_i - S_j\left(\tan\alpha_з + \tan\frac{\psi_2}{2}\right),$$

where A_i - is the amplitude of the jaw oscillations in the i-th section of the chamber; A_{i+1}–is amplitude of jaw oscillations in i+1 section of the chamber; ψ_2 - is rotation angle of the active jaw relative to the suspension axis; $\alpha_з$ – is capture angle.

The throughput i+1 of the cross section will decrease by:

$$\Delta\Pi_{i+1} = bS_j\left(h_i\gamma_i k_{зi} - h_{i+1}\gamma_{i+1}k_{зi}\right).$$

By comparing with the previous section, the volume i + 1 of the working chamber section will also be reduced by:

$$\Delta V = bS_j^2\left(\tan\alpha_з + \tan\frac{\psi_2}{2}\cos\alpha_з\right).$$

The decrease in throughput and decrease in the volume of material is compensated by a decrease in the loosening factor and an increase in the filling factor of the i+1-th section of the working chamber. This increases the bulk density of the material, which can be changed from the density of the bulk material in a free state to values close to the density of the material in the pillar.

When the boundary values are reached, the material pressing mode starts followed by jaw opening, reduce of chamber efficiency and vibrating shock grinder productivity.

The parallel zone is the narrowest cross section of the working chamber. The practically no capture angle and a slight change in the amplitude oscillation of the jaw along the length of the zone provide the conditions for calibrating the material coming from the grinding zone. The capacity of the parallel zone for the period will be:

$$\Pi_\Pi = h_\Pi bS_j\gamma_\Pi k_\Pi,$$

where $h_п$ - is the height of the chamber in the parallel zone at the lower position of the active jaw; $\gamma_п$ - is the density of the material layer in the parallel zone; $k_п$- is the filling factor of the parallel zone with the material.

Featuring the smallest throughput of all sections of the working chamber, the throughput of the parallel zone determines the throughput of the vibrating shock grinder, as well as the performance of its feeder.

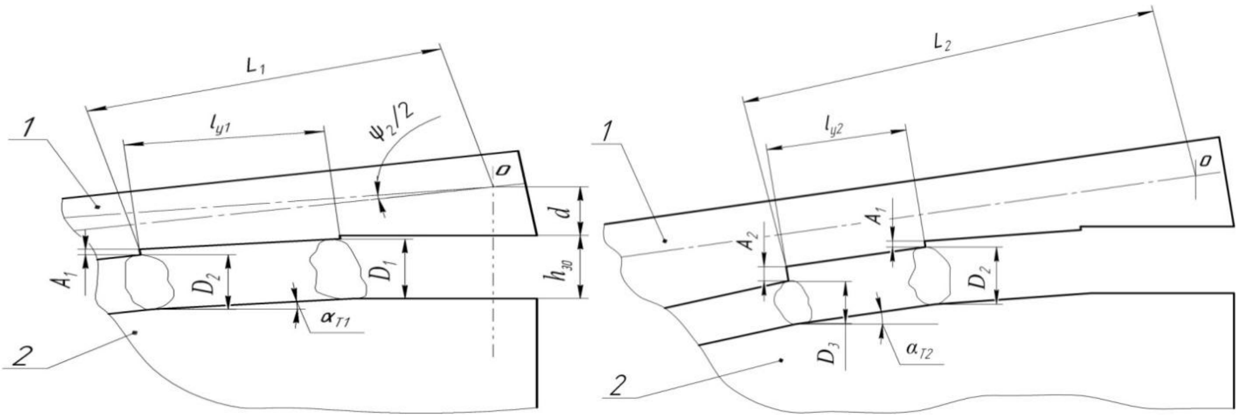
Analysis of expression (1) from the standpoint of increasing the throughput of the grinder shows that the technological coefficients $\gamma_п$ and $k_п$ are characterized by instability during the operation of the grinder, the design parameters b and $h_п$ depend on the size of initial and final product, the real parameter that allows increasing the throughput is the distance which the material will pass, taking into account the closing of the jaw per one period of oscillation or the speed of the material layer moving.

An increase in speed can be achieved by increasing the angle of inclination of the parallel zone. With this design of the working chamber, the speed of discharge of the finished product and the entry of material into the parallel zone can differ significantly.

Based on this, the problem arises of coordinating the speeds of material movement in different areas, which requires the development of a rational profile of the working chamber.

Such a profile can be formed by a series of interconnected rectangular sections. As a result, a multifaceted surface of the passive jaw and a stepped surface of the active jaw are formed.

In Figure 3a, formation of the loading zone and the first rectangular section of the working chamber is shown. Here, as in all subsequent sections, in the position of static equilibrium, the working surfaces of the jaws are parallel and the capture angle is determined by the amplitude of the rotary oscillations of the active jaw, that is, $\alpha_з=\psi$. The height of the loading zone $h_{зо}$ (the height of the loading window) is determined by the maximum size of a piece of material entering for grinding and occupying a stable position.



а) б)

1 –is active jaw; 2 - is passive jaw; d - is distance from the suspension axis to the working surface of the active jaw; $h_{зо}$ - is loading zone height; D_1, D_2, D_3 - is size of a piece of material; l_{y1}, l_{y2}- is , the length of the first and second sections of the grinding zone, respectively; L_1, L_2 - is distance from the suspension axis to the end of the first and second sections; Ψ_2 - is angle of rotation of the active jaw; $\alpha_{т1}$, $\alpha_{т2}$- are angle of inclination of the conveying surface of the first and second sections of the grinding zone; A_1, A_2 - are amplitude of jaw oscillations at the end of the first and second sections

Figure 3 – Calculation scheme for the profile formation of the working chamber

The length of the loading zone is set based on the required amplitude oscillation of the active jaw, which provides the amount of deformation of the piece before grinding. This section defines the transition from the loading zone to the first rectangular section of the working chamber. Here, the destruction of the pieces to sizes that allow them to freely enter the adjacent rectangular area is completed.

The cross section of the loading zone has the maximum dimensions and, accordingly, the maximum throughput $\Pi_з$ for a given working chamber.

Throughput Π_1 of the first rectangular section of the grinding zone should be no less than the throughput $\Pi_з$ of the loading zone. Based on this condition, the required length of the path that the material passes over the period is determined:

$$\Pi_1 = \Pi_з = \Pi_\Pi = h_1 b S_j \gamma_\Pi k_\Pi,$$

$$S_j = \frac{\Pi_1}{h_1 b \gamma_\Pi k_\Pi}.$$

A piece of material of size D_1, which enters the first section of the grinding zone, will interact with the active jaw at the moment of passing the last position of static equilibrium, where the speed of the jaw movement is maximum. At the end of the section, the size of the piece will decrease by:

$$A_1 = L_1 \tan\frac{\psi_2}{2}\cos\alpha_{T1},$$

where A_1 is the oscillations amplitude of the jaw at the end of the first section; $\alpha_{т1}$–is angle of inclination of the first section of the crushing zone.

The distance from the jaw suspension axis to the end of the first section $L_1$is:

$$L_1 = \sqrt{\left(d + l_{y1}\sin\alpha_{T1}\right)^2 + \left(l_{Tз} + l_{y1}\cos\alpha_{T1}\right)^2},$$

where d- is the distance from the suspension axis to the working surface of the active jaw in the loading area; l_{y1}- is length of the first section of the grinding zone; l_{y3}- is length of the loading zone.

The length of the first section will be determined based on the required number of impact on the piece during the period of its passage through the section. By assuming a one-impact mode, at which one-impact occurs during the period of jaw oscillations, we get:

$$l_{T1} = nS_j,$$

where n is the number of impacts.

The maximum size (D_2) of the material exiting the first section is:

$$D_2 = D_1 - L_1 \tan\frac{\psi_2}{2}\cos\alpha_{T1}$$

and is the initial product of the second (subsequent) section.

In order a piece of material of the D_2 in size interacts with the active jaw in the second section (Fig. 3b) at the moment it passes the position of static equilibrium, where the speed of the jaw movement is maximum, it is necessary to make a ledge on the working surface of the active jaw with a height h_{y1} equal to the amplitude oscillations A_1 of jaws in this section, i.e. $h_{y1} = A_1$.

The ledge reduces the cross section of the second section, however, its throughput must retain its specified value, that is $П_2 = П_1 = П_з$. This requirement is ensured by increasing the speed of material movement by increasing the angle of inclination $\alpha_{т2}$ of the second section relative to the first, i.e. the following condition must be fulfilled: $\alpha_{т2}>\alpha_{т1}$.

Similarly, the following sections of the working chamber are developed, in which the distance from the suspension axis to the end of the i-th section will be:

$$L_i = \sqrt{\left(d + \sum_{i=1}^{n} l_{yi} \sin \alpha_{Ti}\right)^2 + \left(l_{Tз} + \sum_{i=1}^{n} l_{yi} \cos \alpha_{Ti}\right)^2}.$$

The height of the ledge of the i-th section is:

$$h_{yi} = A_i = L_i \tan \frac{\psi_2}{2} \cos \alpha_{Ti}.$$

The length of the i-th rectangular section is:

$$l_{yi} = n_i S_{ji},$$

where n_i - is the required number of impacts in the i-th rectangular area; S_{ji} is the necessary distance which the material will pass in the i-th rectangular section.

The number of rectangular sections depends on the required degree of grinding of the material.

Conclusion. The calculation of the kinematic parameters of the crusher with an inclined crushing chamber is the basis on which, with the known information about the physical and mechanical properties and dimensions of initial and final products, the dynamic and power (energetic) parameters of the crusher are determined.

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ПІДВИЩЕННЯ ЕФЕКТИВНОСТІ РОБОТИ ВІБРОУДАРНОГО ПОДРІБНЮВАЧА З ПОХИЛОЮ РОБОЧОЮ КАМЕРОЮ

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Анотація. У загальному ланцюзі технологічного процесу переробки корисних копалин дробильно – подрібнювальна операція є найдорожчою у зв'язку із споживанням значної кількості електроенергії. Це зумовлює необхідність створення нових економічних машин та технологій. Проведений у Національному технічному університеті «Дніпровська політехніка» великий обсяг досліджень дозволив вперше обґрунтувати можливість застосування віброщокової дробарки з вертикально розташованою камерою та маятниковим підвісом щік як самостійного подрібнюючого агрегату для одержання порошкових матеріалів, а також у виробничих процесах, що потребують спеціальних технологічних режимів. Розвитком цього напряму є створення віброударного подрібнювача з похилою робочою камерою, що забезпечує регулювання величини силового впливу на матеріал у широких межах.

Вібраційний подрібнювач із похилою робочою камерою включає основні елементи: пасивну щоку, розташовану на амортизаторах, активну щоку, шарнірно встановлену в корпусі та пов'язану з ним за допомогою пружних зв'язків, двохвальний інерційний віброзбудник.

На підставі наведеної розрахункової схеми руху матеріалу до розвантажувальної щілини, визначено скорочення обсягу та пропускної здатності в кожному поперечному перерізі робочої камери. При досягненні граничних значень настає режим пресування матеріалу, розсування щік, зниження ефективності робочої камери та продуктивності подрібнювача. Будучи найменшою пропускною здатністю з усіх перерізів камери дроблення, паралельна зона визначає пропускну здатність дробарки, а також продуктивність її пристрою живлення. Розглянуто можливість підвищення пропускної здатності за допомогою збільшення кута нахилу паралельної зони та узгодження швидкостей руху матеріалу на різних ділянках робочої камери. На підставі проведених досліджень розроблено профіль камери у вигляді багатогранної робочої поверхні пасивної щоки та ступінчасту поверхню активної щоки. Наведено аналітичні вирази для розрахунку параметрів профілю похилої робочої камери віброударного подрібнювача.

Ключові слова: вібраційний подрібнювач, камера, пропускна здатність.

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