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# RESEARCH OF OPERATIONAL PARAMETERS OF THE CENTRIFUGAL MODULE DURING ROCK MASS PROCESSING

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**Abstract.** This article presents research of the operating parameters of a centrifugal disintegrating module when processing rock mass. It consists of determining the dependence of the material degree of crushing on the rock mass characteristics and the disintegrator operational parameters, using a physical research method. At the initial stage, the percentage distribution of particle size classes of the material after grinding was established. It confirmed the feasibility of using an additional screening surface in the form of a mesh, which significantly affects the increase in the percentage yield of small classes of crushed material, namely classes -160 and –100 microns. It can be explained by the continuous screening of the finished material product, which helps to improve the grinding process by eliminating the effect of volumetric compression of the material. It was found, that the use of vibration when using a mesh is mandatory, since the presence of vibration from the rotation of the rotors and the movement of air inside the grinding chamber were insufficient for fine material screening. The main part of the research was to establish the nature of degree of the material grinding dependence on three types of raw materials differing in strength and initial size, as well as the amplitude of vibrations of the screening surface. It was determined, that the stronger is the source material, the lower is degree of its grinding. But it should be taken into consideration, that for many natural materials, with increasing of their strength, their fragility also increases, which improves grinding performance. Also, the larger pieces of material are loaded into the disintegrating module, the greater is degree of its grinding. It is explained by the peculiarity of the operation of centrifugal disintegrators, which use centrifugal forces to accelerate a piece of material with its subsequent impact on the lining or oncoming flow of material, with the most optimal initial size of the material, for the given dimensions and operating parameters of the centrifugal disintegrating module, is within the range $\Delta$ = 7–9 mm. It was established that an increase within acceptable limits in the amplitude of vibrations of the screening surface leads to an increase in the degree of grinding. In general, the conducted research confirmed the prospects of using a centrifugal disintegrating module at the last stages of fine grinding in order to reduce energy costs and increase the grinding fineness of rock mass.

**Keywords:** rock mass, grinding, disintegrator, degree of grinding, vibration.

## 1. Introduction

Currently, there is an urgent need to find ways to solve the problem of developing new grinding machines for the mining industry, since existing designs have proven unable to meet the ever-increasing requirements for reducing energy consumption in the grinding process. In this context, one of the very promising methods is the use of centrifugal-impact disintegrators at fine stages of crushing and grinding. This approach, based on centrifugal impact designs, has the potential to significantly improve crushing and grinding processes, optimize energy costs and ensure more efficient use of resources [1–3].

After analyzing the existing designs of disintegrators, as well as searching for opportunities to reduce energy consumption during grinding, a two-rotor centrifugal impact disintegrator was developed at the Institute of Geotechnical Mechanics of the NASU and, during experimental research on it, the efficiency of its operation and the prospects for use were confirmed [4, 5]. The advantage of this machine over single-rotor centrifugal disintegrators is that with the help of two rotors the material flows are directed towards each other in the central part of the grinding chamber. This increases the proportion of shear deformations during the interaction of crushed particles, which, in turn, can significantly reduce the energy costs required to destroy the material.

Subsequently, the two-rotor centrifugal impact disintegrator was improved by converting it into a modular design. It allows for material processing and consists directly of the disintegrator itself and a sieve installed under the grinding chamber with a suitable mesh size, which screens the finished rock mass by size, preventing excessive grinding [ 6]. This effect is achieved by installing a grinding chamber with a sieve on shock absorbers and, under the influence of vibration exciters located on the chamber body, vibration screening of the material is carried out, hence significantly intensifying the grinding process. In the course of experimental research of this design of a centrifugal disintegrating module, the nature of the influence of technological parameters on its productivity and the expended drive power was established, namely, the efficiency of sifting the rock mass in the centrifugal module is in the range of 60÷70%, depending on the separation size class and the density of the processed rock masses. In this case, the productivity of the module increases by 20%, and with the use of vibration excitation of the grinding chamber - by 25–30% [7]. At the same time, in this research, one of the main parameters of material grinding was not disclosed, such as the degree of grinding of the rock mass λ, an indicator that characterizes the degree of reduction in the size of material particles as a result of grinding processes; this parameter is important, since the industry requires to obtain materials of a certain fraction or dispersion to achieve the required product characteristics.

Based on this, the purpose of this work is to research the operating parameters of a centrifugal disintegrating module, namely, to determine the dependence of the degree of grinding on the characteristics of the material and the operating parameters of the disintegrator.

## 2. Methods

When conducting experimental research of the operating parameters of the centrifugal disintegrating module and determining the degree of grinding of materials, a physical research method was used, consisting of the following procedure:

- Preparation of material for grinding.
- Setting up the operation of the module, in which experimental parameters are specified, such as centrifugal disintegrating rotor speed, vibration amplitude, size and strength of the starting material, its quantity, grinding time.
- The material is crushed in the selected equipment in accordance with the configured parameters. The grinding process is carried out for a specified time.
- Once the grinding process is complete, the material is removed from the equipment.
- The crushed material is subjected to sieve analysis, where the sample is screened through a series of sieves of different sizes.
- The data obtained is processed and analyzed to determine the average particle size, distribution, degree of grinding and other characteristics.

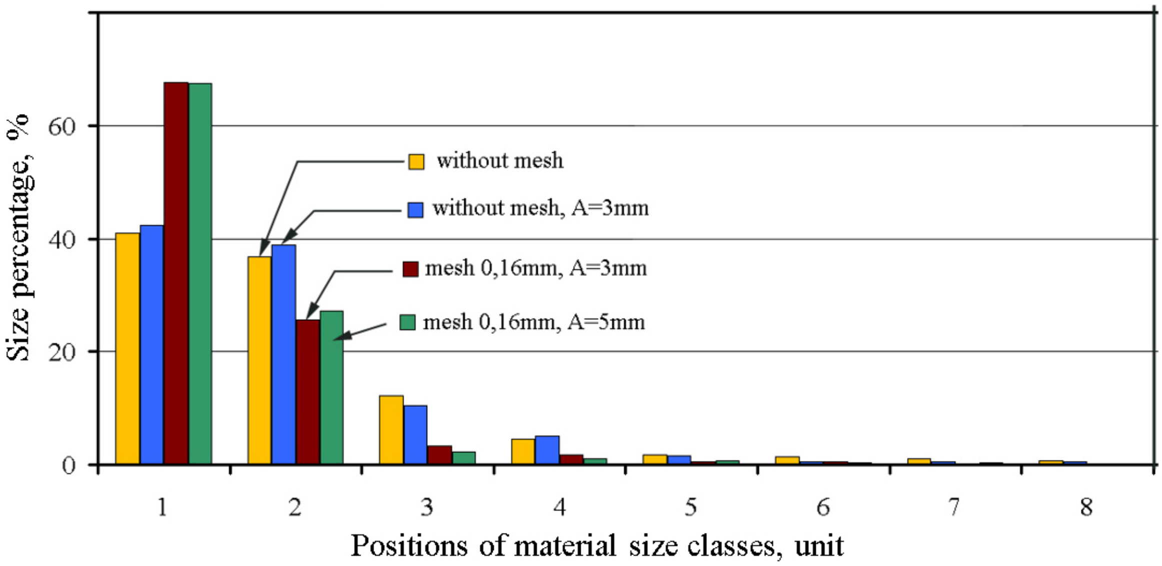
- Depending on the goals and scope of the experiment, the data may be subjected to statistical processing, including the calculation of average values, standard deviations, etc.
- The data obtained is interpreted taking into account the set grinding goals, which makes it possible to draw conclusions about the effectiveness and quality of the crushed material.
- The results are compared with existing grinding methods and material quality requirements for specific scientific applications.

All stages of the experiment, parameters and results obtained are documented for the possibility of their repetition and subsequent analysis

**3. Results and discussion**

Before conducting basic research to determine the degree of grinding of materials under various conditions, it is necessary to research the percentage distribution of size classes after grinding in order to establish the significance of changes in various parameters and the advisability of using them for more detailed research.

For this purpose, marble was chosen as the initial material under research, with the strength $\sigma = 110$ MPa and initial average size $\Delta = 8{,}5$ mm (-10 +7 mm). The mass of crushed material was m = 0.5 kg, and grinding time t = 1 min. The rotor speed was 3000 $min^{-1}$, and vibration vibrations were created by two vibration exciters IV-127-U2, of power 0,27 kW and rotation frequency $\omega = 1500$ $min^{-1}$. At the beginning, the marble was crushed without a mesh, a plate was installed instead, then vibration was added, with a vibration amplitude A = 3 mm. Next, a mesh size of 0.16 mm was installed and the vibration amplitude was A = 3 mm, then the vibration amplitude was increased to A = 5 mm. The obtained data on the percentage distribution of marble size classes after grinding are presented in Figure 1.




Abscissa axis: 1– (-100мкм; 0), 2– (-160; +100мкм), 3–(-250; +160мкм), 4– (-400; +250мкм), 5– (-630; +400мкм), 6– (-1мм; +630мкм), 7– (-1,6; +1мм), 8– (-2,5; +1,6мм)

Figure 1 – Percentage distribution of marble size classes after grinding

When analyzing the data obtained, it is obvious that the use of a screening surface in the form of a mesh significantly affects the percentage increase in the yield of small classes of crushed material, namely -160 and -100 microns, the production of which is the main task of fine grinding, which is explained by the continuous screening of the finished product in the form of small classes material. This helps to improve grinding by eliminating the effect of volumetric compression of the material, which, with this type of impact grinding, reduces the performance of the disintegrator. Adjusting the amplitude of module oscillations also affects the change in the degree of grinding, although not to such a significant extent as using a mesh, but also requires more detailed research.

Additional preliminary research was carried out with the installation of larger mesh cells in the disintegrating module in order to determine the optimal performance characteristics. It showed low grinding rates; this can be explained by the fact that the crushed material simply did not have time to be subjected to repeated exposure to disintegrating rotors but was immediately screened. In general, the size of the sieve cells is selected depending on the requirements for the size of the finished product, as well as the size of the rotors and their speed.

Experiments were also carried out on grinding material with a mesh without vibration. However, they showed negative results due to the fact that the crushed material lay in a layer on the sieving surface, and the presence of vibration from the rotation of the rotors and air movement inside the grinding chamber were insufficient, therefore the presence of forced vibration with these operating parameters of the centrifugal disintegrating module is mandatory.

Based on this, it was decided to research three materials of different strength, namely granite ($\sigma$ = 250 MPa), sandstone ($\sigma$ = 165 MPa) and marble ($\sigma$ = 110 MPa), with different initial sizes $\Delta$ = 12,5 mm (-15; +10 mm); 8,5 mm (-10; +7 mm); 6 mm (-7; +5 mm). All other parameters, such as the mass of the material, the grinding time and the two different vibration amplitudes, were consistent with the previous experiment.

First of all, the dependence of the degree of grinding $\lambda$ of material of various initial sizes on its strength with and without a screening mesh was established, the vibration amplitude was set to A = 3 mm, graphs of the results obtained are presented in Figure 2.

This graph clearly shows an inversely proportional quadratic dependence of the degree of grinding $\lambda$ of the material on its strength $\sigma$ (MPa): the stronger is the material the lower is degree of its grinding. At the same time, after increasing the strength of the material from $\sigma$ = 170–200 MPa there is a decrease in the influence of an increase in the strength of the material on a decrease in the degree of grinding. It is explained by the fact, that in most minerals, with an increase in their strength, fragility and density also increase, which for centrifugal type disintegrating equipment is a positive factor promoting grinding.

To display the dependence of the degree of grinding $\lambda$ of a material of various strengths on its initial size $\Delta$ (mm), the graphs shown in the Figure 3 were drawn.

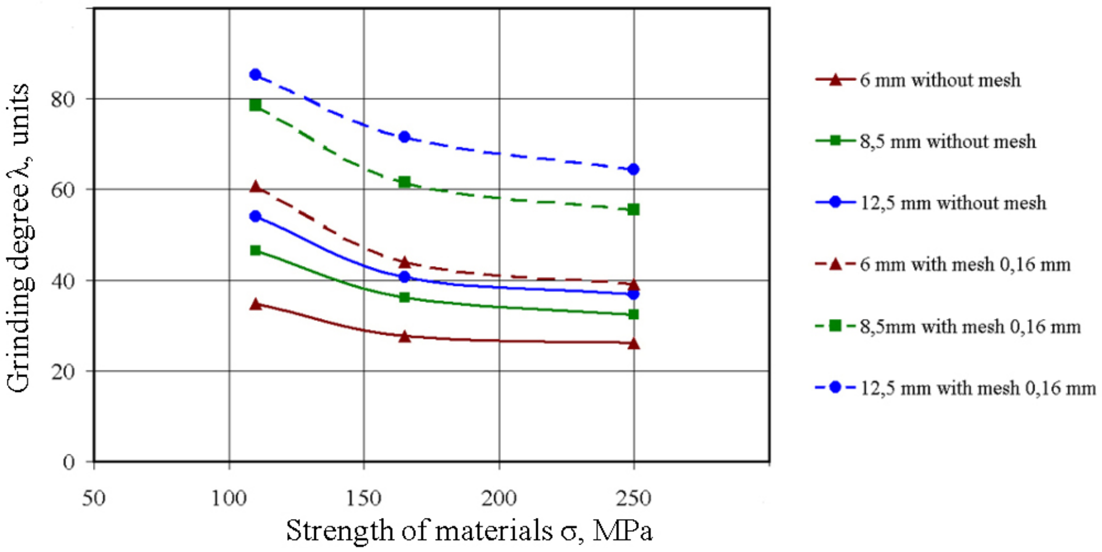



Figure 2 – Graphs of the degree of grinding versus the strength of the starting material

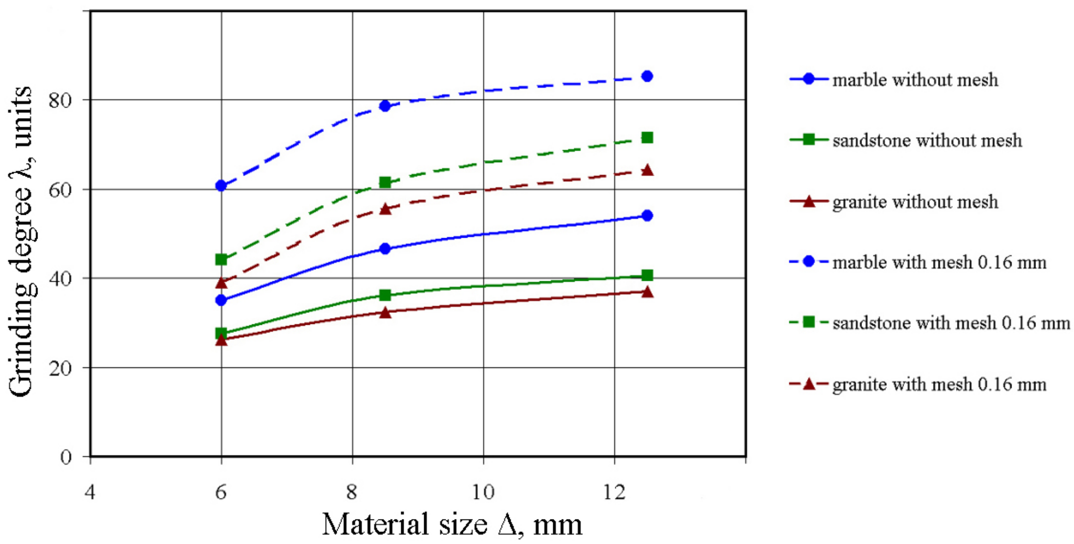



Figure 3 – Graphs of the dependence of the degree of grinding of the material on its initial size

When analyzing the obtained dependencies, a proportional quadratic dependence of the degree of grinding λ of the material on its initial size was established: the larger pieces of material are loaded into the disintegrating module, the greater is degree of its grinding. This observation is explained by the peculiarity of the operation of centrifugal disintegrators, which use centrifugal forces to accelerate a piece of material with its subsequent impact on the lining or oncoming flow of material. The larger is the initial piece of material, the greater is the kinetic energy it acquires when accelerated by the rotor. At the same time, based on the nature of the dependencies, the most optimal initial material size for this installation is within the range Δ = 7–9 mm.

Further research of the operating parameters of the centrifugal disintegrating module consisted of determining the dependence of the degree of grinding of the material on its technological parameters, namely the amplitude of the module's oscillations, since the effect of changing the rotor shaft speed for centrifugal disintegrators was researched in detail in previous research.

The tests were carried out, as in previous experiments, for three different types of materials in terms of strength and three different sizes of the initial product, the amplitude of vibrations varied within the range A = 3–5 mm. All other parameters were consistent with previous experiments. Graphs of the obtained results are presented in Figures 4 and 5.

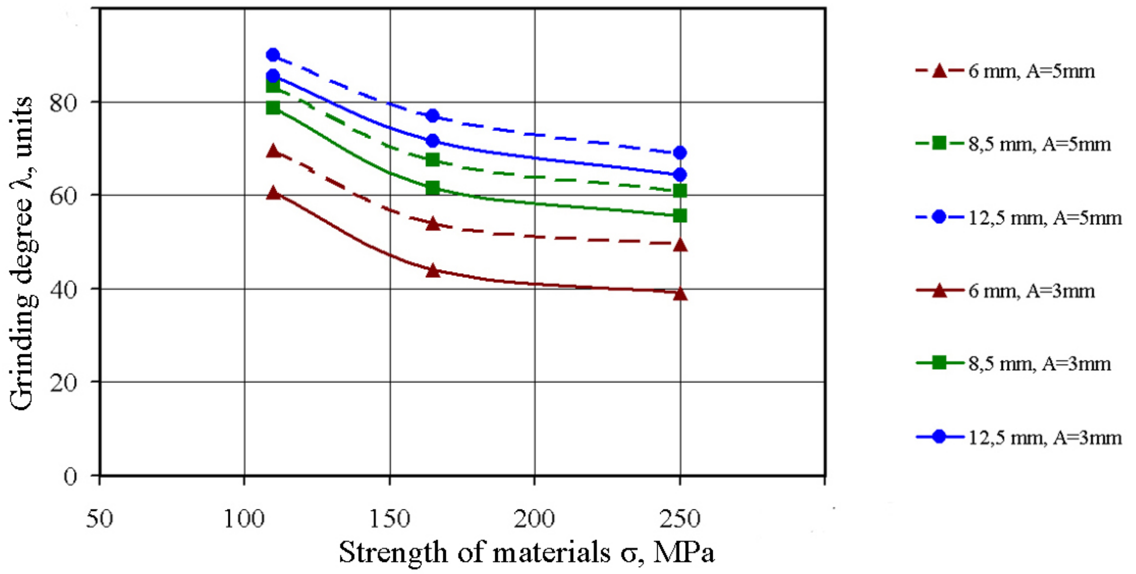



Figure 4 – Graphs of the dependence of the degree of grinding of a material on its strength at different vibration amplitudes

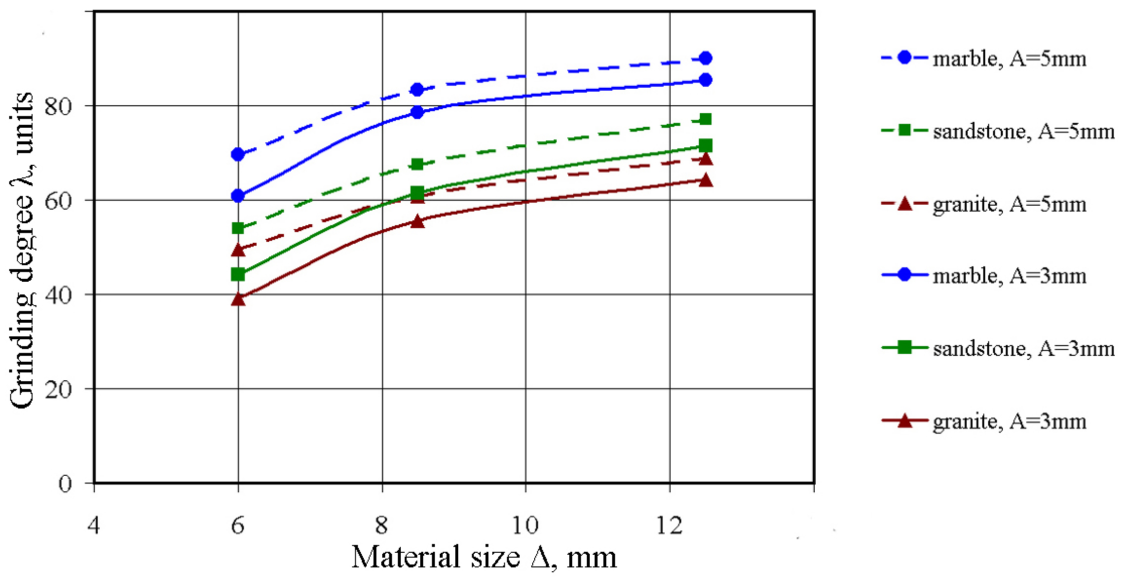



Figure 5 – Graphs of the dependence of the degree of grinding of the material on its initial size at different vibration amplitudes

It becomes obvious, that the degree of grinding of the material is directly proportional to the amplitude, based on the nature of the obtained dependences of the degree of grinding of the material on its strength and initial size, taking into account the influence of the vibration amplitude of the grinding chamber with a sifting surface. The degree of grinding increases together with an increase in the amplitude of vibrations. The most significant effect of increasing amplitude on the degree of grinding of the material is observed in the small and strong initial product. At the same time, the use of a large vibration amplitude of the disintegrating module has a negative impact on the structural and technological elements of a dynamically loaded device, so there is no need for a significant increase in the vibration amplitude.

## 4. Conclusions

As a result of the conducted research, the significant influence of the use of the screening surface of a centrifugal disintegrator on increasing the degree of grinding was established. In particular, the use of a mesh makes it possible to increase the degree of grinding by 30–40% with other parameters being equal and to increase the yield of fine classes of materials (-160 and -100 μm) at processing of rock mass. It was established, that the stronger is the material, the lower is degree of its grinding; also, the larger pieces of material are loaded into the disintegrating module, the greater is degree of its grinding. The influence of changes in the vibration amplitude of the grinding chamber and the screening surface on the grinding process was also determined; an increase in the vibration amplitude within acceptable limits leads to an increase in the degree of grinding.

The practical significance of the results obtained are the confirming the prospects of using the developed design of a centrifugal disintegrating module for processing rock mass and the need to remove the finished material from the grinding chamber in order to avoid its over-grinding and eliminate the effect of volumetric compression. Based on this, recommendations for the practical use of the results obtained are to use this design of a centrifugal disintegrating module at the last stages of fine grinding in order to reduce energy costs and increase the grinding fineness of the rock mass.

The scientific value of the work carried out is determining the nature of the dependence of degree of the rock mass crushing on its strength and the initial size, for different vibration amplitudes, which will allow further mathematical processing of the experimental results obtained in order to calculate the necessary technological parameters of the centrifugal disintegrating module.

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## ДОСЛІДЖЕННЯ ПАРАМЕТРІВ РОБОТИ ВІДЦЕНТРОВОГО МОДУЛЯ ПРИ ПЕРЕРОБЦІ ГІРНИЧОЇ МАСИ

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**Аннотація.** У цій статті представлені дослідження параметрів роботи відцентрового дезінтегруючого модуля при переробці гірничої маси, що полягають у визначенні залежності ступеня подрібнення матеріалу від характеристик гірничої маси та параметрів роботи дезінтегратора при використанні фізичного методу дослідження. На початковому етапі було встановлено відсотковий розподіл класів крупності матеріалу після подрібнення, яке підтвердив доцільність використання додаткової просіювальної поверхні у вигляді сітки, що істотно впливає на збільшення відсоткового виходу дрібних класів подрібненого матеріалу, а саме класів -160 і -100 мкм. Це пояснюється безперервним відсіванням готового продукту, що сприяє покращенню процесу подрібнення за рахунок усунення ефекту об'ємного стиснення матеріалу. Встановлено, що використання вібрації при застосуванні сітки є обов'язковим, оскільки наявність вібрації від обертання роторів та руху повітря всередині камери подрібнення були недостатні для просіювання дрібнодисперсного матеріалу. Основна частина досліджень полягала у встановленні характеру залежностей ступеня подрібнення матеріалу від трьох різних за міцністю та вихідною крупністю видів сировини, а також амплітуди коливань просіювальної поверхні. Визначено, що чим міцніший вихідний матеріал, тим менший його ступінь подрібнення, але слід враховувати, що у багатьох природних матеріалів зі збільшенням міцності зростає та їхня крихкість, що покращує показники подрібнення. Також, чим більші шматки матеріалу завантажуються в дезінтегруючий модуль, тим більший його ступінь подрібнення. Це пояснюється особливістю роботи відцентрових дезінтеграторів, які використовують відцентрові сили для розгону шматка матеріалу з його наступним ударом об футерування або зустрічний потік матеріалу. При цьому найбільш оптимальна вихідна крупність матеріалу, для даних розмірів і параметрів роботи відцентрового дезінтегруючого модуля, знаходиться в межах $\Delta$ = 7–9 mm. Встановлено, що збільшення в прийнятних межах амплітуди коливань просіювальної поверхні призводить до збільшення ступеня подрібнення. Загалом проведені дослідження підтвердили перспективність використання відцентрового дезінтегруючого модуля на останніх стадіях тонкого подрібнення з метою зниження енерговитрат та збільшення тонини помелу гірничої маси.

**Ключові слова:** гірнича маса, подрібнення, дезінтегратор, ступінь подрібнення, вібрація.