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V. P. Nadutyy[1], Dr. Sc. (Tech.), Prof.,
orcid.org/0000-0002-2453-0351,
Haddad Jamil[2], PhD, Assoc. Prof.,
orcid.org/0000-0003-3787-0010,
V. V. Sukharyev[1], Cand. Sc. (Tech.),
orcid.org/0000-0002-7102-4734,
A. O. Loginova[1], Cand. Sc. (Tech.),
orcid.org/0000-0002-7274-5330

1 – Institute of Geotechnical Mechanics named by N. Polyakov of National Academy of Science of Ukraine, Dnipro, Ukraine, e-mail: agnivik@ukr.net
2 – Al-Balqa Applied University, Amman, Jordan, e-mail: drjamil@bau.edu.jo

THE RESULTS OF EXPERIMENTAL STUDIES OF INFLUENCE OF VARIABLE PARAMETERS ON THE PERFORMANCE INDICATORS OF SHOCK-CENTRIFUGAL DISINTEGRATOR

Purpose. A study of the change in the magnitude of productivity of a shock-centrifugal disintegrator and the power output of its drive, with variations in the rotor speed with impactors in the chamber, the size and type of the initial grinded rock mass, and comparison of the technological performance of a single-chamber and two-chamber disintegrator.

Methodology. Laboratory research on bench equipment with subsequent processing of the experimental results obtained by computer programming.

Findings. It is established that in comparison with the single-chamber disintegrator in the new two-chamber design, the yield of the fine fraction of the rock mass is increased by 1.3–1.7 times, and the productivity of the disintegrator and the reduction of grinding time of the rock mass are fixed.

Originality. For the first time, the character of the dependence of productivity of a two-chamber impact-centrifugal disintegrator and the power of its drive on its rotations and characteristics of the crushed rock mass is determined, and the distribution of classes of the crushed rock mass after grinding is established.

Practical value. The new design of the two-chamber impact-centrifugal disintegrator is efficient and promising because it divides the flow of rock mass into two chambers and thereby reduces the load on the rotor shaft, which increases its working time and the productivity of the disintegrator, and also reduces the grinding time of the rock mass. This allows recommending a new construction of a two-chamber impact-centrifugal disintegrator for use in industrial conditions.

Keywords: *disintegrator, destruction, impact, shear, rock mass, productivity, power*

Introduction. Centrifugal disintegrators are widely used in the processing and preparation for the enrichment of the rock mass and their use is a promising direction. The main advantages of centrifugal disintegrators are as follows: a high degree of reduction of the size of the ground material, the possibility of organizing dry and wet grinding process, stable particle size distribution of the product, the possibility of obtaining a cubic form of the material. However, the existing drawbacks in the design of centrifugal disintegrators restrain their widespread use. The analysis of their operation during the processing of various rock mass allowed establishing such deficiencies as intensive wear of the surface of the grinding chamber, accelerating rotors and impactors, bearing unit of the shaft of the working body, elastomeric seals, and also revealed the need to increase the duration of work, disintegrator performance and reduce the time spent on grinding the rock mass. The solution of this problem is one of the components of the physical basis of the rational organization of the processes of preparation of ores for enrichment [1].

Analysis of the recent research and publications. A large number of scientific papers are devoted to solving the problem of increasing the duration of disintegrator operation, from which it follows that extreme conditions of operation of centrifugal disintegrators, which include strong, long-term, stationary cyclic loads, high temperature, fatigue-abrasive wear, and also dissipative heating and aging (instability of properties in time and from the action of aggressive environment), development is damaged as a disintegrator structure and the elastomeric seals, which becomes in some cases dominant, influence on selecting the parameters and forms durable and reliable construction. This subsequently leads to increase in the cost of equipment [2–4]. Since the kinematic schemes of disintegrators of various types differ little, these drawbacks are inherent in almost all structures.

The main factor affecting the increased wear of the disintegrator is the high speed of its rotor, caused by the need to increase the impact speed of a piece of rock mass on a fixed obstacle up to 70–100 m/s required when disintegrating ores, with a maximum size of 40–70 mm. Thus, to achieve high performance, it is necessary to either increase the size of the material loading, which is not always feasible, or to increase the impact speed, by increasing the rotor speed of the centrifugal disintegrator [5].

Based on this information, the authors of the article searched for ways to increase the speed of impact of a piece of material without increasing the rotor revolutions. One of such methods is the grinding by counterflow of materials [6, 7]; therefore, the authors have proposed a new design of a centrifugal impact disintegrator, and carried out its preliminary studies, which will reduce these drawbacks and improve the technological performance of machines of this type [8, 9]. A feature of the proposed design is its dual-chamber design, when the rotor shafts are spaced apart in separate chambers, this also reduces the stress state of the chamber and the rotor with impactors, when, with the rotors rotating, they direct the movement of rock mass in opposing streams. This allows one to use the kinetic energy of motion for grinding particles of rock mass, increasing the impact energy mainly by shear deformation. The shear deformation of the rock mass is preferable from the energy point of view, since the compressive strength of the rock is 5–10 times higher than the shear strength and 8–15 times higher than the tensile strength [10].

Unsolved aspect of the problem. In previous works, the authors developed the design of a two-chamber disintegrator and justified its use, also carried out preliminary experiments on grinding one type of rock mass to confirm the implementation of the material fracture mechanism during shear deformations as the most energy-saving and efficient [8, 9]. Subsequently, the need arose to determine the technological characteristics of a two-chamber shock-centrifugal disintegrator for various types of materials in comparison with the characteristics of a single-shaft disintegrator.

Objectives of the article. To solve this problem, it is necessary to perform a study of the change in the output of a shock-centrifugal disintegrator and the power output of its drive when the rotor rotates with the impactors in the chamber, the size and type of the initial crushed rock mass, and compare the technological performance of a single-chamber and two-chamber disintegrator.

Methods. Laboratory studies were carried out on bench equipment; in the subsequent, experimental data were subjected to graphical and statistical processing using computer programs.

Presentation of the main research and explanation of scientific results. The difference between the grinding process in a two-chamber disintegrator (with respect to a single-chamber one) is that in this case the counter flows have twice the interaction force of the particles, mainly of the shear interaction as opposed to the single-chamber execution of the disintegrator, when particles accelerate the chamber walls and collapse. Counter flows make it possible to more fully utilize the drive energy and increase the efficiency of disintegration of the rock mass

The shock-centrifugal disintegrator developed at IGTM works as follows: disintegration material is fed into a multichannel boot device, where each channel is connected to a hole in the disintegrator cover, through these holes the material enters the accelerating rotors installed along the inner surface of the disintegration chamber on the shafts, rotating in one direction, and directly into the central gap formed in the space between the rotors. Thus, a central zone of disintegration is formed in the gap between the rotors, and a peripheral zone on the fender plates. Due to the cumulative effects of kinetic energy directed towards streams of comminuted material in the central disintegration zone between the rotors, the process of destruction of particles is dominated by shear loads, which allows obtaining a product of a wide range of sizes, controlling the disintegration process, and reducing the oversize output, which leads to a significant increase in the efficiency of disintegration and reduction of energy costs for grinding.

Experiments to determine the technological characteristics of a two-chamber shock-centrifugal disintegrator were carried out on a laboratory sample created at IGTM, with a maximum capacity of 200 kg/h, consisting of a grinding chamber, two 0.18-meter rotors mounted on electric motors connected to a frequency regulator that allows one not only to change engine speed, but also to determine the power required for grinding. In the course of the experiment, in order to determine the scope of application of the new design of the disintegrator, various types of materials with different strength characteristics were subjected to grinding: granite, limestone, tufa, basalt. Also, the initial size of the feed material varied from –10 + 7 mm to –5 + 2.5 mm, the engine speed of the disintegrator was adjusted between 2800 and 4760 rpm, the power and time spent on grinding, disintegrator performance and grinding degree were measured according to the rock mass. The results of the experiments are presented in Table.

The authors of the article carried out a graphical analysis of the obtained research results, which will make it possible to present at the model level the dependencies of performance and power consumption of the disintegrator when varying the parameters of the grinding process of the rock mass in the proposed design.

Fig. 1 shows the dependences of the productivity (Q, kg/h) of the two-chamber disintegrator on the number of rotor turns (n, rev/min) with the initial granite and limestone size $\Delta = -10 + 7$ mm. When analyzing the dependencies, it is obvious that the performance of the disintegrator increases with increasing rotor speed, espe-

Table

The results of experimental studies of two-chamber shock-centrifugal disintegrator

Experiment No.	Grinding material	Number of mill chambers	Size of material, mm	σ, material strength, kg/mm²	*n*, rotational speed of the mill shaft, rev/min	*N*, power consumed for grinding, W	*t*, time of grinding one kilogram, s	*Q*, productivity, kg/h	Percent distribution of classes of size after grinding, %						λ, degree of grinding
									−50 mcm	−100 +50 mcm	−2.5 mm +100 mcm	−5 +2.5 mm	−7 +5 mm	−10 +7 mm	
									Average size of grinded material, mm						
									0.025	0.075	1.3	3.75	6	8.5	
1	Granite	1	−10 +7	110	2800	77	96	38	0.9	1.1	8	8.9	19.3	61.8	1.24
2		2	−10 +7	110	2800	92	79	46	2.5	3	31.5	20.8	17.1	25.1	1.95
3		2	−10 +7	110	3780	114	71	51	5	5	33.6	17.9	15.7	22.8	2.13
4		2	−10 +7	110	4760	123	59	61	8	8	45.3	16.1	11.7	10.9	3.00
5		2	−7 +5	110	2800	74	64	56	3	2.9	29.1	34.9	30.1	0	1.72
6		2	−5 +2.5	110	2800	55	55	65	2.5	3	34.2	60.3	0	0	1.38
7	Tufa	2	−10 +7	35	2800	58	40	90	3	4	30	18.1	19.3	25.6	1.93
8		2	−7 +5	35	2800	49	30	120	4	5	34	27	30	0	1.84
9		2	−5 +2.5	35	2800	43	19	189	4	5	45	46	0	0	1.62
10	Limestone	2	−10 +7	43	2800	60	50	72	3.1	3.4	29.3	20.4	19.5	24.3	1.94
11		2	−7 +5	43	2800	54	34	106	3.3	3.6	27.4	33.9	31.8	0	1.70
12		2	−5 +2.5	43	2800	44	20	180	3.4	3.8	40.7	52.1	0	0	1.51
13		2	−10 +7	43	3780	95	40	90	4.5	4.9	36.1	17.8	15.2	21.5	2.19
14		2	−10 +7	43	4760	113	25	144	6.3	7.2	43.6	16.4	11.4	15.1	2.69
15		1	−10 +7	43	2800	50	70	51	0.8	1.2	9.3	10.3	20.3	58.1	1.28
16	Basalt	1	−7 +5	230	2800	68	90	40	0.7	0.8	3.8	16.9	77.8	0	1.12
17		2	−7 +5	230	2800	83	75	48	1.9	1.5	11	32.7	52.9	0	1.32

cially when grinding materials with low strength characteristics, such as limestone, which, if crushed, increases productivity by 100 %, while granite increases by 25 %

Fig. 2 shows the dependences of the productivity (Q, kg/h) of the two-chamber disintegrator on the initial granite and limestone size (Δ, mm) at constant rotor shaft speeds n = 2800 rev/min. It was established from the graph that an increase in the size of the source material leads to a significant decrease in the disintegrator productivity, especially in less durable materials like limestone, for example, an increase in the initial size of limestone by 2 times resulted in a decrease in the productivity of the disintegrator by 2.5 times.

Fig. 3 shows the dependencies of the disintegrator productivity (Q, kg/h) on the number of grinding chambers used (N_p, pcs.), at constant rotor shaft speeds n = = 2800 rev/min and the initial size of granite and limestone $\Delta = -10 + 7$ mm. Comparison of the performance in single-and two-chamber modes of operation of a centrifugal disintegrator shows that in a two-chamber version, the performance of the disintegrator, when grinding various types of materials, increases by 30–50 %.

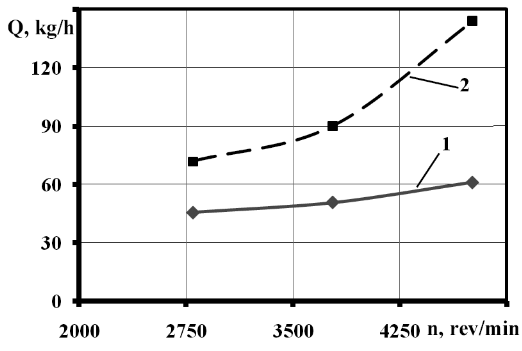

Fig. 1. Dependences of the productivity of the disintegrator on rotor shaft speed:
1 – granite; 2 – limestone

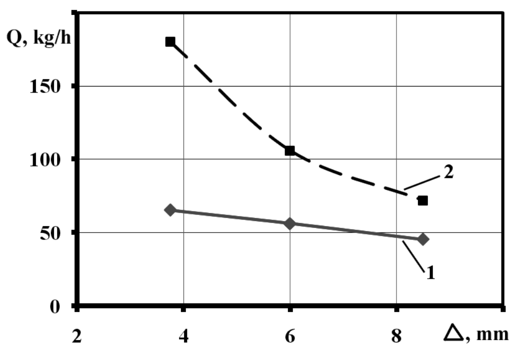

Fig. 2. Dependences of the productivity of the disintegrator on initial material size:
1 – granite; 2 – limestone

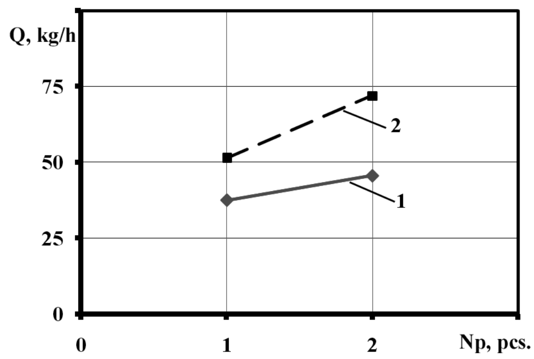

Fig. 3. Dependences of the productivity of the disintegrator on the number of grinding chambers:
1 – granite; 2 – limestone

To determine the energy consumption spent by the disintegrator for grinding, the dependencies of the expended power (*N*, *W*) of the two-chamber disintegrator on the number of rotor turns (n, rev/min) with constant initial size of $\Delta = -10 + 7$ mm were built. (Fig. 4). When analyzing the influence of dependent factors of authority spent on rotor speeds, it was found that with increasing speed, there is an increase in energy costs for grinding, especially for rock mass with low strength characteristics, while, on the basis of previous experiments, an increase in productivity is observed, therefore, to ensure the most. An effective disintegrator grinding process is necessary to consider both of these factors.

Fig. 5 shows the dependences of the power cost (*N*, *W*) on the initial granite and limestone size (Δ, mm) at constant rotor shaft speeds $n = 2800$ rev/min, of which it was found that with increasing initial particle size of solid rock mass, such as granite there is a significant increase in energy costs for grinding, an increase in the initial particle size of less durable comminuted materials causes a smaller increase in energy costs for grinding. The ratio of the increase in energy consumption of durable materials to less durable is approximately equal to the ratio of their strength characteristics.

Fig. 6 shows the dependencies of the expended power (*N*, *W*) of the disintegrator on the number of grinding chambers used (N_p, pcs.), at constant rotor shaft turns $n = 2800$ rev/min and the initial grain size of granite and limestone $\Delta = -10 + 7$ mm. Data dependencies compared to the power consumed for grinding in single-and two-chamber modes of operation of a centrifugal disintegrator show that in a two-chamber design, the consumed grinding power for different types of materials increases by 20–30 %, and the increase in productivity of the disintegrator is respectively 30–50 %.

An important technological indicator of the work of the disintegrator is the percentage distribution of the size classes of the rock mass after grinding and its comparison with single-chamber and two-chamber versions for equal test conditions. Fig. 7 presents the results of such studies for granite with respect to the initial particle

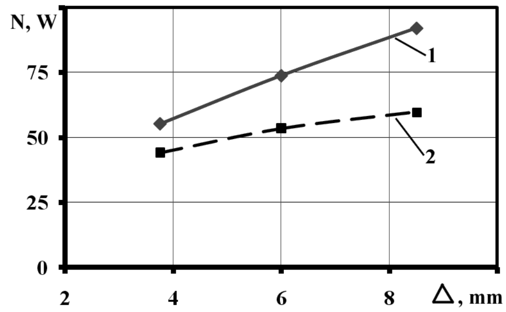

Fig. 5. Dependences of disintegrator power consumption on initial material size:
1 – granite; 2 – limestone

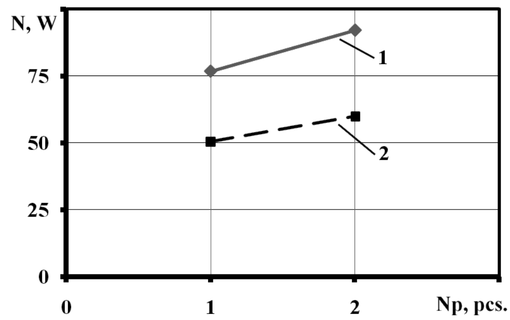

Fig. 6. Dependences of disintegrator power consumption on the number of grinding chambers:
1 – granite; 2 – limestone

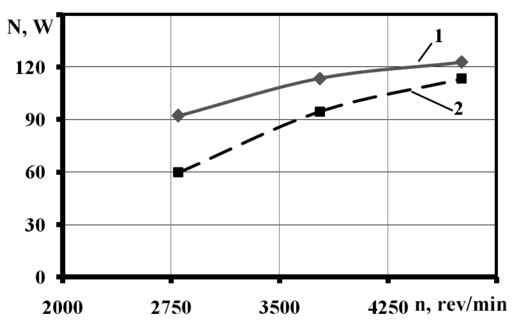

Fig. 4. Dependences of disintegrator power consumption on rotor shaft speed:
1 – granite; 2 – limestone

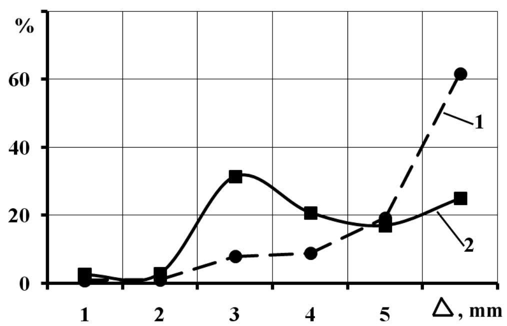

Fig. 7. Percentage distribution of granite size classes after grinding in a disintegrator:
1 – single-chamber; 2 – two-chamber

size $\Delta = -7 + 5$ mm and rotor shaft revolutions $n = 2800$ rev/min. Comparison of the percentage distribution of the size of the rock mass after grinding in the disintegrator shows that when grinding in a two-chamber disintegrator compared to a single-chamber, there is a significant increase in the yield of the fine fraction, which is reflected in the growth of the grinding mass λ within 50 % (Table).

Conclusions. As a result of experimental studies, it was found that the new design of a two-chamber shock-centrifugal disintegrator proposed by the authors is efficient and promising, since it allows the flow of the crushed rock mass to be divided into two chambers, which reduces the load on the rotor shaft and increases the mill operation time. At the same time, the output of the fines fraction of the rock mass increases by 50 %, and the productivity of the disintegrator is recorded depending on the type of rock mass by 25–100 %, which makes it possible to recommend the new design of the two-chamber impact centrifugal disintegrator for use in industrial conditions.

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Результати експериментальних досліджень впливу варійованих параметрів на показники роботи ударно-відцентрового дезінтегратора

В. П. Надутий[1], *Хаддад Джаміль*[2], *В. В. Сухарєв*[1], *А. О. Логінова*[1]

1 – Інститут геотехнічної механіки імені Н. С. Полякова Національної академії наук України, м. Дніпро, Україна, e-mail: agnivik@ukr.net

2 – Прикладний університет Аль-Балка, м. Амман, Йорданія, e-mail: drjamil@bau.edu.jo

Мета. Дослідження зміни величини продуктивності ударно-відцентрового дезінтегратора й потужності, що витрачається його приводом при варіюванні обертами ротора з ударниками в камері, крупністю й типом вихідної подрібнюваної гірської маси, а також порівняння технологічних показників роботи однокамерного та двокамерного дезінтегратора.

Методика. Лабораторні дослідження на стендовому обладнанні з наступною обробкою отриманих експериментальних результатів за допомогою комп'ютерних програм.

Результати. Встановлено, що в порівнянні з однокамерним дезінтегратором в новій двокамерній конструкції вихід дрібної фракції гірської маси збільшується в 1,3–1,7 рази, а також фіксується зростання продуктивності дезінтегратора та зменшення часу подрібнення гірської маси.

Наукова новизна. Уперше визначено характер залежності величини продуктивності двокамерного ударно-відцентрового дезінтегратора й потужності, що витрачається його приводом від обертів і характеристик подрібнюваної гірської маси, а також встановлено розподіл класів крупності гірської маси після подрібнення.

Практична значимість. Нова конструкція двокамерного ударно-відцентрового дезінтегратора є працездатною й перспективною, оскільки розділяє потік завантаження гірської маси на дві камери та цим знижує навантаження на вал ротора, що збільшує його тривалість роботи та продуктивність дезінтегратора, а також зменшує час подрібнення гірської маси. Це дозволяє рекомендувати нову конструкцію двокамерного ударно-відцентрового дезінтегратора для використання у промислових умовах.

Ключові слова: *дезінтегратор, руйнування, удар, зсув, гірська маса, продуктивність, потужність*

Результаты экспериментальных исследований влияния варьируемых параметров на показатели работы ударно-центробежного дезинтегратора

В. П. Надутый[1], *Хаддад Джамиль*[2], *В. В. Сухарев*[1], *А. А. Логинова*[1]

1 – Институт геотехнической механики имени Н. С. Полякова Национальной академии наук Украины, г. Днепр, Украина, e-mail: agnivik@ukr.net

2 – Прикладной университет Аль-Балка, г. Амман, Иордания, e-mail: drjamil@bau.edu.jo

Цель. Исследование изменения величины производительности ударно-центробежного дезинтегратора и затрачиваемой мощности его привода при варьировании оборотами ротора с ударниками в камере, крупностью и типом исходной измельчаемой горной массы, а также сравнение технологических показателей работы однокамерного и двухкамерного дезинтегратора.

Методика. Лабораторные исследования на стендовом оборудовании с последующей обработкой полученных экспериментальных результатов с помощью компьютерных программ.

Результаты. Установлено, что по сравнению с однокамерным дезинтегратором в новой двухкамерной конструкции выход мелкой фракции горной массы увеличивается в 1,3–1,7 раза, а также фиксируется рост производительности дезинтегратора и уменьшение времени измельчения горной массы.

Научная новизна. Впервые определен характер зависимости величины производительности двухкамерного ударно-центробежного дезинтегратора и затрачиваемой мощности его привода от оборотов и характеристик измельчаемой горной массы, а также установлено распределение классов крупности горной массы после измельчения.

Практическая значимость. Новая конструкция двухкамерного ударно-центробежного дезинтегратора является работоспособной и перспективной, поскольку разделяет поток загрузки горной массы на две камеры и этим снижает нагрузку на вал ротора, что увеличивает его продолжительность работы и производительность дезинтегратора, а также уменьшает время измельчения горной массы. Это позволяет рекомендовать новую конструкцию двухкамерного ударно-центробежного дезинтегратора для использования в промышленных условиях.

Ключевые слова: *дезинтегратор, разрушение, удар, сдвиг, горная масса, производительность, мощность*

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