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To cite this article: V V Voronin et al 2020 IOP Conf. Ser.: Earth Environ. Sci. 422 012114

View the article online for updates and enhancements.
Comparative analysis towards the use of needle-shaped working body in sieve and sieve-free multifaceted crushers

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Abstract. The paper provides comparative studies about the use of a needle-shaped working body in a sieve and sieve-free crusher of a multifaceted type. The possibility of reducing the energy intensity regarding the process of grinding feed grain is revealed, taking into account the quality of the end product in a hammer-type multifaceted crusher of a sieve-free type by using the needle-shaped shock elements in a crushing chamber.

To identify the influence patterns of the needle-shaped working elements on the quality and energy indicators of the working process in crushing feed grain performed by a sieve-free multifaceted type crusher, a rotor was produced and tested experimentally.

In the research the energy indicators were measured by the standard method, crusher performance was determined, and a grinding module and the qualitative composition of the crushed product were defined. Based on the research results, the experimental dependencies were built, which allowed to identify the following structural and technological parameters of the crusher: the optimal number of shock elements placed on the rotor; peripheral speed of the working bodies; specific energy consumption; the composition of the particle-size product with a different grinding module, the presence of pulverulent fractions (< 0.2 mm), as well as the amount of coarse fraction (> 2 mm). The experimental results have confirmed the feasibility of using the needle-shaped working element in a sieve-free crusher of a multifaceted type.

1. Introduction

In production lines when concentrated feeds are produced, hammer crushers, simple in design and reliable in operation, are mainly used. They are divided into sieves and sieve-free ones. The active working body in these devices is, as a rule, a plate hammer [1]. The disadvantage of hammer crushers is a significant specific energy consumption and heterogeneity of the granulometric composition of the end product. The explanation for this is the large mass of plate hammers and their uneven placement in packages on the rotor [2, 3, 4, 5]. The work [6] on the feasibility of using needle-shaped elements in a sieve hammer crusher proved the effectiveness of their use. This is explained by the fact that a large number of needle-shaped shock elements and their uniform distribution around the circumference of the rotor contributes to the fact that one working element accounts for a smaller amount of crushed material. This prevents from particles accumulation that occurs in serial crushers between hammer packs. As a result, the grinding intensity increases [7].
2. Methods and materials
In order to identify the operability of the needle-shaped element during grain-free crushing, by analogy with the rotor used on the sieve crusher, a rotor with needle-shaped working elements was manufactured as applied to a twelve-sided sieve-free hammer crusher (Figure 1b).

![a - for a sieve crusher](image1a.png) ![b - for a sieve-free crusher](image1b.png)

**Figure 1.** Rotors experimental samples with needle-shaped working elements

A series of experimental studies was carried out, which allowed to identify the main relationships between the performance indicators when using needle-shaped shock elements in a crushing chamber and to draw conclusions about its most optimal parameters.

Experimental studies were carried out in the university laboratory (Voronezh State Agrarian University) named after Peter I. The fractional composition of the end product was determined by using a sieve classifier, which was designed as prefabricated cylinder of sieves with round holes, with diameter of 0.2 to 3 mm and it was mounted on the mechanism with reciprocating motion [8].

The moment of steady-state operation of the crusher was determined by means of the ammeter E-30. The experiment duration was determined by a stopwatch S-2-1b, accuracy class 2.

The weight of the selected samples of the crushed product from the classifier was determined by using an electronic type balance with measurement accuracy up to 0.01%.

The energy consumption for grain crushing was determined by using an electric meter to account for electric energy with a nominal current frequency of 50 Hz.

In addition, the meter accounts were monitored by using a K-50 control and measuring kit operating in the frequency range of 45–65 Hz. The measurement error of the kit is not more than 0.5%.

The rotor speed of the crusher was determined by using a tachometer T 410-P GOST 13082-71.

The number of percussion elements in the course of research ranged from 170 to 460 pcs. The peripheral rotor speed also varied from 41.4 to 65 m/s by replacing V-belt pulleys.

3. Study on structure of modified lead-tin-base bronze
Based on the research results, experimental dependencies have been built.

Figure 2 shows the dependence of the specific energy consumption on the number of impact elements for various values of the grinding module when crushing grain in a multifaceted sieve-free crusher. Specific energy consumption is presented taking into account idling.
The analysis targeted at the dependence shows that with an increase in the number of elements, the energy consumption first decreases and then increases. The minimum energy consumption is observed when the number of elements is 360. This dependence is explained by the fact that with an increase in the number of elements, the nature of the interaction with the crushed particles changes, and the proportion of idle speed also increases. The graph shows that the optimal zone is in the range from 300 to 400 elements. The use of less than 300 or more than 400 elements is not reasonable.

Figure 3 shows the dependence of the grinding module and specific energy consumption, taking into account the idle speed from the peripheral speed of the impact elements during grain grinding in a sieve-free hammer crusher.

The dependence shows that with an increase in the operating speed, the grinding module decreases, and the energy consumption increases. With an increase in the peripheral speed of more than 60 m/s, an insignificant decrease in the module is observed, and an increase in energy consumption, on the contrary, becomes more significant. This suggests that the rational value is in the range of 60 - 63 m/s.

Based on the studies performed, the comparative dependencies between the grinding module and the specific energy consumption for crushers with needle-shaped working elements and plate hammers [9], involved both in the sieve hammer crusher and in the sieve-free, are constructed. These dependencies are presented in Figure 4.

Figure 2. Dependence of specific energy consumption on the number of working elements

1- M = 1.40 mm; 2-M = 1.6 mm; 3-M = 1.8 mm; 4-M = 2.2 mm; 5-M = 2.2 mm.
1 - Sieve hammer crusher with a standard rotor of 8 packages of hammers; 2 - Sieve-free hammer crusher with a standard rotor of 8 packages of hammers; 3 - Sieve hammer crusher with needle-shaped working elements, \( z = 1000 \text{ pcs/m}^2 \); 4 - Sieve-free hammer crusher with needle-shaped elements, \( z = 460 \text{ pcs. (740 pcs/m}^2) \)

**Figure 3.** Dependence of grinding module and specific energy consumption, taking into account idle speed from peripheral speed of impact elements

**Figure 4.** Dependence of specific energy consumption on grinding module
The analysis of the dependences shows that the smallest unit energy consumption with a slight discrepancy falls on the shredders with the complete set of the rotor with needle-shaped elements. The minimum values of the specific energy consumption were obtained on a sieve-free crusher. So, with the grinding module of 1.6 mm, the energy savings on a sieve-free crusher with a needle-shaped element, in comparison with a sieve with a similar working body, is 1 kWh/t. However, there is a limited range of the grinding module. It was not possible to obtain a fine grinding module on a sieve-free crusher with a needle-shaped organ. This shows to the use of this sieve-free multi-faceted crusher in livestock farms when concentrated medium and large grinding module feeds are used for animals feeding [10].

Figure 5 shows the dependence of the content of the under-grinded and over-grinded fraction left after the grinding module.

The presence of too large and too small particles in the end product is undesirable, therefore, the lower their content, the higher the quality of the product [8, 11, 12, 13].

With an increase of the grinding module, the number of large particles increases, and the number of small particles decreases.

The best indicator of dust content was obtained on a sieve crusher with using needle-shaped elements. So, with the grinding module of 1.25 mm, dust-like fractions (<0.2 mm) amounted to 5%.

Figure 5. Dependence of the content of fine and coarse fractions on the grinding module

1- Sieve hammer crusher with the standard rotor of 8 packages of hammers, fraction output < 0.2 mm; 2- Sieve hammer crusher with a rotor equipped with needle-shaped elements $z = 1000$ pcs/m, fraction output < 0.2 mm; 3- sieve hammer crusher with the standard rotor of 8 hammer packages, fraction output > 2 mm; 4- Sieve hammer crusher with a rotor equipped with needle-shaped elements $z = 1000$ pcs/m, fraction output > 2 mm; 5- Sieve-free hammer crusher with the standard rotor of 8 packages of hammers, fraction output < 0.2 mm; 6. Sieve-free hammer crusher with needle-shaped elements $z = 360$ pcs. (573 pcs/m$^2$) fraction output < 0.2 mm; 7- Sieve-free hammer crusher with the standard rotor of 8 packages of hammers, fraction output > 2 mm; 8. Sieve-free hammer crusher with needle-shaped elements $z = 360$ pcs. (573 pcs/m), fraction output > 2 mm.

The minimum content of the coarse fraction ( >2 mm) was obtained on a sieve crusher with needle-shaped elements, so with the module $M = 1.3$ mm the coarse fraction was 18%.
4. Conclusion
The studies have established:
1. The optimal number of impact elements for a multifaceted sieve-free crusher is in the range of 300-400 elements.
2. The optimal specific energy consumption for the peripheral speed for a multifaceted sieve-free crusher equipped with the impact elements is in the range of 61-63 m/s.
3. Comparative experiments of the sieve and a sieve-free crusher of a multifaceted type, equipped with both impact the needle-shaped elements and plate hammers, showed that the minimum values of the specific energy consumption of 5 kWh/t were obtained on the sieve-free crusher equipped with the needle-shaped impact elements. This allows to reduce the energy costs by 16.7% in comparison with a sieve crusher equipped with a similar working body.
4. Evaluation carried out based on the comparative analysis results targeted at the quality of the end product shows: a lower content of the dust fraction was obtained on a sieve crusher using the needle-shaped elements. So, with the grinding module of 1.25 mm, dust-like fractions (< 0.2 mm) amounted to 5%. The minimum content of the coarse fraction (> 2 mm) was obtained on a sieve crusher with the needle-shaped elements, so with the module M = 1.3 mm the coarse fraction was 18%.
5. The quality of the end product that was obtained on all considered crushers, equipped with both plate hammers and impact elements, corresponds to GOST for feeds. The sieve-free hammer crusher equipped with the needle-shaped impact elements is preferred from the point of the specific consumption rate to obtain the medium and large grinding module, and from the position of the quality the sieve hammer crusher equipped with similar working bodies is in preference.

References
[1]  Alatoom M F A 2016. Features grindes - mixer with optimization of parameters, Innovative Solutions in Modern Science 2 79-94
[2]  Savinyh P, Aleshkin A, Nechaev V and Ivanov S 2017 Simulation of particle movement in crushing chamber of rotary grain crusher Engineering for Rural Development Proceedings 309-316
[3]  Fang Ch and Campbell G M 2003 On predicting roller milling performance iv: effect of roll disposition on the particle size distribution from first break milling of wheat Journal of Cereal Science 37(1) 21-29
[4]  Sare I R, Mardel J I and Hill A J 2001 Wear - resistant metallic and elastomeric materials in the mining and mineral processing industries- an overview Wear 250(1-12) 1-10
[5]  Sysuev V, Savinyh P, Aleshkin A and Ivanovs S 2017 Investigation of oscillations of hammer rotor of grain crusher Engineering for Rural Development Proceedings 1225-1232
[6]  Sundeev A A, Akimenko A V and Voronin V V 2014 Formation of granulometric composition of the finished product when grinding barley on a hammer crusher with needle-like working elements Bulletin of the Voronezh state agrarian University 1-2 87-92
[7]  Bulgakov V, Pascuzzi S, Ivanovs S, Kaletnik G and Yanovich V 2018 Angular oscillation model to predict the performance of a vibratory ball mill for the fine grinding of grain Biosystems Engineering 171 155-164
[8]  GOST 13496.8-72 2011 Complete feed Methods for determining the size of grinding and content of non-ground seeds of cultivated and wild plants (Moscow)
[9]  Voronin V V, Sundeev A A and Yarovoy M N 2015 Evaluation of the efficiency of the use of modernized lattice-less hammer crusher Science and business: ways of development 11 7-10
[10] Fedorenko I Ya and Sadov V V 2017 Production of compound feeds in collective farm and agricultural holding: Recommendations (Barnaul: Altai Srare Agrarian University)
[11] Fedorenko I Ya, Sadov V V and Shagdyrov I B 2012 Theoretical bases of optimization of the aggregate-size distribution of groats is produced by grinding feed grain Polzunovskij Vestnik (2/2) 299-233
[12] Konoshin I V, Bulavintsev R A, Volzhentsev A V and Bashkirev A P 2018 Experimental and theoretical study of hammer crusher operation Bulletin of Kursk State Agricultural Academy named after Prof. I.I. Ivanov 9 198-204

[13] Shub G I 1962 On the issue of improving the efficiency of hammer crushers Milling and Elevator industry 12 18-20