CHARACTERISTICS OF THE FRACTION SIZE DISTRIBUTION AND THE RATE OF CRUSHING FOR A LABORATORY-SCALED COMPLEX PENDULUM JAW CRUSHER

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ABSTRACT. Some of the paramount technological parameters of jaw crushers are the fraction size characteristics of the crushed product and the rate of crushing (*i*). The manual of every machine outlines those but very often it does not specify the width of the discharge gap (b) of the crusher and how this affects the fraction size characteristics of the crushing process and the achieved rate of crushing. All these factors aggravate the choice of crusher purchase and result in errors. For this reason, an experiment has been carried out with a laboratory-scaled complex pendulum jaw crusher with the size of the feeding gap of 100 x 155 mm. The sieve analyses performed have helped construct fraction size characteristics for the crushing products and define the degree of crushing of the mineral at varying widths of the jaw crusher's outlet gap and at varying lump or grain sizes of the input material to be crushed. The results obtained have been analysed and conclusions have been drawn regarding the technological parameters of the jaw crusher under the specified working conditions.

Keywords: jaw crushers, discharge gap, fraction size distribution characteristics, rate of crushing

ЗЪРНОМЕТРИЧНИ ХАРАКТЕРИСТИКИ И СТЕПЕН НА ТРОШЕНЕ НА ЛАБОРАТОРНА ЧЕЛЮСТНА ТРОШАЧКА СЪС СЛОЖНО ЛЮЛЕЕНЕ НА ПОДВИЖНАТА ЧЕЛЮСТ

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РЕЗЮМЕ. Едни от основните технологични параметри на челюстните трошачки са зърнометричната характеристика на натрошения продукт и степента на трошене (*i*). Те се дават в проспекта на всяка машина, но много често не е уточнено за каква широчина на разтоварващия отвор (b) на трошачката се отнасят и какво е влиянието на *b* върху зърнометричната характеристика на продукта от трошенето и постиганата степен на трошене. Всичко това затруднява избора на трошачка при закупуване на нова машина и води до грешки. За целта е направен експеримент с лабораторна челюстна трошачка със сложно люлеене на подвижната челюст и размери на приемния отвор 100 x 155 mm. От извършени ситови анализи са построени зърнометрични криви на продуктите от трошенето и е определена степента на трошене на минерална суровина при различни широчини на *b* на челюстната трошачка и едрини на постъпващия за трошене материал. След анализа на получените резултати са обобщени съответните изводи относно технологичните параметри на челюстната трошачка, при зададени размер на разтоварващ отвор и едрина на изходния материал.

Ключови думи: челюстна трошачка, разтоварващ отвор, зърнометрични характеристики, степен на трошене

Introduction

The jaw crushers are widely used for crushing of a variety of raw materials. The advantages of complex pendulum jaw crushers are their small dimensions and weight and their simple construction. These crushers provide a higher rate of crushing and 15-20% less energy demand than the jaw crushers with a simple swinging of the movable jaw. The choice of the dimension-type of the crusher is related to the following conditions: the feeding gap has to be at least 10-15% wider than the maximum particle size of the feeding product and the size of the sizing gap for discharge has to be suitable for achieving the required fraction size of the crushed product, the rate of crushing, and the productivity.

A number of technological parameters characterising the operation of the jaw crusher are determined under laboratory conditions, the most important being the rate of crushing and the fraction size characteristic of the crushed product. The establishment of the fraction size of the crushed material and the crushing rate are essential conditions for good management of the crushing process and its optimisation.

The purpose of the present study is to determine the fraction size and crushing rate of a laboratory-scaled complex pendulum jaw crusher at different widths of the discharge port and fraction grain sizes of the feeding material.

Materials and methods

The grain size distribution, or the grain size characteristics, shows the quantitative distribution of the grains/fractions in a certain material according to their size. The grain size distribution is determined by the methods of the grain size analysis. The grain size analysis of the grain materials is unified and is performed by the method of the sieve analysis. For this purpose, average samples are collected from representative samples of the crushed products and they are sieved through a set of sieves of different mesh sizes (16.0, 12.5, 8.0, 4.0, 2.5, and 1.0 mm). Thus, average samples of the crushed products are sieved by size, obtaining the following classes: +16 mm, -16 + 12.5 mm, -12.5 + 8 mm, -8 + 4 mm, -4 + 2.5 mm, -2.5 +1 mm, and -1 + 0 mm.

The results of the sieve analyses are presented in a graphical form. To determine the total sum production of the resulting classes, their private productions (y_i) are calculated using the formula:

$$\gamma_i = \frac{M_i}{Q}.100, \% \qquad (1)$$

where:
M_i is the mass of the respective class, kg;
Q is the total mass of the sample, kg.

The total sum grain size curves of the material passed through the meshes (by "–" in Fig. 2, 3, 4, 5, and 6)) represents the regularity of grain size distribution in the crushed products obtained after the crushing of the feeding material of different sizes and at different widths of the discharge port of the crusher.

The achieved rate of crushing (i) under the set test conditions (size of b and size of the input material) is determined by the formula:

$$i = \frac{D_{av}}{d_{av}} \qquad (2)$$

where:
D_{av}, d_{av} are the average diameters of the material, respectively before and after the crushing, mm.

The average diameters of the crushed material are defined with the following formula:

$$d_{av} = \frac{\sum_{i=1}^{n} \gamma_i . d_i}{\sum_{i=1}^{n} \gamma_i} \qquad (3)$$

where:
d_{av} is the average diameter of the grains of the whole material, mm;
d_i is the arithmetic mean diameter of the grains in the different classes, mm;
γ_i is the production of a class with a diameter d_i %.

The experiment sets the following parameter that defines the test conditions: average diameter of the material to be crushed (D_{av}, mm).

The material is pre-selected and sieved until the relevant crushed class is obtained. The dimensions of the prepared classes are shown in Table 1.

Table 1.
Dimensions of the feeding material for crushing.

Class, mm	*D_{av}, mm*
-55+45	50
-45+35	40
-35+25	30
-25+15	20

The sizing gap for discharge is selected and compliant to the dimensions and capabilities of the laboratory-scaled facility. The experiments were performed at widths of the sizing gap for discharge of 6, 8, 12, 16, and 20 mm.

For the experiment, a laboratory-scaled complex pendulum jaw crusher and a feeding gap of 100 x 155 mm was used. Fig. 1 presents the longitudinal section of a jaw crusher with a complex swinging.

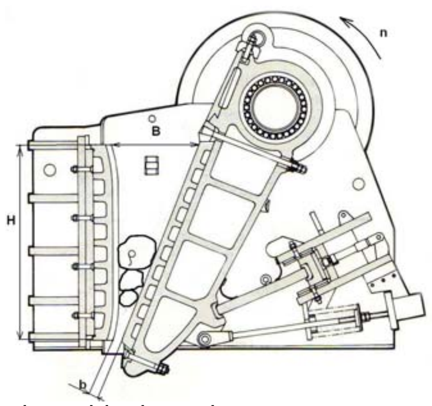

Fig. 1. Complex pendulum jaw crusher

- Width of the discharge port of the crusher (*b, mm*).

Results and discussions

The total sum of grain size curves (drawn by "-") of the crushed products at different widths of the discharge port and fraction sizes of the feeding material are shown in Figures 2, 3, 4, 5, and 6.

The characteristics of the grain sizes in Figures 2, 3, and 4 (at b = 20, 16 and 12 mm) show that the larger classes at all sizes of the feeding material (D_{av} = 50, 40, 30 and 20 mm) predominate in the crushed products. This is less prominent in the products obtained by crushing the material with a fraction size D_{av} = 50 mm. The dominance of larger classes increases with the reduction of the size of the material to be crushed. By decreasing the size of the discharge port from 20 mm to 12 mm, the content of the class +16 mm is reduced in the crushed products, respectively for:

- ✓ D_{av} 50 mm: from 41,5% to 5,2%;
- ✓ D_{av} 40 mm: from 47,2% to 0%;
- ✓ D_{av} 30 mm: from 46,5% to 0%;
- ✓ D_{av} 20 mm (at b=16 and 12 mm): 0%.

The grain size curves in Figure 5 show that for a discharging gap of the crusher b = 8 mm, a steady distribution of classes in the crushed products for all fraction sizes of the feeding material is achieved. This is most evident in the crushed product obtained from the material with D_{av} = 50 mm. All the crushed products are with fraction sizes less than 12.5 mm. The resulting contents of the +8 mm class in the crushed products are respectively:

- ✓ for D_{av} 50 mm: 30.0%;
- ✓ for D_{av} 40 mm: 26.6%;
- ✓ for D_{av} 30 mm: 23.2%;
- ✓ for D_{av} 20 mm: 20.6%.

The grain size characteristics in Figure 6 (at b = 6 mm) show the predominance of the fine classes in the crushed products for all fraction sizes of the input material. With this size of the discharging port, the content of the +8 mm class in the products from the crushing of the relevant in sizes material is:

- ✓ for D_{av} 50 mm: 9.6%;
- ✓ for D_{av} 40 mm: 9.4%;
- ✓ for D_{av} 30 mm: 6.7%;
- ✓ for D_{av} 20 mm: 5.0%.

At the same sizing gap for discharge (b = 6 mm) of the jaw crusher, the content of the class -1,0 + 0 mm in the crushed products is similar for all fraction sizes of the feeding material. The content of the class -1,0 + 0 mm in the crushed products is respectively:

- ✓ for D_{av} 50 mm: 19.0%;
- ✓ for D_{av} 40 mm: 20.4%;
- ✓ for D_{av} 30 mm: 20.4%;
- ✓ for D_{av} 20 mm: 19.5%.

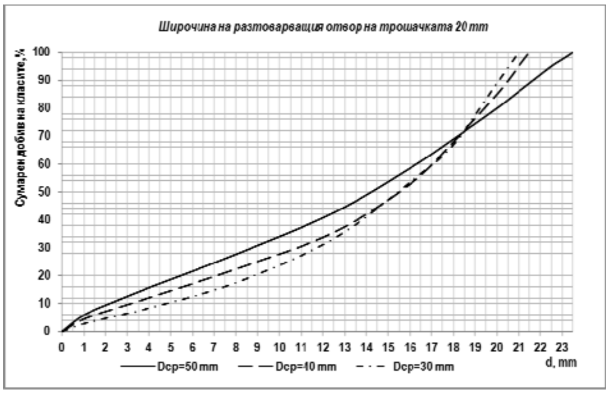

Fig. 2. Grain size distribution characteristics of the crushed products at *b=20 mm*

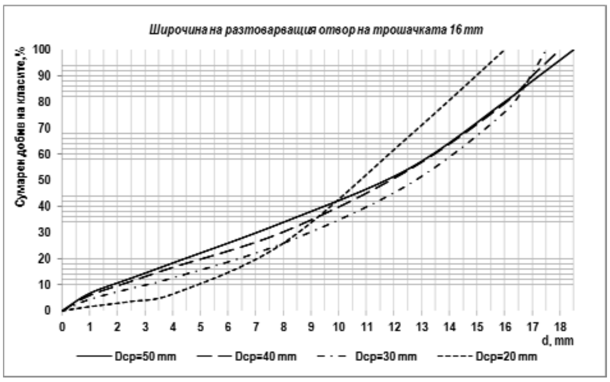

Fig. 3. Grain size distribution characteristics of the crushed products at *b=16 mm*

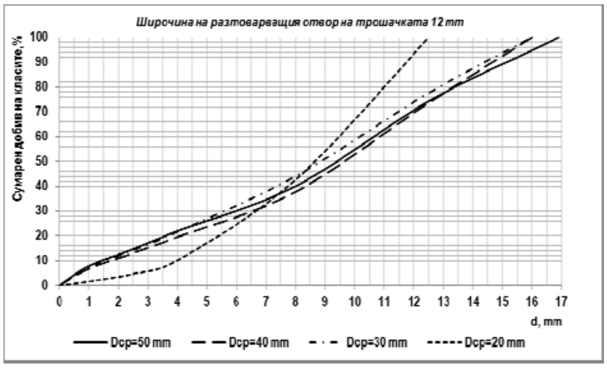

Fig. 4. Grain size distribution characteristics of the crushed products at *b=12 mm*

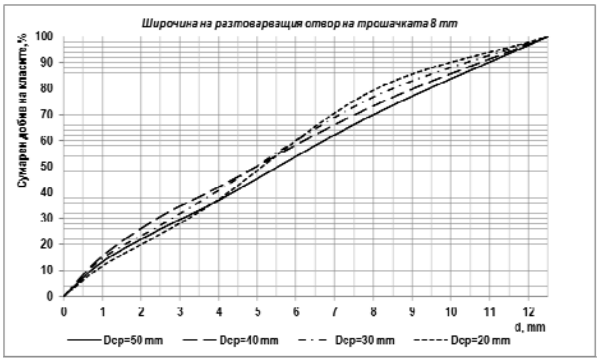

Fig. 5. Grain size distribution characteristics of the crushed products at *b=8 mm*

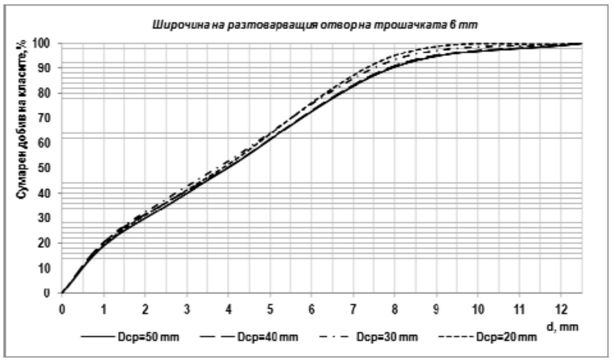

Fig. 6. Grain size distribution characteristics of the crushed products at *b=6 mm*

Table 2 shows thethe results of the calculations performed through formulae (2) and (3) regarding the crushing rates (*i*) and average diameters (d_{av}) of the crushed products at the different fraction sizes of the feeding material and the widths of the discharge port of the jaw crusher. Also, the table shows the fraction sizes d_{50} in the crushed products obtained under different test conditions. The fraction size d_{50} (mm) is a grain size corresponding to a 50% total sum production by minus, reported at the grain size curves represented in figures 2 - 6. The data in the table shows that the d_{av} and d_{50} of the crushed products obtained at the relevant widths of the discharging port have similar values that do not depend on the D_{av} of the feeding material. The rate of crushing decreases with a reduction in the size of the material to be crushed for each one of the chosen widths of the discharge port of the crusher.

Table 2.
Obtained values of i, d_{av} and d_{50} for the crushed products under the certain conditions for the experiments (D_{av} and b, mm).

D_{av}, mm	b=20 mm			b=16 mm			b=12 mm			b=8 mm			b=6 mm		
	D_{av} mm	d_{50} mm	I mm	D_{av} mm	d_{50} mm	I mm	d_{av} mm	d_{50} mm	I mm	D_{av} mm	d_{50} mm	I mm	D_{av} mm	d_{50} mm	I mm
50	13.0	14.3	3.8	10.5	11.8	4.8	8.8	9.3	5.7	5.7	5.5	8.8	4.3	4.0	11.6
40	13.5	15.5	3.0	10.7	12.0	3.7	8.9	9.6	4.5	5.3	5.0	7.5	4.2	4,0	9.5
30	13.8	15.5	2.2	11.2	12.8	2.7	8.4	8.8	3.6	5.3	5.3	5.7	4.0	3.7	7.5
20	-	-	-	10.2	11.0	2.0	8.6	8.6	2.3	5.3	5.2	3.8	4.0	3.9	5.0

For all fraction sizes of the feeding material, the crushing rate is increased by the reduction of the width of the discharging port. The highest rate of crushing is achieved by crushing the raw material with D_{av} = 50 mm, at all widths of the discharge port.

Conclusions

1. By the adjustment of the width of the sizing gap for discharge of the jaw crusher (b), the crushing process is controlled in order to obtain products of different fraction size composition. The total sum grain size characteristics of the crushed products indicate that they are characterised by:
   - a dominance of the larger classes at b > 12 mm;
   - a dominance of the finer classes at *b* = 6 mm;
   - a steady distribution of grain fractions at *b* = 8 mm.
2. For the studied widths of the discharging port of the crusher, a similar value of d_{av} and d_{50} is obtained for the crushed material and it does not depend on the D_{av} of the feeding material. The values of d_{av} and d_{50} vary within the range, respectively
   - at *b*=20 mm – d_{av} from 13.0 to 13.8 mm; d_{50} from 14.3 to 15.5 mm;
   - at *b*=16 mm – d_{av} from 10.2 to 11.2 mm; d_{50} from 11.0 to 12.8 mm;
   - at *b*=12 mm – d_{av} from 8.4 to 8.9 mm; d_{50} from 8.6 to 9.6 mm;
   - at *b*=8 mm – d_{av} from 5.3 to 5.7 mm; d_{50} from 5.0 to 5.5 mm;
   - at *b*=6 mm - d_{av} from 4.0 to 4.3 mm; d_{50} from 3.7 to 4.0 mm.
3. For all the investigated fraction sizes of the feeding material, the rate of crushing increases with the reduction of the width of the discharge port.

It is known that the rate of crushing, as well as the frequency of rotation of the eccentric shaft (swing frequency of the movable jaw), exert influence on the performance of the crusher and the consumed power. In order to determine these dependencies, it is necessary to continue the experiments for the actual crusher.

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