Научная статья / Research Article
УДК 321.313

Джасур Садриддин угли Олимов
olimovjasur2328@gmail.com
Навоийский государственный горно-технологический университет, Навои, Республика Узбекистан

ОПРЕДЕЛЕНИЕ ЗАВИСИМОСТИ РАБОТЫ КОНУСНОЙ ДРОБИЛКИ ОТ ЕЕ СРЕДНЕЙ ПОТРЕБЛЯЕМОЙ МОЩНОСТИ

Аннотация. *Дробление и измельчение минерального сырья широко распространены в горнодобывающей и строительной промышленности и являются технологическими процессами, требующими больших затрат электроэнергии, на долю которых приходится около 25 % потребляемой горнодобывающими предприятиями электроэнергии. В настоящее время процессы дробления являются одними из самых энергоемких операций, на их долю приходится более 55–65 % общих энергоресурсов перерабатывающих предприятий. Поэтому актуальным является выбор оборудования для повышения энергоэффективности процесса подготовки и развития руды, применение высокопроизводительного оборудования с большой единичной производительностью, усиление процессов дробления, разработка технических решений. Были проведены экспериментальные эксперименты с использованием основных параметров конусной дробилки (коэффициент дробления (фракционирования), усилие сжатия, скорость вращения конуса и нагрузка) и выявлены основные приоритеты для достижения оптимальной работы и энергоэффективности.*

Ключевые слова: *конусные дробилки, коэффициент дробления (фракционирования), усилие сжатия, электроприводы, мощность электродвигателя, диаметр днища дробящего конуса, ширина приемного отверстия с открытой стороны, рабочая мощность, крепость руды, электропривод, скорость вращения, уровень нагрузки*

DETERMINING THE RELATIONSHIP BETWEEN THE WORKING PROCESS OF A CONE CRUSHER AND ITS AVERAGE POWER CONSUMPTION

Jasur Sadriddin ugli Olimov
olimovjasur2328@gmail.com
Navoi State Mining and Technological University, Navoi, Uzbekistan

Инженерные системы и энергетика. 2025. № 2. С. 21–28.
Engineering systems and energy. 2025;(2):21-28.

Abstract. *In the mining and construction industries, the processes of crushing and grinding of mineral raw materials are widespread and are energy-intensive technological processes, accounting for about 25 % of the electricity consumed by mining enterprises. Currently, crushing processes are one of the most energy-intensive operations, accounting for more than 55–65 % of the total energy resources of processing enterprises. Therefore, in the process of ore preparation and development, it is urgent to select equipment, use high-performance equipment with large unit capacity, strengthen crushing processes and develop technical solutions to increase energy efficiency. Experiments were conducted using the main parameters of the cone crusher (crushing (fractionation) coefficient, compression force, cone rotation speed and load), and the main priority tasks for achieving optimal working process and energy efficiency were identified.*

Keywords: *cone crushers, crushing (fractionation) coefficient, compression force, electric drives, electric motor power, bottom diameter of the crushing cone, width of the receiving hole on the open side, working power, ore hardness, electric drive, rotation speed, load level*

Introduction. In order to determine the specific energy consumption of a crusher and evaluate its energy efficiency, it is necessary to study its energy characteristics and the relationship between the crusher's performance and its average power consumption. Through this, a series of recommendations are introduced for the evaluation of the energy efficiency of a cone crusher and energy saving.

Object, method and results of the study. Using an analytical model, a numerical experimental method is used to determine the power consumption and specific energy consumption depending on the parameters of the crushed material and its operating modes [1, 2]. In the study, the following formula was used to determine the power consumption of an electric motor.

$$N_m = \frac{\sigma_{sj}^2 \pi D_k}{0{,}01224\ \eta E}(D_{sv}^2 - d_{sv}^2) n K_{pr} \quad (1)$$

Where; σ_{sj} – compressive strength of a material over time, *MPa*; D_k – diameter of the base of the crushing cone, m; E – modulus of elasticity of the material, *MPa*; η – mechanical efficiency of the drive; D_{sv} and d_{sv} – the average size of the starting material and the crushed product, respectively, m; n – Rotation frequency of the grinding cone, *rpm*; K_{pr} – the total correction factor, taking into account the size and design of the crusher, the dynamics of the crushing process and the degree of filling of the crushing chamber.

The research was carried out in the ore crushing process at the 2nd Hydrometallurgical Plant, 1st workshop, on a KKD-1500/180 GRSh cone crusher on an AK4-450Y-10UZ phase rotor asynchronous motor shaft. This type of crusher has high reliability, high productivity, simple and easy maintenance, which makes it preferable over other types of crushers [3, 4].

Table 1

The technical parameters of the selected crusher, KKD-1500/180 GRSh

Parameter	KKD-1500/180 GRSh
Base diameter of the crushing cone, mm	180
Width of the receiving hole on the open side, mm	1500
The largest size of the loaded material, mm	1200
Working capacity, m^3/h	2240
Weight, tons.	406
Electric motor power, kWt	400

The parameters of the crushed material are given in accordance with the Muruntov deposit: compressive strength of the material over time σ_{sj}– 60–130 *MPa*; average value of material compressive strength σ_{sj}– 99 *MPa*; modulus of elasticity of the material *E* – 7000 *MPa*; material softening coefficient *m* – 0,5; ore density r_m – 2,7 t/m^3.

To calculate the power of the electric motor for the various parameters under study, it is necessary to calculate K_{pr} – a general correction coefficient that characterizes the size and design of the grinder.

To find the value of K_{pr} according to formula (1), the following expression is used:

$$K_{pr} = \frac{0{,}01224 E N_m \eta}{\sigma_{sj}^2 \pi D_k (D_{sv}^2 - d_{sv}^2) n}. \quad (2)$$

For the KKD-1500/180 GRSh cone crusher under consideration, the total correction coefficient, K_{pr} = 1,39, characterizing the size and design of the crusher, was calculated, assuming a discharge gap width of 10 mm with a D_{sv} = 60 mm and an average size of crushed particles of d_{sv} = 20 mm [5–9].

Assuming that the size of the crushed product is equal to the width of the discharge gap, the dependences of the productivity (Q), the power consumed by the electric motor (P), and the specific energy consumption of the cone crusher (W) on the crushing (fractionation) coefficient (i) are calculated and presented in Table 2 and Figure 1.

Table 2

Dependence of specific energy consumption on the fractionation coefficient

Diameter of the outlet slot *d, m*	Disintegration coefficient, *i*	Power consumed by the motor at compression σ_{sj} = 60 MPa, P	Power consumed by the motor at compression σ_{sj} = 100 MPa, P	Power consumed by the motor at compression σ_{sj} = 130 MPa, P	Productivity *Q, t/h*	Specific energy consumption in compression at σ_{sj} =60 MPa, W	Specific energy consumption in compression at σ_{sj} =100 MPa, W	Specific energy consumption in compression at σ_{sj} =130 MPa, W
0,011	6,00	51,24	142,38	242,65	296,45	0,17	0,47	0,82
0,014	4,63	50,25	139,57	235,87	384,09	0,14	0,36	0,61
0,016	3,74	48,98	136,04	229,93	472,73	0,10	0,28	0,48
0,020	3,15	47,45	131,75	222,68	561,36	0,09	0,23	0,40
0,022	2,72	45,63	126,76	214,27	650,00	0,07	0,20	0,33
0,024	2,41	43,57	121,04	204,53	738,64	0,06	0,17	0,28
0,031	1,87	37,76	104,79	177,16	945,46	0,04	0,11	0,18
0,037	1,59	31,57	87,72	148,23	1122,73	0,03	0,08	0,13
0,045	1,34	23,06	67,07	109,22	1329,55	0,02	0,05	0,08

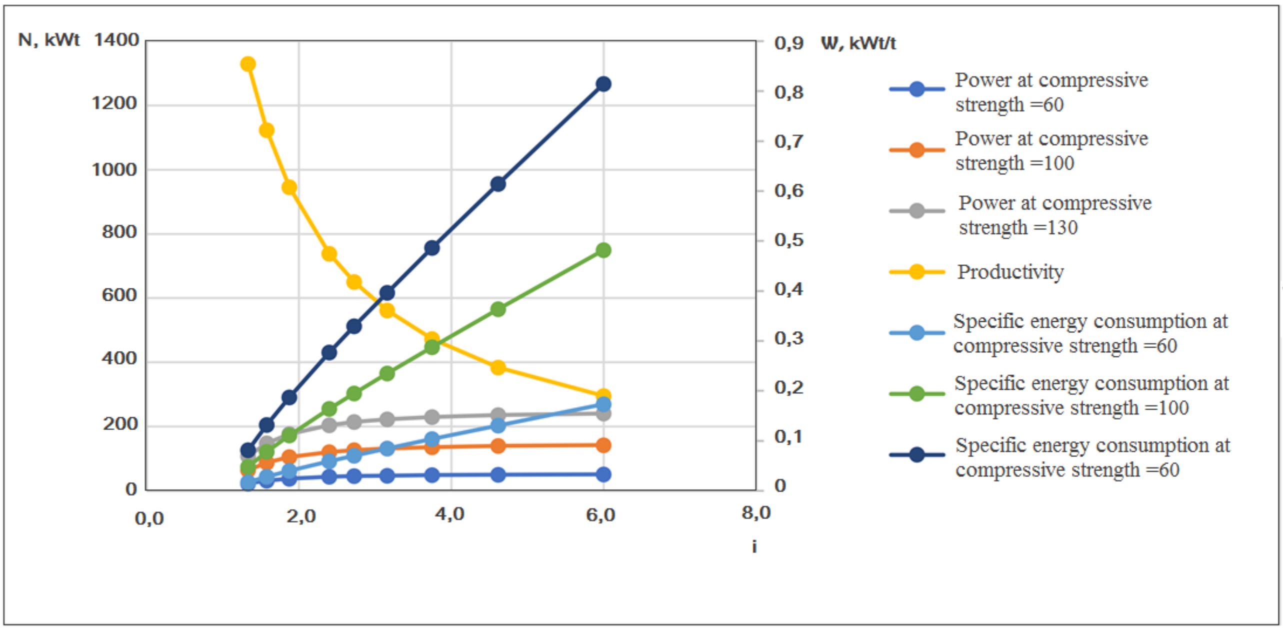

Fig. 1. Dependence of the specified energy consumption on the fractionation coefficient

From the data in Figure 1, it follows that when the crushing coefficient changes from *i* = 1.3 to 6 for a material compressive strength of = 130 *MPa*, the crusher productivity decreases from 1330 *t/h* to 296 *t/h*; the power consumed by the electric motor increases from 109 to 242 *kWt*, and the specific energy consumption increases from 0.08 to 0.82 *kW /t*.

The dependence of specific energy consumption on the compressive strength of the source material and the dependence of specific energy consumption on the compressive strength of the material are presented in Table 3 and Figure 2 below.

Table 3

Dependence of specific energy consumption on the compressive strength of the material

Compressive strength σ_{sj}, *MPa*	Power consumption at *i*=1.9, *P*	Power consumption at *i*=3.2, *P*	Power consumption at *i*=4.6, *P*	Productivity at *i*=1.9, *Q, t/h*	Productivity at *i*=3.2, *Q, t/h*	Productivity at *i*=4.6, *Q, t/h*	Specific energy consumption at *i*=1.9, *W*	Specific energy consumption at *i*=3.2, *W*	Specific energy consumption at *i*=4.6, *W*
60	37,75	47,46	55,2	945,5	561,4	385,1	0,04	0,08	0,14
70	51,3	64,4	68,4	945,5	561,4	385,1	0,05	0,12	0,18
80	67,1	84,36	89,35	945,5	561,4	385,1	0,07	0,15	0,23
90	84,98	106,7	113,1	945,5	561,4	385,1	0,09	0,19	0,29
100	104,8	131,8	139,6	945,5	561,4	385,1	0,11	0,23	0,36
110	126,8	159,47	168,98	945,5	561,4	385,1	0,13	0,28	0,44
120	150,9	189,7	201,0	945,5	561,4	385,1	0,16	0,34	0,52
130	177,17	222,7	239,9	945,5	561,4	385,1	0,19	0,40	0,62

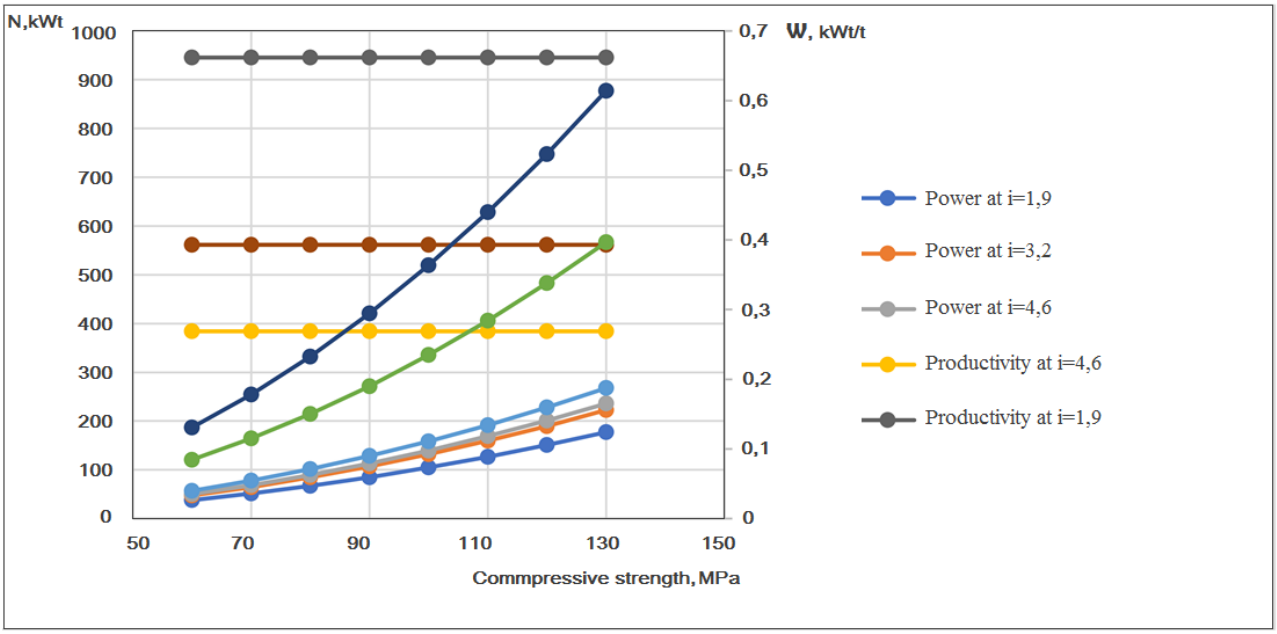

Fig. 2. Dependence of specific energy consumption on the compressive strength of the material

When the compressive strength changes from 60 *MPa* to 130 *MPa* at *i*=4.6, the power consumed by the crusher electric motor increases as a quadratic function from 50 *kWt* to 235 *kWt*, while the productivity remains equal to 385 *t/h*, and the specific energy consumption increases from 0.14 *kW/t* to 0.62 *kWt*. Table 4 and Figure 3 show the dependence of power, efficiency, specific energy consumption on the cone rotation speed.

Table 4

Dependence of energy consumption on the cone rotation speed

Cone rotation speed, *rpm*	Power consumed by the electric motor, *kWt*	Productivity *Q*, *t/h*	Comparative energy consumption, *kWt/t*
700	129,3	174,3	0,745
800	146,7	197,0	0,745
900	165,0	221,6	0,745
1000	183,3	246,2	0,745
1100	201,7	270,8	0,745
1200	225,0	298,5	0,745

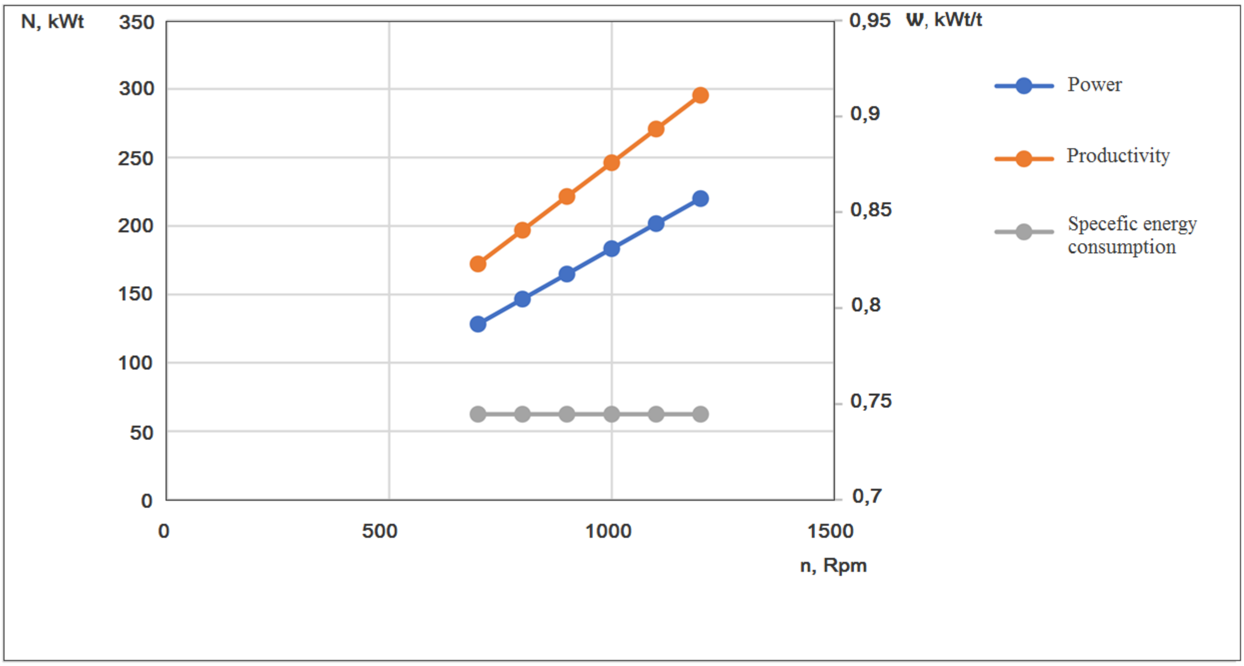

Fig. 3. Dependence of the specified energy consumption on the cone rotation speed

From Figure 3, it follows that when the crusher rotation speed increases from 700 to 1200 *rpm*, the productivity increases from 174 to 298 *t/h*, while the power increases from 129 to 225 *kWt* in direct proportion to the crusher productivity, and the specific energy consumption remains unchanged at 0.745 *kWt/t*.

The study allowed us to identify the parameters that affect certain energy consumption. Based on the above relationships, the following conclusions can be drawn:

1. As the grinding ratio increases, the power consumed by the electric drive motor increases unevenly, the efficiency of the crusher decreases, and the specific energy consumption value increases;

2. With an increase in the compression force limit and a constant grinding ratio, the power consumed by the electric motor of the crusher and the specific energy consumption increase, but the efficiency does not change;

3. With an increase in the rotation speed, the power consumed by the electric motor of the crusher and the productivity of the crusher increase in direct proportion. In this case, the specific energy consumption does not change;

4. The established dependences of specific consumption on the initial material parameters and the operating modes of the crusher allow assessing its energy efficiency and can be used to automate the crushing process.

In conclusion, based on the analysis of the research results, technical solutions are proposed to increase the energy efficiency of the cone crusher. That is, the hardness of the ore being processed is directly proportional to the force required to crush it, and an increase in this force leads to an increase in the power consumption of the electric motor. At the same time, increasing the cone rotation speed leads to a significant increase in productivity. However, this also leads to a proportional increase in power consumption. Therefore, by providing an optimal operating mode of the cone crusher, taking into account the size of the ore discharge slot, cone speed, ore hardness and fractionation coefficients, it is possible to stabilize the power consumption of the electric motor. As a result, it becomes possible to achieve significant energy savings.

References

1. Babokin G.I., Derevnin I.A. Power stabilization system for the electric drive of a cone crusher // Electrical complexes and systems. 2021. Vol. 8. P. 269–273. DOI: 10.24412/2071-6168-2021-8-269-273.
2. Controlling power of short circuited induction motor via modern sensors without speed change/ J.S. Olimov [et al.] // E3S Web of Conferences, 417, 03001 (2023). DOI: 10.1051/e3sconf /202341703007.
3. Olimov J., Ramazonov B., Sayfiyev Sh. Increasing efficiency of induction motor by predictive control system // E3S Web of Conferences, 525, 03004 (2024). DOI: 10.1051/e3sconf/ 202452503006.
4. Analysis of patterns of electricity consumption in mining and processing enterprises / S. Shirinov [et al.] // Vibroengineering Procedia. 2024. Vol. 54. DOI: 10.21595/ vp.2024.24073.
5. Eshmirzaev M., Narzullayev B. Improvement of the control system with the drive of high voltage arc furnaces // Vibroengineering Procedia. 2024. Vol. 54. DOI: 10.21595/vp.2024.23995.

6. Jumaev O., Arziev E., Turaev S. Intelligent vector-frequency control system for asynchronous electric motors // E3S Web of Conferences, 414, 05008 (2023). URL: https://www.e3s-conferences.org/articles /e3sconf /abs /2024/71/e3sconf_wfces2024_02009/e3sconf_wfces2024_02009 .html.
7. E3S Web of Conferences 525, 03009 (2024) / F. Raximov [et al.]. URL: https://www.e3sconferences.org/articles/e3sconf/abs/2024/55/e3sconf_geotech2024_03009/e3sconf_geotech2024_03009.html.
8. Use of reactive power sources in improving the quality of electricity / A.N. Tovboyev [et al] // Journal of Physics: Conference Series. 2021. Vol. 2094(5). URL: https://www.e3sconferences.org/ articles/e3sconf/pdf/2023/54/e3sconf_geotech2023_03001.pdf.
9. Calibration and Validation of a Cone Crusher Model with Industrial Data / R.A. Duarte [et al.] // Minerals. 2021. Vol. 11. P. 1256. DOI: 10.3390/ min11111256.

Информация об авторе:

Джасур Садриддин угли Олимов – Навоийский государственный горно-технологический университет, ассистент преподавателя кафедры энергетики

Information about the author:

Jasur Sadriddin ugli Olimov – Navoi State Mining and Technological University, Assistant teacher, Department of Energy