

TECHNOLOGIES FOR INCREASING THE ENERGY EFFICIENCY OF
STATIONARY CRUSHERS IN THE ORE CRUSHING DEPARTMENT

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Abstract: The article addresses issues of reducing energy consumption of stationary crushers during ore crushing, optimal load management, improving the design parameters of the crushing chamber, and increasing efficiency using intelligent control technologies. Practical recommendations are provided to reduce energy consumption by 15-35%, improve crushing quality, and extend the service life of the units.

Keywords: stationary crusher, energy efficiency, cone crusher, vibration diagnostics, automation, crushing chamber.

Introduction

The ore crushing process is one of the most important and energy-intensive stages in the mineral raw material processing cycle. According to the experience of global mineral processing enterprises, 40-60% of the total electricity consumption in the technology is spent on crushing and size sorting processes. Therefore, the issue of increasing the energy efficiency of crushing units is relevant not only from an economic perspective but also from technical and environmental standpoints.

The process of crushing mineral raw materials is theoretically based on the laws of Kick, Rittinger, and Bond. Energy consumption throughout the crushing process is closely related to the physical and mechanical properties of the material, especially its power resistance (MPa) and the medium hardness coefficient (f) according to the Protodyakonov scale.

Theoretical laws for crushing energy:

1. According to Rittinger's law, the energy required for crushing is:

$$E = k_R \left(\frac{1}{d_2} + \frac{1}{d_1} \right)$$

d_1 - initial particle size, mm

d_2 - final particle size, mm

k_R - Rittinger coefficient

This law is applicable for fine grinding (0-5 mm).

2. Kick's Law - for coarse crushing:

$$E = k_K \ln \left(\frac{d_1}{d_2} \right)$$

3. Bond's Law - the most widely used model in industry:

$$E = 10 \cdot W_i \left(\frac{1}{\sqrt{d_2}} - \frac{1}{\sqrt{d_1}} \right)$$

W_i - Bond work index, kWh/t (the main parameter indicating the ore's resistance to breakage)

Materials and methods

To study the physical and mechanical properties of mineral raw materials, three types of materials were selected: gold, copper, and iron ore. Their hardness ranges from 6 to 12 on the Protodyakonov scale, their density is 2.7-3.6 t/m³, and their moisture content is 2-6%, which directly affects the energy consumption during crushing.

The following Table 1 served as the basis for the scientific analysis of the main properties of the materials:

Table 1

Ore type	ρ (t/m ³)	W (%)	f	W _i (kWh/t)
Gold	2.7	3-4	6-8	12-17
Copper	2.9	4-6	8-10	10-14
Iron	3.6	2-3	10-12	7-12

Physical and mechanical characteristics of the ores used in the research

The most common stationary crushers in industry were selected as the objects of research: jaw crusher (SHDP-9/12), cone crushers (KSD-2200, KMD-1750), rotary crusher (RD-1200) and high-pressure grinding rolls (HPGR). Their operating parameters - feed opening, crushing chamber geometry, engine power, CSS (Closed Side Setting), eccentricity, and roller pressure - were studied as the main factors influencing energy consumption.

The HPGR (High Pressure Grinding Rolls) technology deserves special attention, as it operates at a pressure of 3.5-5.5 MPa, causing the ore to be crushed in a layered compression mode. This method reduces energy consumption by 20-30% compared to classical grinding.

Energy monitoring devices (Siemens Multimeter, EM-330) were used to determine energy consumption in industrial conditions. These devices were used to measure active power P reactive power Q current harmonics and motor efficiency indicators. Energy consumption was calculated using the following integral:

$$E = \int_0^T P(t) dt$$

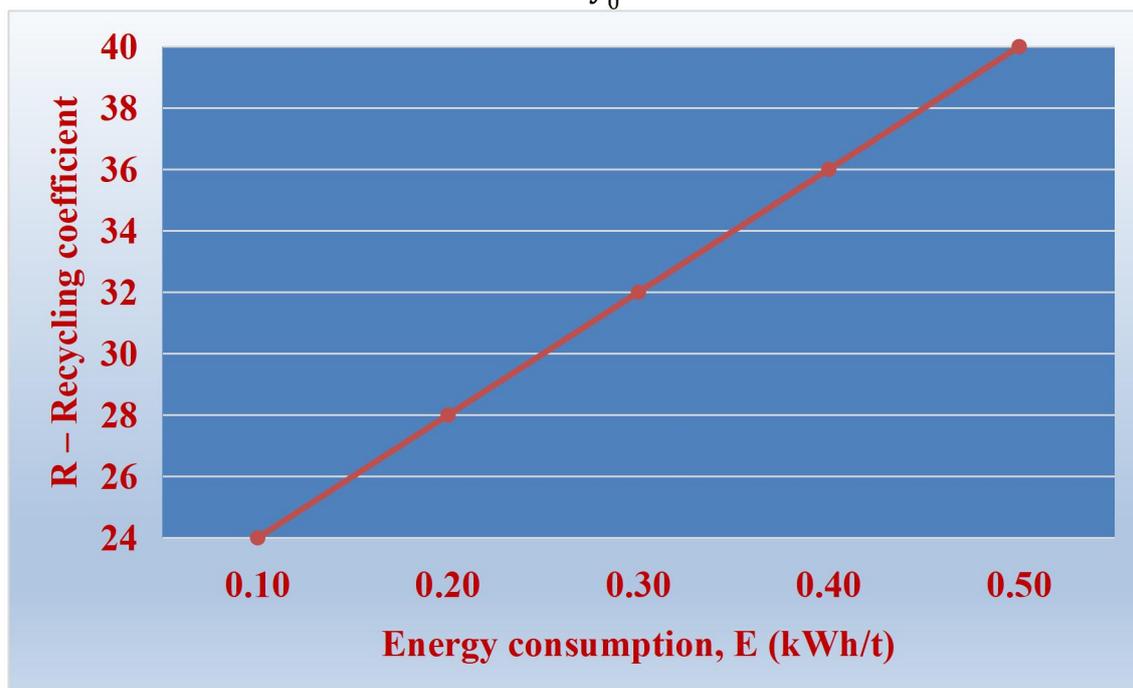


Fig. 1. Grinder power consumption P (t) graph

In assessing the mechanical condition of the grinding units, vibration diagnostics (Fluke 810, VCH-3200) were employed to determine bearing vibration, rotor imbalance, and chamber filling. Vibration amplitude is one of the main indicators of energy loss. For instance, it was found that when vibration increases from 4 mm/s to 7 mm/s, energy consumption rises by 8-12%.

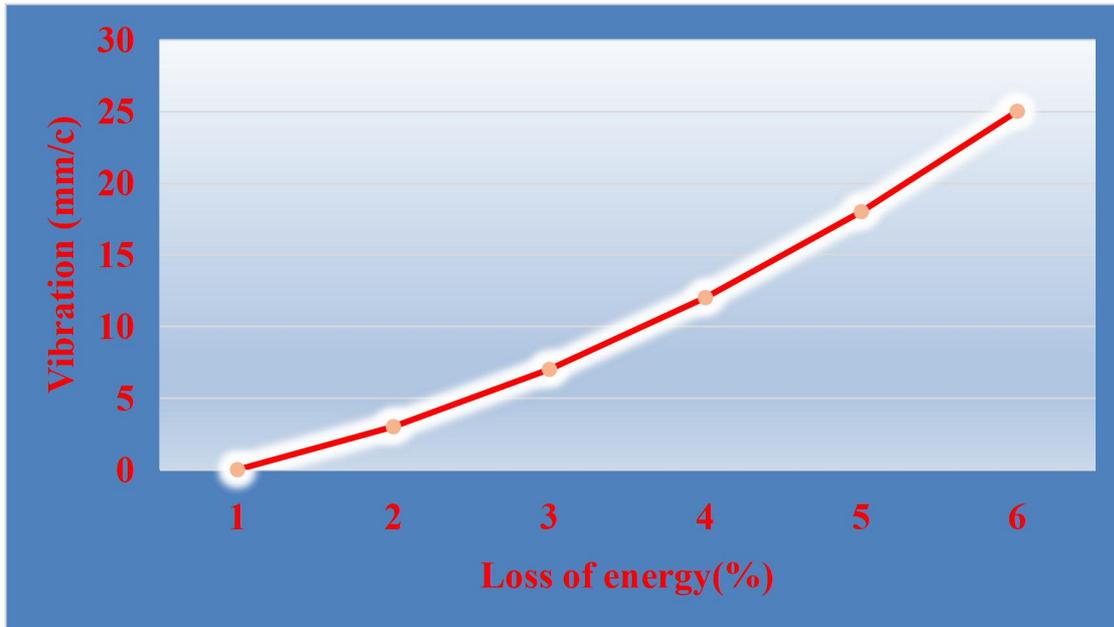


Fig. 2. Graph of vibration changes in the crusher units.

This research was conducted based on an in-depth study of technological and design solutions aimed at increasing the energy efficiency of stationary crushing units in the ore crushing department. Analyses showed that the grinding process accounts for 40-60% of the total energy consumption in processing plants, and improving its technological efficiency is crucial for the enterprise's economy and production stability.

Conclusions

In the study, energy consumption models were calculated based on physical and mechanical properties and Bond index (Wi) for three types of mineral materials - gold, copper, and iron ores. According to the obtained results, it was determined that an increase in the recirculation coefficient, rising vibration levels, and incorrect selection of chamber geometry and liner wear lead to an increase in energy consumption by 10-35%. This necessitates ensuring load stability in crusher operation modes, optimizing CSS parameters, and implementing preventive maintenance based on vibration diagnostics.

During the research process, modern solutions were examined - HPGR roller presses, variable-frequency drives (VFD), intelligent load control based on PLC-SCADA, and Smart Screening vibrating screen technologies. HPGR technology stood out for reducing energy consumption by 20-30% compared to traditional conical crushers while increasing the fine fraction by 15-20%. The application of VFD enabled motor power consumption control in accordance with the load, allowing for 12-18% energy savings. Intelligent control algorithms increased overall efficiency by 10-15% through reducing recirculation and stabilizing material flow.

Based on this, the proposed technological solutions yield the following general results:

- overall energy consumption is reduced by 25-35%;
- crushing efficiency increases by 10-20%;

- the recirculation coefficient decreases by 30-40%;
- The stability against vibration and mechanical loads increases, and the service life of the units is extended by 20-25%;
- Automation of the control system improves working conditions and safety.

In conclusion, the problem of increasing the energy efficiency of stationary crushers requires a comprehensive approach. Modernization of the design, integration of intelligent control systems, energy-saving electric drives, and innovative crushing technologies such as HPGR ensures reliable, stable, and economically efficient operation of ore crushing units. The methods and algorithms proposed in this study are technically and economically sound solutions for practical implementation at mineral raw material processing enterprises.

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