AMERICAN JOURNALS
Open Access, Peer Reviewed Journals

American Journal of Technology and Applied Sciences
ISSN (E): 2832-1766 Volume 41, October - 2025

DEVELOPMENT OF AN ENERGY-SAVING OPERATING MODE FOR MILLING INSTALLATIONS, TAKING INTO ACCOUNT THE VARIABILITY OF INCOMING ORE PARAMETERS

Mavlonov Jonibek Ashurovich
Navoi State Mining and Technologies University

A B S T R A C T	K E Y W O R D S
Globally, particular attention is being paid to ensuring the energy efficiency of large-scale equipment in the mining and metallurgical industry by optimizing its operating modes to reduce energy costs and improve production efficiency. Currently, in developed countries, "...global energy consumption in the mining and metallurgical industry accounts for approximately 3.5% of global energy annually, with crushing processes accounting for 30-40%. By 2060, energy consumption is projected to increase by 2-8 times due to declining ore quality and growing demand for metals."	Synchronous motor, mill, grinding, ball loading, rotation speed, power.

Introduction

Research Objective

Improving methods for ensuring energy efficiency of energy-intensive equipment in the mining and metallurgical industry based on an analysis of the influence of technological factors on the operation of ball mills.

Materials and Methods

A ball mill's adjustable synchronous electric drive must ensure optimal operation, taking into account the variability of incoming ore parameters (weight, moisture, hardness, and particle size distribution). This paper presents a mathematical model that accounts for the dynamics of the electric drive and mechanical system, taking into account the impact of changing ore characteristics.

Results and Discussion

Model of a synchronous motor in the d-q coordinate system:

$$U_d = R_s I_d + L_d \frac{dI_d}{dt} - \omega L_q I_q$$

$$U_q = R_s I_q + L_q \frac{dI_d}{dt} - \omega L_q I_q + E_f \quad (1)$$

where: U_d U_q − voltage components in the d- and q-axes; I_d I_q− current components; $L_d L_q$− inductances; are the stator winding resistance; ω – rotor angular velocity; E_f − excitation EDF. Motor torque: ψ

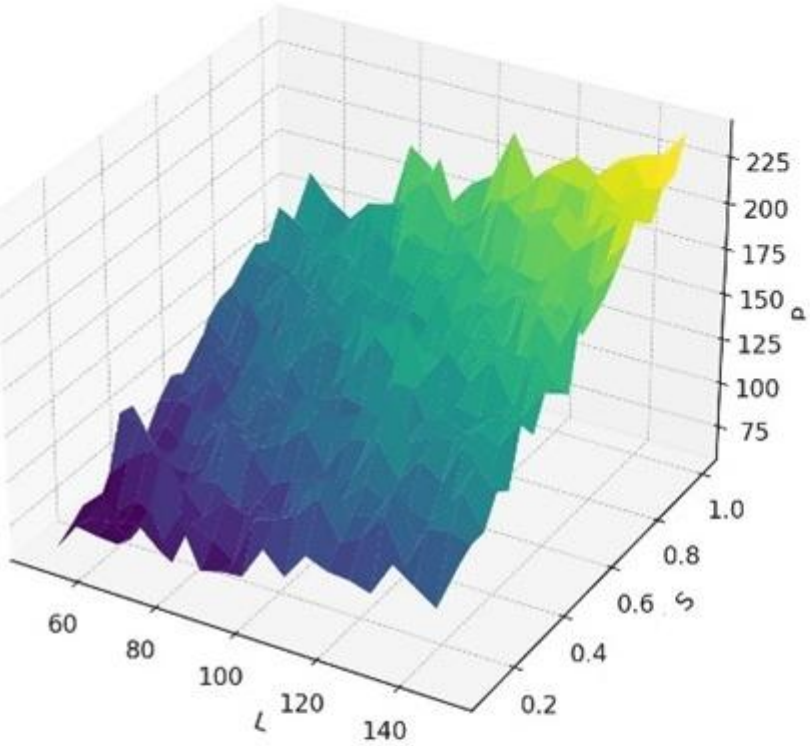

Fig. 1. With fixed ore variability W ≈ 0.5.

$$M_e = \frac{3}{2} p\left[\psi_d I_q - \psi_q I_d\right]$$

where p - number of pole pairs, $\psi_d \psi_d$ −flux linkage.

Differential equation of motion of a mechanical system:

$$J\frac{d\omega}{dt} = M_e - M_c - M_f \qquad (2)$$

where: J - moment of inertia of the system; M_e − electromagnetic torque of the engine; M_c– moment of resistance to ore crushing; M_f – moment of mechanical losses.

The moment of resistance to ore crushing is described by the empirical relationship:

$$M_c = k_1 \cdot m_r^{\alpha} \cdot d_r^{\beta} \cdot \omega^{\gamma}$$

m_r– mass of loaded ore; – average particle size; $d_r k_1, \alpha, \beta, \gamma$ – experimentally determined coefficients.

The control system includes a PID speed controller, implemented by the equation:

$$U_{reg} = K_p(\omega_{reg} - \omega) + K_i \int(\omega_{ref} - \omega)dt + K_d \frac{d(\omega_{ref} - \omega)}{dt} \qquad (2.2)$$

Where $K_p, K_{i,} K_d$ − regulator coefficients.

The influence of ore parameter variability. To account for ore parameter variability, stochastic disturbances are introduced in the form of random processes affecting m_r, d_r − and other parameters. The Monte Carlo method is used to model these disturbances. The stochastic change model:

$m_r(t) = m_{ro}$+ξ1(t)

$d_r(t) = d_{ro}$+ξ2(t)

where ξ1(t) and ξ2(t) are random processes with given statistical characteristics. The proposed mathematical model allows for the impact of ore characteristic variability on the operation of a ball mill electric drive. Implementation of the model in a digital environment will enable the development of adaptive control algorithms that compensate for the impact of input parameter instability.

Table 1.

Parameter	Average value	Range
Density ρ\rho	2800 kg/m³	2600–3000 kg/m³
Humidity W	8%	6–12%
Particle diameter d	20 mm	10–30 mm

Equation of motion of a mill

The motion of a ball mill can be written as follows based on Newton's second law:

$$J\frac{d\omega(t)}{dt} = T_{дв}(t) - T_{наг} \quad (1)$$

Here:

J — moment of inertia, ω(t) — angular velocity, $T_{дв}$— motor torque, $T_{наг}$ — load torque (torque of ore, ball and resistances).

Based on the above, a mathematical model of the grinding mill MMS 70x23 ball mill operating with synchronous motors was developed. Variability in incoming ore parameters was taken into account. The modeling results showed that changes in ore parameters can directly impact energy consumption. It is recommended to configure the control systems using an adaptive (neuro-adaptive) approach.

Conclusion

The paper examines various types of excitation of synchronous motors and the resulting performance characteristics with variable frequency drive control for new or upgraded installations, and develops mathematical models for automatic control of excitation current and variable frequency drive, taking into account the variability of incoming ore parameters, for synchronous motors of ball mills.

References

1. Ishnazarov O.X. Mavlonov J.A. Basic Directions of Improvement and Improvement of Efficiency Ore Grinding // International Journal of Advanced Research in Science, Engineering and Technology Vol. 6, Issue 4, April 2019. India
2. Mavlonov J.A., Sayidov M.K. Assessment of the Reliability of Power Supply for Mining Enterprises Taking into Account Changes in the Technical Condition of Transformers // https://doi.org/10.5281/zenodo.15743063 Problems of Energy and Resource Saving. Tashkent – 2025. No. 2 – pp. 40–45
3. Mavlonov J.A., Sayidov M.K. Influence of Changes in the Technical Condition of Transformers on the Reliability of Power Supply in Mining Enterprises // Scientific and Technical Journal "Mashinasizlik". www.andmiedu.uz Andijan – 2025. No. 1 – pp. 172–180

4. Ishnazarov O.Kh., Mavlonov J.A. Optimization of Energy Consumption of Ball Mills in Mining Metallurgy by the Two-Criteria Approach // Scientific and Technical Journal "Vestnik TF NRNU MEPhI". Tashkent – 2025. No. 1 – pp. 115–124
5. Ishnazarov O.Kh., Mavlonov J.A. Study of the Energy Efficiency of Ball Mills in the Mining and Metallurgical Industry // Scientific and Technical Journal "Vestnik TF NRNU MEPhI". Tashkent – 2025. No. 1 – pp. 124–132