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IMPROVEMENT OF METHODS OF ENSURING ENERGY EFFICIENCY OF ENERGY-INTENSIVE EQUIPMENT IN THE MINING AND METALLURGICAL INDUSTRY

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A B S T R A C T

In the current stage of socioeconomic development and amidst significantly rising energy prices, the task of efficient energy use in various sectors of the country's economy is particularly important. The development of the mining and processing industry—increasing processing volumes, deeper deposits, declining ore quality and quantity, steadily rising energy prices, and reducing energy cost is one of the most pressing challenges of world. Therefore, improving methods for ensuring the energy efficiency of energy-intensive equipment in the mining and metallurgical industry is a pressing issue.

K E Y W O R D S

Control system, ball mill, thyristor, electric drive.

Introduction

Research Objective

Development of methods for reducing energy costs and increasing production efficiency by adapting the operating modes of ball mills.

Materials and Methods

Mining, processing, and beneficiation plants are among the largest industrial enterprises in terms of energy consumption. Energy efficiency is defined as the optimal (cost-effective) use of energy for ongoing production or service delivery. Recently, the annual electricity consumption of ore processing plants worldwide has been approximately 2.5 TWh. Primary ore grinding is performed by jaw and hammer crushers. The ore is then transferred to ball mills, where it first undergoes coarse grinding. In the second stage (i.e., fine grinding), it is processed by grinding media (rods or cylpebs) introduced into the mill. To improve the electrical energy efficiency of the ball mill electric drive system, it is necessary to reduce energy losses in the electromechanical system of the mill (especially in a synchronous or asynchronous drive) and increase the operating efficiency through optimal control of the electric drive power (automatic power distribution, adaptive control algorithms), as well as increasing the power factor in the drive and reducing reactive power.

Results and Discussion

Improving the energy efficiency of hydrometallurgical plants through system management using software and analytical tools will reduce energy consumption and costs, improve enterprises' ability to manage energy resources across the organizational and technical chain, and enhance their competitiveness. Therefore, efforts to expand the use of energy-saving technological tools are insufficiently effective due to the low level of implementation of energy management as a complex human-machine process. Regardless of the type of electric drive used, the qualitative and quantitative characteristics of the finished product (crushed ore), which characterize the system's operation, are determined by the operating conditions of the plant, motor, control devices, and transmission mechanisms. This is also confirmed by the total active power generated at the axis of rotation of the mill drum.

$$P = \frac{P_o + P_\Pi}{\eta_D \eta_M}, \qquad (1)$$

where: η_D- motor efficiency; η_M- transmission drive mechanism efficiency, which allows taking into account the drive mechanism losses in the ring gear and in the clutch;

P_o- useful power; P_Π- power loss.

Taking into account (1) and the formula for determining engine power, we obtain:

$$mIU \cos\varphi = \frac{P_o + P_P}{\eta_D \eta_M}, \qquad (2)$$

where m - number of phases; I - stator current; U - network supply voltage; cos φ - power factor.

To study the system's state in various operating modes, the following formulas are used. To construct the model, expression (2) is introduced using the following basic units:

$$\frac{d^2\theta}{dt^2} = \frac{1}{T_{m\mu} B} \cdot \left[\left(\left(\frac{mUE_f \sin\theta}{x_d} + \frac{mU^2}{2} \sin 2\theta \left(\frac{1}{x_q} - \frac{1}{x_d} \right) \right) \frac{1}{\omega} - m_c g R_{01} \frac{\omega_c}{\eta_M \omega} \sin\alpha \right) \frac{d\theta}{dt} + \left(\frac{mUE_f \sin\theta}{x_d} + \frac{mU^2}{2} \sin 2\theta \left(\frac{1}{x_q} - \frac{1}{x_d} \right) \right) \frac{1}{\omega} - m_c g R_{01} \frac{\omega_c}{\eta_M \omega} \sin\alpha \right] \qquad (3)$$

Where:

$$T_{m\mu} = \frac{GD^2 n^3 p}{3450\sqrt{3} \cdot 10^{-3} \cdot UI}$$

$$B = \frac{\sqrt{3} UIp}{\omega}$$

and where GD^2 - accelerating torque of the rotor; n - synchronous frequency

Taking into account (3) and using the circular diagram of the synchronous motor, the graphical relationships between the electrical parameters of the motor and the degree of filling of the base material(K_h) were confirmed (Fig.1). The relationships were obtained by measuring the electrical parameters of the motor $\cos\phi = f(K_h), \sin\varphi = f(K_h)$ $I = f(K_h)$

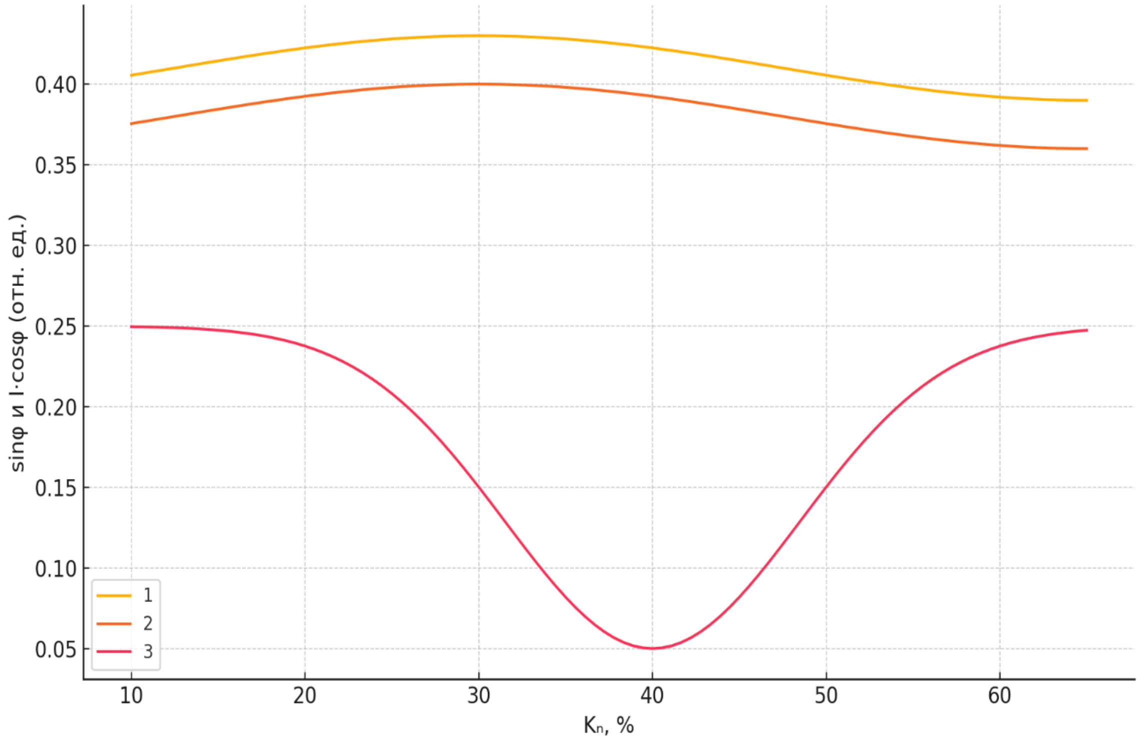

Fig.1. Dependence of the electrical parameters of the mill drive electric motor on the degree of load filling

1 - dependence of the stator current on the degree of load filling; 3-2 $-\cos\varphi = f(K_h)$ $\sin\varphi = f(K_h)$.
From Fig.1 it follows that the most sensitive curve is $\sin\varphi$. Taking into account the dependence and the dependence obtained for the angle θ, it is determined $\sin\varphi\cos\varphi = f(K_h)$ that:

$$\theta = \text{arctg}\frac{I\cos\phi}{U/x_q + I\cos\phi} \qquad (4)$$

the change in angle θ due to the change in the degree of filling of the mill can be estimated.
Many works investigating the dependence of a synchronous motor on $\theta = f(t)$, are known.
but they limit themselves to only confirming the dependence of the synchronous machine for studying the change in angle θ by $\Delta\theta$ considering relative to its constant value θ_o: $\theta = \theta_o + \Delta\theta$. Accordingly, for the electromagnetic torque M_E the following dependence is used, which is a function of the angle θ

$$M_E = M_{Eo} + \Delta M_E$$

Such studies do not allow us to assess the operating dynamics of the motor that powers the mill under the conditions of the qualitative and quantitative characteristics of the fed ore and voltage variations. To develop models for studying the operating modes of the mine's electric drive system's electric motor, we use a relationship that characterizes the relationship between the mechanical characteristics of the motor and the mill:

$$M_D = M - M_c \qquad (3.4)$$

where M - is the moment of the synchronous motor; $M_c -$ moment of ore resistance; $M_D -$ dynamic moment of the drive system.

Conclusion

Thus, the speed control method for a ball mill's synchronous electric motor has been improved, the design parameters of ball mills intended for the mining and metallurgical industry have been determined, and, taking into account process requirements, an operating mode has been developed that ensures the durability of the ball mill's protective coating, which impacts energy consumption. As a result, it allows for the degree of erosion of the mill's protective coating to be taken into account.

References

1. Avetisyan A.M. Model of investigating the dynamic processes of the ore-grinding mill electromechanical system by applying MATLAB software package//SEUA Proceedings -75: Collection of scientific and methodic articles. Yerevan. – 2008. – P. 115–118.
2. Baghdasaryan Marinka, National Polytechnic University of Armeni, Professor, Doctor of Department of Electrical Engineering. «Developing the mathematical model for investigating the ore mill electric drive system» Developing the mathematical model for investigating the ore mill electric drive system 2006. P. 89-94
3. 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
4. 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
5. 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
6. 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
7. 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.