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Improvement of methods to ensure energy efficiency of ball mills functioning

Jonibek Mavlonov*, *Davron* Mardonov*,* *Mirzohid* Eshmirzayev*,* and *Islomjon* Togayev

Navoi State University of Mining and Technologies, Navoi, 210100, Uzbekistan

Abstract. Mining, metallurgical, enrichment and processing enterprises require a large amount of electricity consumption. Among them, hydrometallurgical and enrichment enterprises currently consume 50-60% of total costs and 5.2% of all world electricity. The main reason for this is the use of traditional ball mills. Including metallurgical, enrichment and processing enterprises consume 5-20% of the electricity produced in the world. The main way to improve the performance of ball mills is to optimize the operating modes of the electric drive and mill equipment, to ensure stable operation of the ball mill and electric motor at full load. To determine such operating modes and ensure the operation of equipment in them, modern control systems, methods for assessing the energy efficiency of ball mills and optimizing the operating modes of electrical systems are required.

1 Introduction

Ball mills are used for the stage of grinding ore in mining operations with the alignment of grinding balls. Controlling the operating conditions of ball mills is a key factor for optimal mill operation and high mill productivity. The main factors affecting the efficiency of a ball mill are ball loading, drum rotation, lining wear. Optimal distribution of balls throughout the mill volume improves the efficiency of the grinding process and reduces energy costs. In addition, the properties of the ore are also important for the optimal operation of the ball mill. The ore can have different properties such as hardness, density, moisture content, etc., which can affect the grinding capacity and efficiency.

Various methods, such as monitoring and adaptive control methods, can be used to consider the properties of the ore when controlling the operation of ball mills. Adaptive control is a systems management technique that allows the system to respond to changes in external and internal factors, such as changes in ore properties, to ensure optimum mill performance and quality. It is based on the feedback principle and allows the control system to respond to changes in ore properties in real time. For example, if the properties of the ore change during mill operation, the adaptive control system can automatically change the operation parameters of the mill, generating signals and influencing the ball load and excitation current of the synchronous motor to achieve the required performance. [2]

As is known in many technological mechanisms, the most common factor on which the total and specific energy consumption depends is the performance of this mechanism. The

* Corresponding author: jonibek.nsmi@gmail.com

fundamental difference in the calculation of the influence of mill productivity on the power consumed by the mill is a very complex and not fully understood problem. In our opinion, the performance of the mill cannot affect the power consumed by the mill, and this is precisely in the sense that the energy consumption increases with the increase in the efficiency of the mill. In fact, when the mill is running at a certain power, the total mass of the mill in the revolving motion is greater than the total mass of the idle mill. The increase in the mounting mass of the mill occurs due to the crushed material obtained in the mill. The choice of the optimal mill configuration depends on the particle size of the raw material, the desired size of the product to be ground, as well as other properties that determine the relative hardness and abrasiveness of the material. The productivity of ore mills depends on the resistance to grinding of the material, its granulometric composition, humidity and temperature, the filling factor, the range of the crushed medium, their operation mode (lift height, mill length classification), aspiration intensity, depends on the adsorption properties of the medium and series, as well as on particle size distribution. The composition of the feed, the desired size of the crushed product and other factors that determine the relative hardness and education of the material. When processing coarse-grained material, the filling volume of the wet semi-automatic mill inside the mill is 25-30%, including balls - 8-15%, which contributes to the stable operation of the mill. and ensures full utilization of the plant's capacity. When working with a small feed, an increase in cycle productivity is provided by a high load on the ball and a decrease in the total filling volume of the mill by 15-18% (2-5% above the ball load level). [1]

The operation of the mill affects the power consumed by the mill, and in terms of increasing energy consumption with increasing mill productivity. The increase in the mass of ball mills occurs due to the crushed material supplied to the mill - ore and pulp. In a ball bed mill, the pulp volume reaches approximately 60-70% of the drum volume, which is separately occupied only by the ball load. As the mass of the total load of the rotating mill increases (the position of the center of gravity of the load changes), the moment of inertia of the mill load relative to the axis of rotation of the mill drum and its energy consumption increase. The effect of mill performance in a hydrometallurgical plant on energy consumption (specific energy consumption) can be relatively easily established from experimental studies, measurements of processed ore at the mill and electricity consumed 8 hours (per shift). However, it should be taken into account that other technological factors such as productivity, rotational speed, wear of the lining and ball load also affect the level of electricity consumed. Therefore, the experimental data used to obtain the quantitative laws of the interdependence of these quantities should be relatively homogeneous in relation to the values of other technological parameters that affect the level of electricity consumption by the plant [1].

2 Materials and methods

An adaptive control system for ball mills is proposed, in which the loading of balls (of the required diameter) and the motor excitation current are controlled depending on the noise signals and the stator current of the synchronous motor. Thus, the system consists of two input signals and two output parameters.

In most cases, ball mills do not consider the wear of the mill lining, the filling of balls, the speed of rotation of the mill drum for the consumed electrical energy. The main problem is that at certain times the wear of the mill linings, the reduction of the balls affects the energy consumption. The result of the experiment shows that after a certain time the protective layer of ball mills wears out, and its inner diameter increases by 25-30 centimeters.

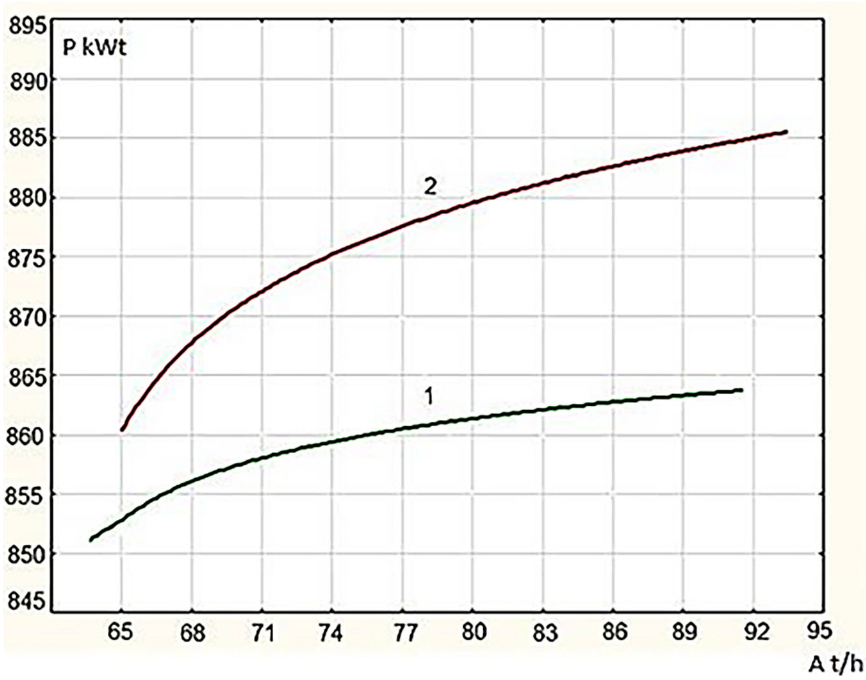

Fig.1. Energy characteristics P=f(A) of the mill. Ball mill with central discharge with new (1) and worn (2) lining.

Consequently, utilizing of electricity in mills is expanded when operating in waterfall or cascade mode. In common works, as can be seen, the development of the operating modes of the electric drive system that provides grinding of ore, different authors have developed unique methods of work in separate ways. Observations of operating modes, and significant theoretical experimental studies have been implemented. Investigated experimental and theoretical materials do not consider the characteristics structural in the electromechanical system mill - synchronous motor, especially, the dynamic behavior of the load. [1] [2-7]

Figure 1 we have carried out an experiment on the effect of wear on ball mill linings Ball mill with central discharge 45x60 in terms of energy characteristics. Analysis of the energy characteristics of the studied ball mills Ball mill with a central discharge shows that the average value of power $P_{distrupt.}$ the power consumed by a mill with a worn lining, exceeds the corresponding value of P_{new}. power consumed by the new lining, by about 100-120 kW.

3 Results

Extending mathematical models for studying the operating modes of synchronous motors of the electric drive system, a relation is used that characterizes the reliance of the mechanical characteristics of the motor and ball mills:

$$M_D = M - M_c \quad (1)$$

here M - the moment of the synchronous motor of ball mills; M_c - grinding resistance moment; M_d is the dynamic moment of the drive system, which related to the moment of inertia of the system and is determined as follows:

$$M_D = T_m \frac{ds}{dt} \quad (2)$$

where T_m is the constant of inertia; The torque of a synchronous motor is determined by:

$$M = \frac{mUE_f \sin\theta}{x_d \omega} + \frac{mU^2 \sin 2\theta}{\omega}\left(\frac{1}{x_q} - \frac{1}{x_d}\right) \quad (3)$$

where m is the number of phases, U-phase voltage applied to the stator winding; E_f-electromotive force of excitation; θ-angle of phase shift between the main electromotive force and the network voltage vectors; x_d - inductive resistance of the stator phase along the longitudinal axis; x_q-inductive resistance of the stator phase along the section axis; ω - angular speed of the engine.

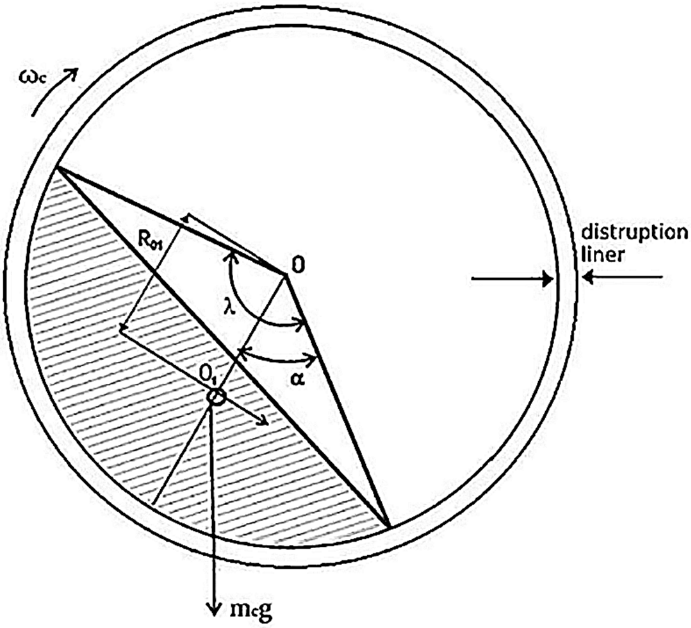

Fig. 2. Scheme for determining the moment of resistance of the ore The mass of material ground in the mill is determined as follows.

M_c is the moment of resistance of the ore mill and is defined as follows:

$$M_c = m_c g R_{01} \sin\alpha$$

And if we bring it to the engine, we get:

$$M_c = m_c g R_{01} \frac{\omega_c}{\eta_M \omega} \sin\alpha \quad (4)$$

where ω_c-angular speed of rotation of the mill; g-acceleration of gravity, η_M-transmission efficiency from the motor shaft to the mill drum; α - the bypass angle of the material in the mill; R_{01} - distance 00_1 (fig.1); m_c - mass of material ground in the mill. [1]

Distance 00_1 is determined by:

$$R_{01} = \frac{2R\sin^3\frac{\lambda}{2}}{3\left(\frac{\lambda}{2} - \sin\frac{\lambda}{2}\cos\frac{\lambda}{2}\right)} \quad (5)$$

Where λ is the central angle of the sector, corresponding to the degree of filling of the material in the mill (Figure 2); R-radius of the mill drum.

$$m_c = \frac{\gamma L R^2 N}{2Vf}(\lambda - \sin\lambda) \quad (6)$$

where γ is the bulk density of the base material; L is the length of the mill drum. Placing equations (1), (3) and (4) in (5), we obtain:

$$T_m \frac{ds}{dt} = \left(\frac{mUE_f \sin\theta}{x_d} + mU^2 \sin 2\theta \left(\frac{1}{x_q} - \frac{1}{x_d}\right)\right)\frac{1}{\omega} - m_c g R_{01} \frac{\omega_c}{\eta_M \omega} \sin\alpha \quad (7)$$

4 Conclusion

Thus, based on the given electrical characteristics, the following conclusions can be drawn lining wear leads to an increase in specific power consumption and energy consumption by 5-6% (in relation to these values with a new lining of ball mills). The level of electricity consumed by a ball mill is significantly affected by such technological factors as ball loading, rotational speed, productivity, and with an increase in the absolute values of these factors, the level of electricity consumed by a ball mill also increases. The performance of the mill affects the power consumed by the mill, and this effect is statistical in nature.

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