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Self-grinding mills synchronous motor start-up mode

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ABSTRACT: The article presents the results of experimental and theoretical studies to determine the effective start-up regime of mill installations of the mining and metallurgical industry. The influence of the starting current of the synchronous motor on the start intensity is determined. Methods for increasing efficiency when starting a synchronous mill motor are indicated.

KEY WORDS: Wet Self-Grinding Mill, Synchronous Motor, Start-Up, Ore, Efficiency, Moment.

I.INTRODUCTION

Ore preparation is the most energy-intensive and time-consuming process in the enrichment of minerals. The energy consumption for ore grinding is about 2/3 of the total energy consumption of mining plants. Despite the search and discovery of new ways of grinding minerals, crushing and grinding in drum mills remains the most acceptable. Previously, ball mills were mainly used for grinding ores, where pig-iron balls are used as a grinding medium, but recently self-grinding has been increasingly introduced, i.e. when larger pieces of the same ore are used as grinding media.

The development of the self-grinding method is primarily associated with improving the technology for processing gold-bearing ores, since the process of gold extraction using cyanide required finer grinding of the ore, as well as the exclusion from the grinding of metal grinding bodies to minimize the amount of iron impurities in the pulp as strong inhibitor in the recovery of gold.

Recently, practice has been searching for ways to intensify all varieties of self-grinding processes. One of them is the loading of balls in the amount of 5-10% of the total volume of the mill load in the mills of self-grinding, therefore, the term “semi-grinding” was introduced in relation to this kind of self-grinding process.

The main trend in the development of mineral grinding is to increase the unit capacity of grinding equipment, and with it a significant increase in the power of drive motors. As the drive motor of modern mills, a synchronous motor (SM) is used. This is due to the significant advantage of SM over an induction motor at high powers (over 500 kVA). Along with these drawbacks of the SM are the complexity of the design and the complexity of the launch [1].

To start drive SM self-grinding mills, an asynchronous start-up circuit from the mains voltage or through the reactor is currently used. However, this does not provide a normal starting mode under difficult starting conditions, as in the case of a self-grinding mill, when the resistance moment during acceleration reaches 0.75 - 1.0 of the nominal resistance moment.

We conducted a study at the facility, as a result of which it was revealed that more than half of the failures in the operation of the electric mill mill type MMS 90-30A were associated with overloads of the SM during start-up. During emergency stops of the mill and its subsequent start-up with a full load, 2–3, and in some cases up to 4 repeated launches of the mill were used. Experimental studies showed that the voltage landing at the start of the start-up was 25%, and at the sub-synchronous speed - up to 15%. In this case, the starting current reaches 5-6 times the value of the rated.

II. SIGNIFICANCE OF THE SYSTEM

The main attention in the article is paid to how the normal and rational start-up of the SM mill in terms of energy performance is ensured, taking into account the features of the process and the drive mechanism. The most effective solution to this problem is to use the frequency start-up circuit of the SM. A study of the literature review is presented in section III, the methodology is explained in section IV, and section V discusses future research and conclusion.

III. LITERATURE SURVEY

For a long time, when starting synchronous motors, the role of the accelerating motor was played by a conventional asynchronous motor, mechanically connected to a synchronous one. The rotor of a synchronous motor is rotated to a sub-synchronous speed. Further, the engine itself is drawn into synchronism. Typically, the starting motor power is 5-15% of the power of the synchronous motor. This allows you to start the synchronous motor only at idle or with a small load on the shaft. The use of a starting motor with a power sufficient to start a synchronous motor under load makes this installation cumbersome and expensive. Recently, the so-called asynchronous start-up system of synchronous motors has been used. For this purpose, rods that resemble the short-circuited winding of an induction motor are driven into the pole pieces.

In the last ten years, the asynchronous starting mode of the mill synchronous motor has been widely used. The asynchronous start method is by far the most common. Such a start was made possible after a change in the design of the rotor. Its advantage is that an additional accelerating motor is not needed, since in addition to the field winding, short-circuited squirrel cage rods were mounted in the rotor, which made it possible to start it in asynchronous mode. Under such a condition, this method of starting was widely used.

Frequency starting of synchronous motors is used to start high-power devices (from 1 to 10 MW) with an operating voltage of 6, 10 KV, both in the easy start mode (with the fan nature of the load) and with heavy start (ball mill drives). For these purposes, soft frequency start devices are available. The principle of operation is similar to high-voltage and low-voltage devices operating according to the frequency converter circuit. They provide a starting torque of up to 100% of the nominal, and also provide the launch of several engines from one device. You see an example of a circuit with a soft starter below, it turns on for the time the engine starts, and then it is removed from the circuit, after which the engine is connected to the network directly.

A. Korshunov considered the process of uniformly accelerating the frequency start-up of a synchronous motor at idle, at a constant load moment. On the phase plane of the motor, on the abscissa axis of which the rotor lag is delayed from the stator field, the stability region of uniformly accelerated acceleration is determined.

D. Ustinov and Yu. Konovalov considered various options for starting synchronous motors and proposed a combination that minimizes inrush current, increases the input torque and limits heating. The issues of matching the output voltage of the frequency converter with the supply voltage when switching a synchronous motor from the frequency converter to the network and vice versa are considered.

A.P. Cherny, K.N. Bogatyrev and A. Yu. Romanov substantiated the principle of the formation of a mathematical model. It is shown that the modelling of the common supply line and cable lines for connecting motors must be performed in a three-phase coordinate system with the voltage at the stator of each synchronous motor converted to orthogonal, taking into account the angle of rotation of its rotor. Such a mathematical model allows one to take into account the mutual influence of electromagnetic processes in starting engines. This problem is solved in order to improve the start-up conditions of synchronous motors, increase the reliability of the system, reduce the influence of their start-up modes on reducing the voltage in the network at start-up and on the operation modes of electric equipment or other electric motors connected to the same network. This is done by maintaining the voltage in the network to which the synchronous motors are connected, by transferring the motors that are started into over-excitation mode for the period when the engines are started. The simulation results are given for starting synchronous motors with and without taking into account the forcing of the excitation voltage.

M. Baghdasaryan and A. Avetisyan obtained the conditions for the stable entry of the engine of the electric drive system of the ore-grinding mill into synchronous mode in order to prevent accidents in the electric drive system as a result of the engine falling out of synchronism under the influence of various influences.
G.G. Pivnyak, V. Kirichenko and R. Borovik developed algorithms for programmatically controlling the power supply of the windings of synchronous motors in order to reduce dynamic loads and form the desired shape of the electromagnetic moment.

B. Abramov, L. Datskovsky, I. Kuzmin, A. Pridatkov and P. Limorenkowere analysed the choice of the type of starting device for electric drives with high-voltage synchronous motors depending on the nature of the change in the load moment of the mechanism, the number of synchronous drive motors to be started (one engine or sequential start of several motors) and the requirements of the technological regime, as well as the parameters of the synchronous motor. Single-line diagrams of the implementation of soft starters for driving high-voltage synchronous motors of large grinding units, axial shaft fans of the main and auxiliary ventilation are presented.

IV. METHODOLOGY

Consider the transients in the electromechanical drive system of the mill, taking into account the electromagnetic processes in the SM and the basic laws of change in the moment of resistance.

The increment in the energy of the rotating masses occurs only due to the moments M_i; acting on the drum of the mill: M_d - the electromagnetic moment of the engine and M_b - the static moment of the drum, according to the equation of motion of the system:

$$M_d + M_{br} = J_\Sigma d\omega / dt \qquad (1)$$

where $J_\Sigma = J_d + J_b$ is the moment of inertia of the rotating masses;
J_d, J_b- moments of inertia of the motor and mill drum, reduced to the motor shaft;
ω - is the motor speed;
M_{BR} - the moment of resistance of the mill drum, reduced to the motor shaft;

An electromagnetic moment is applied to the motor rotor, described according to [2] and [3] by the system of equations of a synchronous machine with frequency regulation in p.u.

$$i_d = -i\ sin(\varphi + \theta) \qquad \mathbf{(2)}$$

where Ψ_d, Ψ_q are the longitudinal and transverse components of the stator flux linkage;
$i_в$ - field current;
i_d, i_q - longitudinal and transverse components of the stator current;
u_d, u_q - longitudinal and transverse components of the voltage on the stator;
u, i - voltage and current of the stator;
μ is the engine moment;
φ is the angle of shift between the first harmonics of the current and voltage of the stator;
θ is the load angle;
α is the frequency of the stator voltage;
x_{ad}, x_d, x_q - longitudinal and transverse components of synchronous reactance;
r is the stator resistance.

The moment of resistance of the mill drum is determined, first of all, by the nature of the movement of the grinding medium. At the first moment of starting the mill, it is necessary to overcome only the friction forces in the bearings [4].

$$\mathbf{M_{стр} = k \cdot G \cdot f \cdot r,} \qquad \mathbf{(3)}$$

where k is the coefficient of proportionality;
G is the weight of the rotating parts, t;
f is the coefficient of friction;

r is the radius of the pin.

Immediately after the start of movement, the moment increases sharply due to the appearance of an additional moment from loading :

$$\mathbf{M_{b0} = G \cdot l (4)}$$

where G is the gravity of the ball load, l is the length of the perpendicular omitted from t. On the direction of the force G.

Express ball gravity

$$\mathbf{G = 1000\, M_{sh} \cdot g,} \qquad (5)$$

Where$M_{sh} = 4,6\varphi\frac{\pi D^2}{4} l$ - mass of the mill load.

Next, we define

$$\mathbf{l = x \sin\theta\ (m)} \qquad (6)$$

where x is the distance from the centre O to the centre of gravity S, m.

According to [5], the static moment of the drum M_b consists of two components: constant M_{b0} - equal in magnitude to the product of the load weight G located at the bottom of the drum and shoulder L, equal to the distance from the centre of gravity of the load to the drum axis, and a variable component: the impact moment, which depends from the loading position in the drum at each instant of time Mb ~. But at the same time, unlike the steady-state regime, M_{b0} will constantly change throughout the start-up, due to a change in the position of the mill load in the mill drum and, consequently, a change in the arm L.

According to [6], depending on the speed of rotation of the drum, the mill operation mode can be cascade, mixed (cascade-waterfall) and waterfall.In a cascade mode of operation, crushing bodies rise along concentric circular paths and slide down a cascade along a slope in parallel layers. A cascade mode of operation is observed at the initial speed of rotation and, with an increase in speed, first passes into a mixed (cascade-waterfall), and then into a waterfall mode, i.e. when the crushing bodies rise along circular paths and then fall down a parabolic path by a waterfall.

Obviously, the crushing body will be pressed against the wall of the drum until the sum of the radial components of the weight and friction force is less than the centrifugal inertia force. With a further increase in speed, a part of the material breaks away from the main mass and switches to parabolic flight paths. The value of the critical speed at which the waterfall operation begins can be found from the expression, according to [7]:

$$\mathbf{M\omega_{кр} (R - d / 2) = g \cdot m.} \qquad (7)$$

That is, the centrifugal force of the crushing body is equal to the gravity of gravity, where m is the mass of the particle, R is the radius of the drum, d is the diameter of the particle.

$$\mathbf{\omega_{cp} = (g / R - d / 2)\ 1 / 2 \approx (g / R)\ 1/2 \text{ for } R >> d.} \qquad (8)$$

An additional shock moment is added to the moment of resistance. According to [5], the impact moment is the result of the grinding material falling downward, imparting a shock pulse to the lower zone. Such pulses follow continuously one after another and are transmitted to the inner surface of the drum and from it to the drive.

However, unlike the steady state, the occurrence of a shock moment when the mill is started is caused by a short-term decrease in the load weight by the total weight of the torn off part of the material, and after its fall, by an increase in the load weight. In subsequent time instants, the shock moment increases somewhat, since due to the increase in speed, the mass of the detached part of the load increases. This process will continue until the mass of the tearing and falling parts of the material becomes approximately the same.

Thus, the value of the moment of resistance will be determined from the following relationships:

$$M_c = \begin{cases} M_{\text{тр}};\ \omega \to 0 \\ M_{60} = G\,l\,(for\ l = var);\ 0 \le \omega \le \omega_{\text{кр}} \end{cases} \qquad (9)$$

From (9), it is possible to determine from the formulas (3-8) the moment of resistance of the mill drum when changing the speed of rotation of the drum during start-up.

V.CONCLUSION AND FUTURE WORK

As a result of the study, it was found that more than half of the failures in the operation of the mill were associated with SM overloads during start-up. The most effective solution to the problem of starting the SM mill is the use of a frequency start, while one of the most important research tasks is to determine the conditions for starting the SM.

The moment of resistance of the mill during start-up is a complex quantity, depending on several parameters:
- structural data of the drum;
- mass and size of grinding media;
- process parameters (drum filling, etc.)
- from the speed of rotation of the drum and, therefore, the operating modes of the mill.

The occurrence of a shock moment during mill start-up, in contrast to the steady state, is caused by a short-term decrease in the load weight by the total weight of the torn off part of the material, and after its fall, by an increase in the load weight.

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