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A SYSTEM FOR DIAGNOSING THE RUNNING ORDER OF THE ORE MILL ELECTROMECHANICAL SYSTEM

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Abstract

A system for diagnosing the running order of the ore mill electromechanical system including subsystems for local diagnosis of the ratter, mechanical transmissions and the drive motor is proposed. This allows to obtain comprehensive information on the state of the system. The system developed gives an opportunity to improve the maintenance conditions of the electromechanical system providing the grinding process by a timely exposure of defects.

Keywords: **grinding process. electromechanical system, running order, mechanical transmissions, drive motor, motor starting time.**

Introduction.

The productions engaged in processing metallic concentrate are characterized by a significant concentration of electrical power conditioned mainly by application of a powerful electromechanical system providing the grinding process of these materials. The grinding process is the main manufacturing method in ore beneficiating enterprises, as well as in productions manufacturing construction and chemical materials, therefore the reliable maintenance of the electromechanical system providing their operation has a significant role for raising the operation efficiency of corresponding production enterprises. Diagnosing and estimating the electromechanical systems providing the ore grinding processes is a primary problem as its unplanned repair, adjustment, and preventive maintenance lead to the decrease in the profitability of the whole production process.

On the other hand, in all units and parts of technological equipment, carrying out diagnosis which must naturally operate automatically, can lead to an increase of the cost in the whole technological equipment, as well as an unstable operation of the production process. That is why, to diagnose, it is necessary to reveal the equipment and units which are subject to primary diagnosis, and based on them, develop a system for the running order diagnosis.

The electromechanical systems providing the ore grinding process have a simple scheme: engine – transmitter – rattler. But it is difficult to diagnose that seemingly simple electromechanical system as it operates in a dynamic regime. From that point of view, the problem of diagnosing such an electromechanical system should be considered in a complex form taking into account the technological and electromechanical factors.

Despite the results of the electromechanical diagnosis providing the ore grinding process [1-2], there are important problems concerning the universal control of that system's separate elements, estimation of the state and the exposure of defects. The development and proposal of the diagnosing system aimed at solving the mentioned problems is an urgent task.

Statement of the problem. The analysis of the well known works devoted to the diagnosis of the electric drive system providing the ore grinding process shows that different authors have carried out theoretical and experimental investigations aimed at revealing the possible defects of different units. Great experience has been stored up for creating means for diagnosing ore mills and automated diagnosing systems, and improving the latter. According to the diagnosed elements, the mentioned works can be conventionally classified into 2 groups: These groups are:

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- works in which the system is diagnosed by means of control and estimation of technological factors;

- works in which the system is diagnosed by means of control and estimation of mechanical factors.

It is obvious that the mentioned works refer to particular cases and do not allow to provide the high efficiency of the mill – motor system maintenance. At the same time, it should be mentioned that the known works do not take the interrelation of technological, mechanical and electrical factors into account.

The ore grinding process undergoes uncontrollable, disturbing impacts influencing the operation of the electromechanical system. That is why, for efficient diagnosis of the system, a special approach taking into consideration the possible operating modes of the rattler, the running order of the electromechanical system's mechanical transmissions and the drive motor is required[3-5].

The solution of the problem set may be realized by developing such a system for the electromechanical system diagnosis which will include local subsystems for diagnosing the rattler, mechanical transmissions and the drive motor, and this is the goal of the work.

A subsystem for diagnosing the running order of a rattler.

The comparative analysis of the standardized spectral density of the drive motor active power at new (Fig. 1, a) and worn (Fig. 1, b) linings shows that at a frequency close to the frequency (ω =3,3....3,7Hz) of the lining projections into the ground material, the active power signal amplitude decreases at the lining wear [6].

Based on the results of the investigations carried out, a method for diagnosing the operating regimes of the rattler taking into account the situation arising in the areas close to the intramill loading oscillation frequency, and the lining projection frequency of the mill into the ground material is proposed.

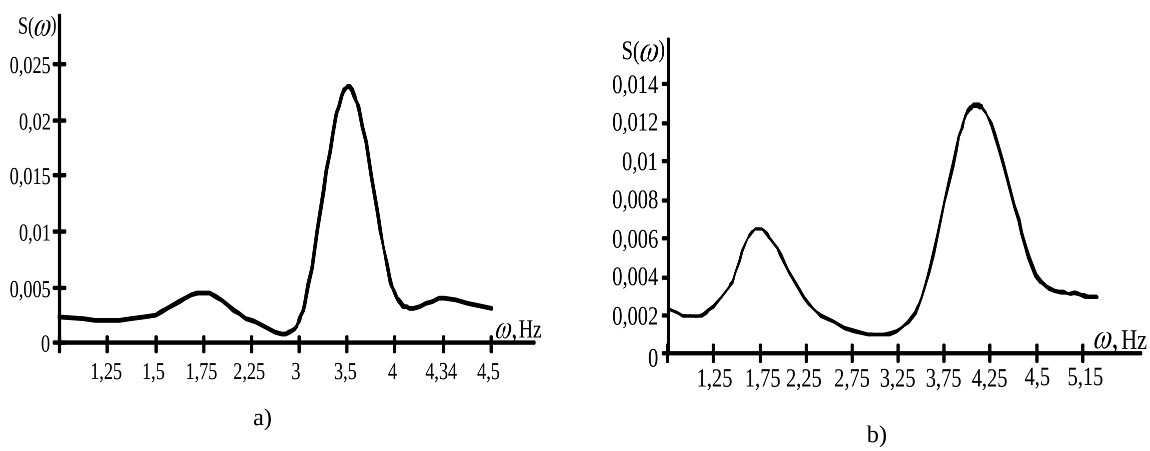

Fig. 1. Standardized spectral densities of the drive motor active power at new a) and worn b) linings.

The essence of the method is that the increase in the mill efficiency is realized at the expense of increasing the intramill loading oscillation amplitude by periodically changing the instantaneous rotation frequency of the mill drive motor by phase coincidence with the oscillation centre of gravity of the intramill loading, and the timely exposure of the required wear degree of the lining.

The block diagram of the diagnostic subsystem for a rattler based on the developed method is introduced in Fig. 2.

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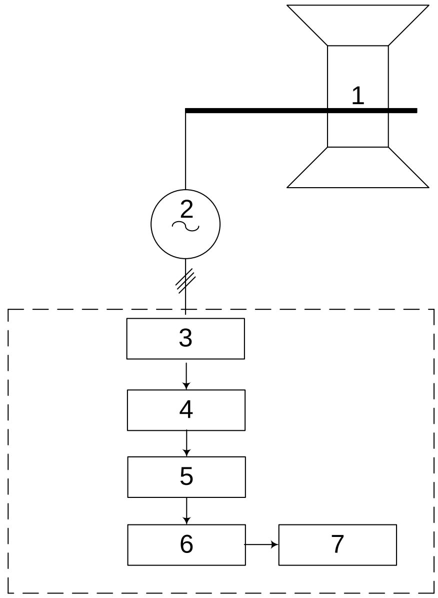

Fig. 2. The block diagram of the diagnostic subsystem for a rattler taking into account the state of the lining. 1- the mill, *2* - drive motor, *3* - three-phase power transformer, *4* - the spectrum analyzer, *4* - the difference determining unit, *6* - the comparator, *7* - the register.

The diagram operates in the following way. The drive motor active power is

transformed into voltage by means of the three-phase transformer switched to the synchronous engine The signal proportional to the active power comes out of the transformer and enters the spectrum analyzer intended for extracting a signal of adequate frequency close to that of the entrance of the mill lining into the ground material. The extracted signal is registered in the difference determining unit and is determined by the formula:

$$\Delta S(\omega) = S_{н}(\omega) - S_{p}(\omega),$$

where $S_{н}(\omega)$ is the peak value of the active power signal at a new lining, $S_{p}(\omega)$ - the peak value of the active power current signal.

The obtained value $\Delta S(\omega)$ in unit 6 is compared with the set $\Delta S_3(\omega)$, and if $\Delta S(\omega) > \Delta S_3(\omega)$, the register receives corresponding information on the change in the rotation frequency of the rattler, or the necessity of terminating the grinding process for the purpose of replacing the lining plates by new ones.

A subsystem for diagnosing the running order of the electromechanical system mechanical transmissions.

The operation of the proposed subsystem is based on estimating the running order of the system through determining the changes in the detour angular shift of the bearing sub-crown gear fixed on the motor shaft and the crown gear fixed on the mill drum [6]. The block diagram of the subsystem is introduced in Fig. 3. The diagram includes: the ore mill (1), the mill drive motor (2), the torque strain-gauge of the motor (3), the rotation speed transducer of the motor (4), the filling degree gauge of the mill (5), the transducer of the rattler rotation speed (6), the strain-gauge of the mill load moment (7), the ore feeder (8), the weight of the supplied ore (9), the transducer of the mill concentrate density (10), and the calculation unit (11).

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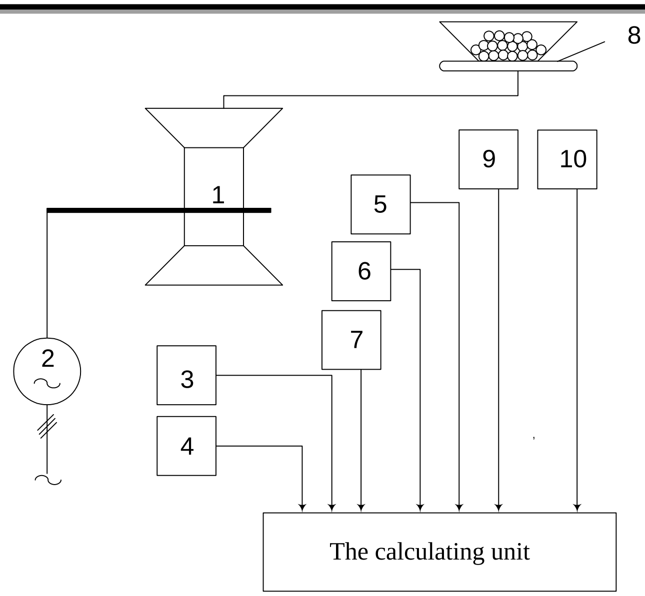

Fig. 3. A subsystem for diagnosing the running order of the electromechanical system mechanical transmissions

The peak values of the mill and motor torque signals, the angular velocities of rotation, the filling degree of the mill, the volume density of the pulp, the mass of the supplied ore are measured by a set periodicity. The signals are transmitted to the calculating unit in which the obtained signals are digitized and calculated using the additional information stored up in the registers of the calculating unit.

The rattler moment of inertia is:

$$J_1 = m_p x^2, \qquad x = \frac{2}{3}\frac{R}{K\pi}\sin^3\left(\frac{\lambda}{2}\right),$$

where m_p is the intramill load mass, K - the filling degree of the rattler, R - the inner radius of the drum, λ - the central angle of the drum filling determined by the following formula:

$$\lambda - \sin\lambda = 2K$$

as a result of solving the transcendental equation.

The periodical changes in the shift of the detour angle of the crown gear attached to the body of the rattler, and the velocity and acceleration $\varphi_1, \dot{\varphi}_1, \ddot{\varphi}_1$, as well as the periodical changes in the shift of the detour angle of the sub-crown gear connected to the motor shaft and the velocity and acceleration $\varphi_2, \dot{\varphi}_2, \ddot{\varphi}_2$, are determined by the following equations respectively:

$$\begin{cases} \varphi_1(t) = a_0 + a_1\cos\omega t + b_1\sin\omega t, \\ \varphi_2(t) = A_0 + A_1\cos\omega t + B_1\sin\omega t, \end{cases}$$

$$\begin{cases} \dot{\varphi}_1(t) = a_1\omega\sin\omega t - b_1\omega\cos\omega t, \\ \dot{\varphi}_2(t) = A_1\omega\sin\omega t - B_1\omega\cos\omega t, \end{cases}$$

$$\begin{cases} \ddot{\varphi}_1(t) = -a_1\omega^2\cos\omega t - b_1\omega^2\sin\omega t, \\ \ddot{\varphi}_2(t) = -A_1\omega^2\cos\omega t - B_1\omega^2\sin\omega t. \end{cases}$$

Here a_0, a_1, b_1, A_0, A_1, B_1 are coefficients for whose solution the mathematical model of diagnosing the state of mechanical transmission developed by us has been used [7].

The values obtained for the shift of the detour angle of the crown gear attached to the rattler body and the sub-crown gear connected to the motor shaft, and the periodical changes in the velocity and acceleration are compared with the

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corresponding values of the calculating unit, and as a result of that, according to the set admissible shift, information on the running order of mechanical transmissions is given.

By means of the block diagram introduced in Fig. 3, it is possible to reveal the operation modes of the elastic units of the electromechanical system. For that purpose, the peak values of corresponding torques are registered by the set Δ_t period by means of strain-gauges of the mill load torque and the motor torque. The values registered are digitized and transmitted to the calculating unit. Through these values, the dynamic moment of the system in the set interval is determined:

$$M_j = M_{Dj} - M_{Mj}, \quad j = 1,2,\ldots,k$$

where j is the registration number, and k is the number of registrations.

From the mass obtained for the dynamic moment peak values, their minimum M^{min} and maximum M^{max} peak values are determined and separated, and the asymmetry coefficient is determined:

$$\rho = M^{min} / M^{max}.$$

The calculation value of the asymmetry coefficient is compared with the admissible value set beforehand. If the calculation value is smaller than the admissible value, operation of the system is inadmissible, and so a message is given about it.

A subsystem for diagnosing the running order of the drive motor.

To reveal the drive motor running order,

- the motor starting moment,
- the motor starting time,
- the motor efficiency

have been used as controlled parameters.

The block diagram of the subsystem is introduced in Fig. 4. The system consists of the rattler (1), the drive motor (2), the tension sensor of the motor torque (3), the transducer of the motor rotation speed (4), the unit for measuring the motor stator current, voltage the phase shift, the calculating unit.

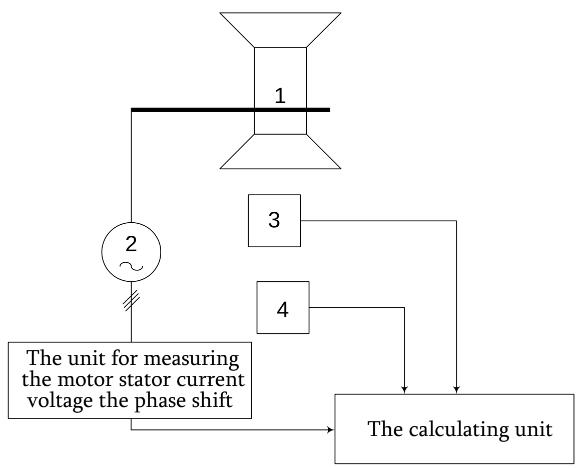

Fig. 4. The block diagram of the subsystem for revealing the running order of the mill drive motor.

Below, the control procedures for the above-mentioned parameters are introduced in sequence.

The control of the starting moment is carried out in the following way. The measurements of the starting moment are carried out with a periodicity

$$t_1, t_1 + \Delta_t, t_1 + 2\Delta_t, t_1 + 3\Delta_t, \ldots, t_n. \quad \Delta_t = \frac{t_n - t_1}{10}.$$

The values of the measured moment are transmitted to the analog –to-digital and digital – to-analog calculation unit, in which the starting moment value is calculated:

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$$M_{\Pi} = \frac{\sum_{i=1}^{i=n} M_{\Pi i}}{10}.$$

The starting moment M_{Π} is compared with the admissible value $M_{\Pi dop}$. If the condition $M_{\Pi} \geq M_{\Pi d}$ is satisfying, we pass onto controlling the starting time. To determine the whole time of the motor start-up, the peak values of the motor torque and the mill moment of resistance are measured in the interval from the rotation speed 0 to ω_c by the step $\Delta\omega = \frac{\omega_c - 0}{n}$. The obtained signals are transmitted to the calculation unit in which, for each section, the dynamic moment and the run-up time of the system are calculated:

$$M_{din\,i} = M_{D\,i} - M_{M\,i},$$

$$\Delta t_{i+1} = J\frac{\omega_{i+1} - \omega_i}{M_{din\,i} - M_{din\,i+1}} \ln\frac{M_{din\,i}}{M_{din\,i+1}}, \quad i=0,...,n.$$

In the calculation unit, by addition of the run-up times in all sections, the actual value of the system starting time is obtained:

$$t_{\Pi} = \Delta t_1 + \Delta t_2 + \Delta t_3 + ... + \Delta t_n.$$

Then, it is compared with the admissible value of the starting time $t_{\Pi dop}$.

The efficiency of the electromechanical system drive motor is largely conditioned by the thermal mode of the stator winding. At the same time, the increase in power losses can be conditioned by the load overloading, asymmetry of the suppying voltage, the change in the parameters of the motor stator and rotor windings, the change in the symmetry of the magnetic system [5,8]. To reveal the above-mentioned situations, it is necessary to control the motor efficiency at different values of the intramill load.

During the operation of the rattler drive system, according to the set Δ_t interval, the torques M_{Mi} of the drive motor, the I_i current of the motor stator winding, the U_i voltage, the phase shift angle φ, the angular speed of the motor rotation ω_{Mi} are measured. The measured quantities are transmitted to the calculation unit, in which the actual value η of the motor efficiency at the given load is calculated.

$$\eta = \frac{\sum_{i=1}^{i=n} M_{Mi}\omega_{Mi}}{m\sum_{i=1}^{i=n} I_i U_i \cos\varphi}.$$

The obtained value of η is compared with the admissible value of the motor efficiency η_{adm} in the calculation unit at the same load. If $\eta \geq \eta_{adm}$, it is clear that the motor losses have not increased, otherwise, information on the increase in the motor power losses is given.

Diagnosing the electromechanical system providing the ore grinding process.

The block diagram obtained by combining the subsystems for diagnosing the running order of the rattler, the running order of mechanical transmissions of the electromechanical system, and the running order of the drive motor is introduced in Fig. 5.

By means of that diagram, it is possible to carry out a comprehensive diagnosis of the electromechanical system providing the drive of the ore mill by applying a small number of devices.

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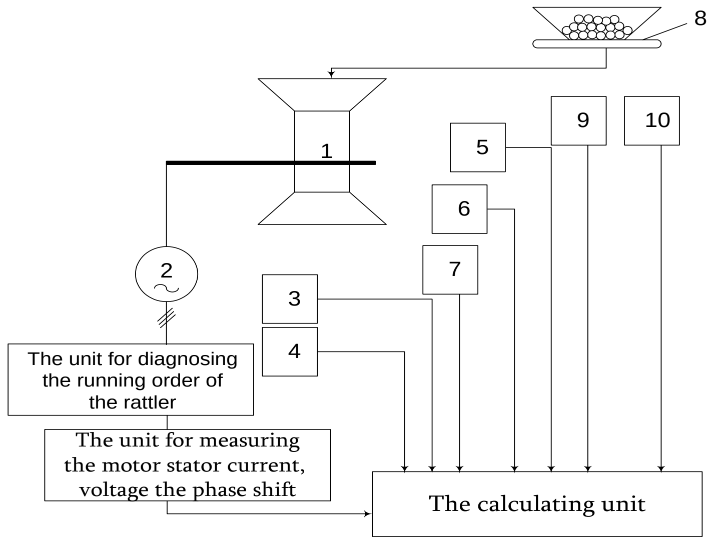

Fig. 5. The block diagram of the system for diagnosing the electromechanical system providing the ore grinding process.

Conclusions

The developed system allows:

- to improve the maintenance conditions of the electromechanical system providing the grinding process by timely exposure of possible defects.

- By taking the arisen situation into account, to avoid additional power expenditure and create prerequisites for developing and optimal control system for the ore grinding process.

References

1. Development and application of diagnosis techniquie for elektrical and control facilities / Okitsu Hiroto, Saijo Yoshio, Nakamoto Tadashi, Shirafuji Toshio, Ishida Naruo // NKK Techn. Rev.-1989, 55. P.50-58.
2. Diagnostics and protections for an induction motor controller /Gururaja Rao T.R., Bhuvansewari G., Sastry V.V. //TENKON189: 4th IEEE Red. 10 Int. Conf."Inf.Technol.90's:Energy, Electron., Comput., Commun." Bombay, 22-24
3. Palme Oliver, Kloden Wolfgang. Modelling and control of the comminution process in a ball mill. //Proc. Int. Miner. Process. Congr. Aachen. 21-26 Sept. 1997, Vol. 2. P.307-315.
4. Lira B.B., Kavatsky A. Application of a new model-based mehod of ball mill simulation and design //Minerals Engineering. - 1990. - Vol. 3, N 1/2. - P. 149-163.
5. Nord St. Fault detection in AC drives by procees parameter estimation motors //Elec. Power Syst. Res.-1988,Vol. 15,3 P.189-195.
6. Baghdasaryan M.K. A System for Controlling the Process of the Mineral Raw Material Grinding. LAP Lambert Academic Publishing, 2012. – 184p.
7. Baghdasaryan M.K., Alaverdyan S.S. A mathematical model for investigating the Electromechanical system Mill-Motor //Proceedings of NAS, RA and SEUA. Series: ES, 2013, vol. LXVI, N 2, pp. 148-155.
8. Nord St. Fault detection in AC drives by procees parameter estimation //Autom. Countr.: Selec. Pap. 10-th Trien Wolrd Congr. Int. Fed. Autom. Countr., Munich, 27-31 Juli, 1987.Vol 3. Oxford etc., 1988-P.399 - 404.