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Assessing the Ways of Improving the Power Saving Modes in the Ore-Grinding Technological Process

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Abstract**—**Monitoring the distribution of electric power consumption in the technological process of ore grinding is conducted. As a result, the impacts of the mill filling rate, the productivity of the ore supply, the volumetric density of the grinding balls, the specific density of the ground ore, and the relative speed of the mill rotation on the specific consumption of electric power have been studied. The power and technological factors affecting the reactive power generated by the synchronous motors, operating within the technological scheme are studied. A block diagram for evaluating the power consumption modes of the technological process is presented, which includes the analysis of the technological scheme, the determination of the place and volumetric density of the ore-grinding mill, the evaluation of the technological and power factors affecting the energy saving process, as well as the assessment of the electric power standards.

Keywords**—**Electric power standard, factor, ore grinding, power consumption, reactive power, technological.

I. Introduction

THE main consumers of the electric power are the industrial enterprises. In power consuming productions, energy saving is of decisive importance for the economic development. Within the competitive environment of the modern market economy, depending on the situation, new requirements are set to the product quality. On the other hand, the problem of decreasing the production costs is getting extremely urgent. Under such conditions, the evaluation and control of the factors, affecting the power consumption modes in some power-consuming productions are considered quite important. One of such power-consuming production processes is the ore-grinding technological process which is the main production stage of obtaining metallic concentrate in the ore-beneficiating plants, as well as for obtaining some construction and chemical materials. The costs of power consumption in the mentioned productions represent the largest proportion within the overall expenses made. In practice, the ore-grinding technological process uses a variety of single-stage, two-stage and three-stage schemes of a topological structure, which differ in the sequence of the operations, the number of the existing cycles in the scheme, and the operations including these cycles. Any technological scheme of grinding includes a certain number of technological devices of this or that type, carrying out operations of grinding, classification and delivery operations and are characterized by special operation modes. To investigate the factors affecting the power consumption modes, studies of the distribution of electricity consumption in the technological process have been carried out [1]-[3].

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The observations of the electric power consumption distribution in the grinding technological process introduced in Figs. 1 and 2 refer to different technological cases of grinding – in the first case the crushing operation proceeds the grinding process, while in the other case the latter is missing.

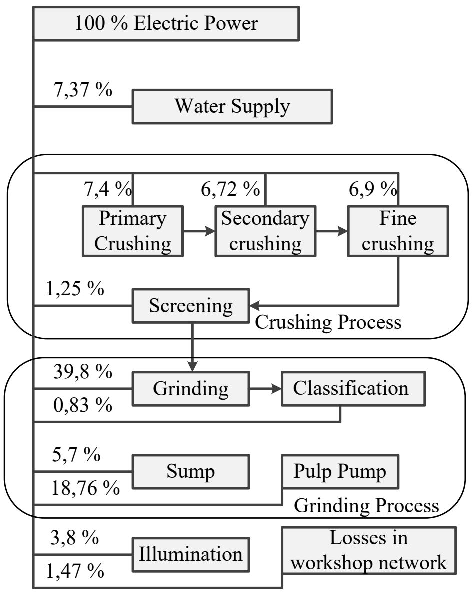

Fig. 1 A scheme of distribution of electric power consumption of the grinding process (when crushing proceeds the grinding process)

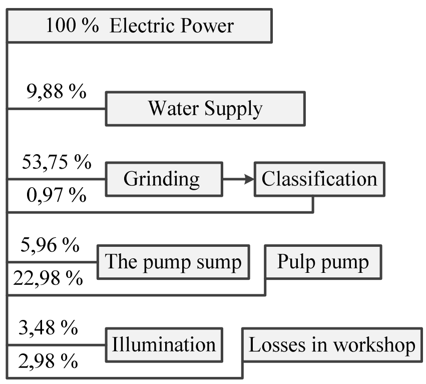

Fig. 2 A scheme of distribution of electric power consumption of the grinding process (when the crushing process is missing)

The distribution introduced in Figs. 1 and 2 has been obtained by analyzing and averaging the electric power consumption in ore beneficiating plants in different years [4].

The observations carried out confirm that in the grinding technological process, most part of electric power is consumed by mills. Therefore, the improvement of the power consumption modes of the electromechanical system, ensuring the ore-grinding mill operation is of utmost importance.

There are numerous scientific works devoted to the theoretical and experimental investigations of power consumption modes of different technological processes in different industrial enterprises [5]-[7]. In the well-known work, the power consumption modes have been studied according to the factors given below:

- Organizational-technical measures of the technological process;
- Application of the power-saving equipment and technologies;
- A decrease in the electric power losses in power supply system;
- Regulation of interdepartmental issues (investment of electric power tariffs);
- Estimation of voltage deviations.

Despite the results achieved in the area of the power consumption mode investigation, their application at changing the technical and economic requirements set to the grinding process becomes inexpedient. In particular, the power consumption modes of the ore-grinding technological process and the ways of their improvement are conditioned by the structure of the used technological scheme, the characteristics and number of the devices used in the scheme, the unstable nature of the process implementation, and the quality requirements set to the concentrate. Considering the above-mentioned, it becomes necessary to estimate the ways of improving the power consumption modes of the ore grinding technological process, which is the very goal of the present work.

II. The Factors Affecting the Power Consumption Modes

A. The Technological Factors Affecting the Electric Power Consumed in the Ore-Grinding Process

The power consumption modes of an ore-grinding mill are conditioned by more than 20 technological factors. Below are considered the technological factors changing in the system's maintenance process, which, according to the experts, change more frequently [8]. According to the estimates, the impact of the mill filling degree (K), the productivity of the ore supply to the mill (Q), the volumetric density of the grinding balls (γ), the specific density of the ground ore (δ), the relative velocity of the mill rotation (ψ) on the specific consumption of electric power (w) are considered [9].

The analysis of Figs. 3-7 shows that the mill filling degree, the rotation velocity, the productivity of the ore supply, the specific density, and the volumetric density of the grinding balls have a significant impact on the specific consumption of the ore-grinding mill electric power, which confirms the impact of those technological factors on the modes of electric consumption of the grinding process.

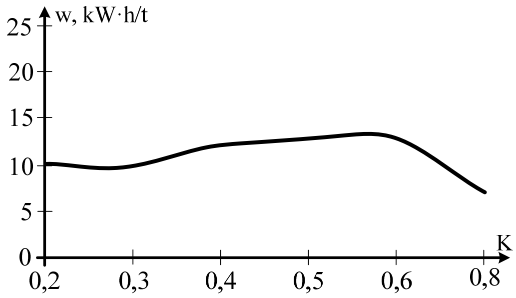

Fig. 3 The dependence of the specific consumption of electric power of the grinding process on the mill filling degree

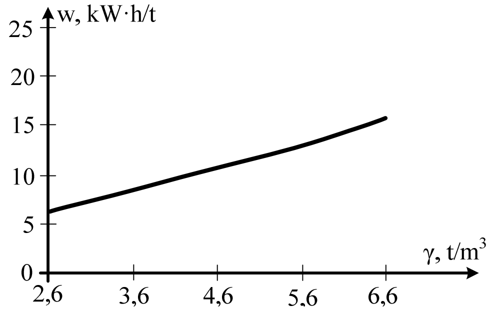

Fig. 4 The dependence of the specific consumption of electric power of the grinding process on the volumetric density of the grinding balls

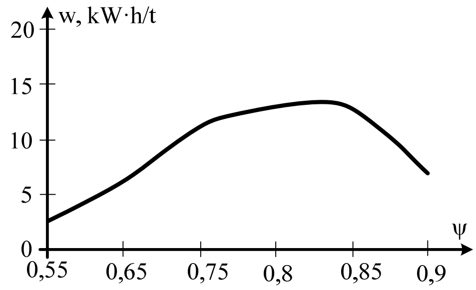

Fig. 5 The dependence of the specific consumption of electric power of the grinding process on the relative velocity of the mill rotation

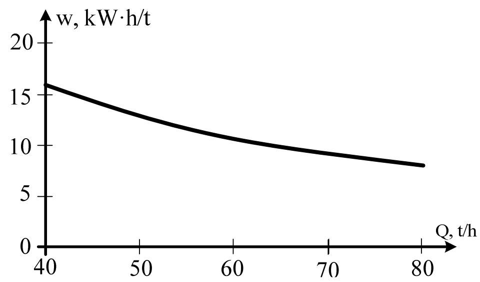

Fig. 6 The dependence of the specific consumption of electric power of the grinding process on the productivity of the ore supply to the mill

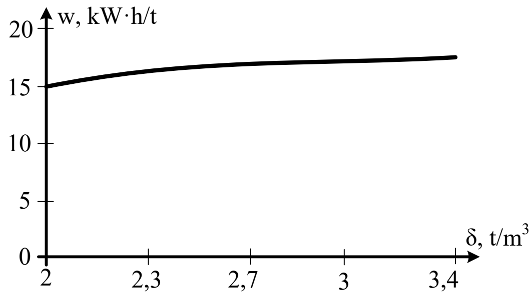

Fig. 7 The dependence of the specific consumption of electric power on the specific density of the ground ore

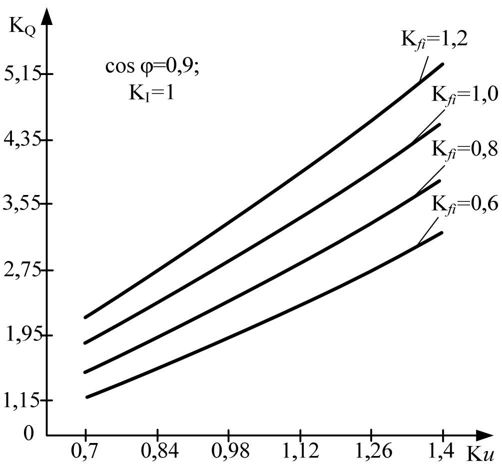

Fig. 8 The dependence of the relative value of reactive power of the synchronous motor on the voltage coefficient at different coefficients of the excitation current

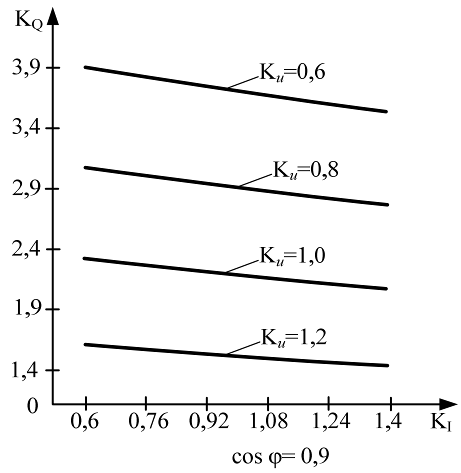

Fig. 9 The dependence of the relative value of reactive power of the synchronous motor on the motor stator current at different values of supply network voltage

B. The Power Factors Affecting the Electric Power Consumed in the Ore Grinding Process

In the ore-grinding technological process, the powerful motors used for the ore mill electric drive can be a source of reactive power for the electric drive induction motors of ore cutters, classifiers, pulp pumps, which are consumers of reactive power used in the same process. That fact has a significant impact on the improvement of the power consumption modes of the process. Considering that the reactive power generated by the synchronous motor is conditioned by numerous power and technological factors, the impacts of the supply network voltage and the stator current on the reactive power generated by the synchronous motor used in the grinding technological process have been estimated (Figs. 8, 9) [10].

As it is seen, the reactive power Q supplied to the circuit of the synchronous motor, conditioned by the change in the load undergoes a significant change. Consideration of that fact becomes more important, when the ore mill is used as a load at which Q reactive power is determined as follows:

$$Q = \left(P_0 + P_x + P_{dop}\right) tg\,\varphi / \eta ,$$

where P_x is the idle run power consumed for the rotation of the drum without the intramill load; P_{dop} are the additional power losses conditioned by the friction of the bearings; P_o - the useful power consumed to set the intramill load into motion; η -the motor efficiency.

C. Standardizing the Electric Power Consumption of the Grinding Process

To improve the power consumption modes, the issue of the accurate standardization of the consumptions is very important. The consumptions of electric power are usually divided into technological, total workshop and total factory consumptions [11], [12]. The total workshop consumption includes the main and additional technological processes, as well as the additional needs of the workshop (heating, illumination, current repair, power losses in the workshop nets and transformers).

Determining the electric power norm in the ore-grinding process is different at various production conditions. In particular, that difference is conditioned by differences of the technological scheme structure, the type of the equipment used, and the qualitative properties of the processed ore.

The power of the main devices, including both power-consuming and non-power-consuming technological devices is determined through:

$$P = \sum_{i=1}^{n} P_i , \qquad (1)$$

where P_i is the consuming power of the i-th main device; n - the number of the operating devices.

Formula (1) is correct in the case, if, in the technological scheme, the place and the sets of the devices are unchanged. However, in practice, the mills of the same type and geometrical dimensions are used at different stages of grinding. The consuming powers of the mentioned mills are considerably different, while they are nearly similar at the same stage. Therefore, the place occupied by the mill at the corresponding stage of the technological scheme is taken into account. In the case of different possible volumetric ratios of ore mills and the known *m* number of similar mills, the consuming power of the main devices is determined by [9]:

$$P = P_M + \sum_{i=1}^{q} P_i \ , \qquad (2)$$

where P_M is the total consuming power of the mills used, which, for a two-phase grinding process, is determined by [9]:

$$P_M = mP_{M1} + mP_{M2} \text{, at the volumetric ratio of the mills } 1:1,$$

$$P_M = 2mP_{M1} + mP_{M2} \text{, at the volumetric ratio of the mills } 2:1,$$

where P_{M1} and P_{M2} are the consuming powers of the mills of the first and second phases respectively.

The analysis carried out comes to prove that the improvement of power consumption modes of the ore-grinding technological process can be implemented by a complex estimation of the process. An algorithm for estimating the power consumption modes of the technological process whose block diagram is introduced in Fig. 10 is proposed.

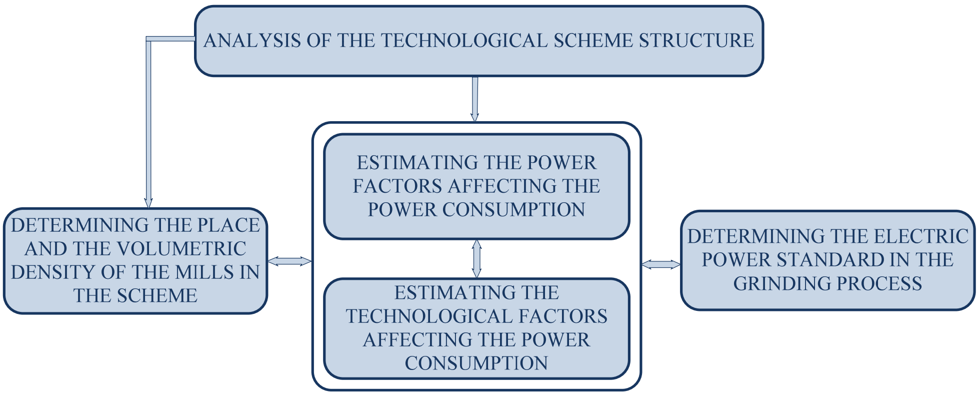

Fig. 10 The block diagram of estimating the power consumption modes of the ore-grinding process

III. Conclusion

The analysis carried out allows to conclude that the improvement of the power consumption modes of the ore-grinding technological process may be implemented by a comprehensive estimation of technological and power factors affecting the process. This gives an opportunity to estimate the process regardless of the scheme's topological structure, the type and number of devices involved in it, and introduce proposals for improving the power consumption modes.

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