Ore preparation multi-criteria energy-efficient automated control with considering the ecological and economic factors

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Abstract
A comprehensive optimization criterion of the ore preparation technological complex control process considering the factors of energy efficiency, environmental and economic performance of mining factory is presented.
Keywords: CONTROL CRITERIA, ORE PREPARATION, ENERGY EFFICIENCY, ENVIRONMENTAL AND ECONOMIC INDICATORS.

Recently observed, the mining companies production outputs growth leads to the growing influence of technological processes on the environment and to an increase in the risk of exhaustion both a non-renewable and renewable resources.

In this regard, the energy efficiency problem and resource saving management of such enterprises are particularly important, taking into account the ecological and economic factors. An ecological-economic system should be viewed as a hierarchical controlled dynamic system [1, 2]. The simplest hierarchically controlled dynamic system has two levels and comprises: the upper level control source (master), lower level control source (slave) and controlled dynamic system (CDS).

An important indicator of the mining enterprises effectiveness is the cost price and power consumption reduction of the raw iron ore extraction and processing technological processes [3–5, 12-14].

In modern conditions, on average of 5–8 ore technological varieties is processed on mining enterprises [6]. It is often necessary to reconfigure some of the technological regime, which reduces the ore beneficiation processes efficiency.

Issues of iron ore raw materials characteristics operational control at various stages of its processing using modern methods are well studied in the works [5, 8, 12–21]. Thus, it is advisable to explore the issue of ore preparation automated control optimization, considering energy, environmental and economic factors.

In [7] is proved that for the environmental and economic enterprise activity assessment it is useful to compare the value of its harmful effects, and profit from the iron-containing products production, which, considering the necessity of raw iron ore several varieties processing, while optimizing for the period consisting of T intervals as follows

$$J_{\Theta}\left(\overline{\psi}\right)=\max_{t=1\sim T}\left\{\frac{\left[\Theta'\left(\overline{\Omega},\overline{\psi},t\right)\right]+\sum_{j=1}^{N_{\Theta}}\left[\Theta''_{j}\left(\overline{\Omega},\overline{\psi},t\right)\right]}{\sum_{i=1}^{N_{\Omega}}\Omega_{i}\left(\overline{\psi},t\right)\cdot \mathrm{Pr}_{\Omega i}\left(\overline{\psi},t\right)-\left[\sum_{i=1}^{N_{\Omega}}\Omega_{i}\left(\overline{\psi},t\right)\cdot E_{\Omega i}\left(t\right)\right]}\right\}\to \min$$

(1)

where $\overline{\psi}=\{\psi_i \mid i=1\ldots N_r\}$ – is the processed ore amount by separate technological varieties, ton; $\Theta'\left(\overline{\Omega},\overline{\psi},t\right)$ – is the organized dust emission in the interval of t, ton; $\Theta''_j\left(\overline{\Omega},\overline{\psi},t\right)$ – is the j-unorganized dust emission rate in the interval of t, ton; $\Omega_i\left(\overline{\psi},t\right)$ – is the i-th names production output amount in the interval of t considering processing volumes of individual technological varieties, ton; $\mathrm{Pr}_{\Omega i}\left(\overline{\psi},t\right)$ – is the wholesale price of the i-th product names in the interval of t, hrn; N_{Ω} – is the number of the plant production names; $E_{\Omega i}\left(\overline{\psi},t\right)$ – is the specific operating costs for the i-th name of the product, hrn/ton.

In [8] a generalized energy efficiency condition of the mining enterprise, processing several technological types of ore is proposed

$$\begin{cases}\left|\overline{\xi}-\overline{\xi^{*}}\right|\to \min;\\ \Omega_{l}\le \Omega \le \Omega_{h};\\ \beta_{l}\le \beta \le \beta_{h};\\ Q/E\to \max,\end{cases} \quad (5)$$

where $\overline{\xi}=\{\xi_i \mid i=1,\ldots N_r\}$ – is the specific weight of each technological variety in the ore; $\overline{\xi^{*}}=\{\xi_i^{*} \mid i=1,\ldots N_r\}$ – is the optimal specific weight of each technological variety; Ω, Ω_l, Ω_h – is the current, the minimum and maximum weight of the produced concentrate respectively; β, β_l, β_h –is the current, minimum and maximum content of iron in the concentrate respectively; E — is the maximum possible amount of the processing ore; Q — is the total amount of processing ore of all technological varieties.

In order to comply the above term of energy efficiency (5), as well as features of the beneficiation process outlined in [9], it is advisable to use the following criteria proposed in [8].

Thus, the problem of the ore preparation energy-efficient automated control considering ecological and economic factors has a multi-criteria nature, which requires the research of the respective approaches to its formalization and decision. It is known a number of well-established approaches: the main criterion selection, lexicographic, the convolution of individual criteria, the ideal point, etc.

Using the main criterion separating method is justified in the case where one of the particular criteria by far surpasses the other. In this case, the use of this approach is difficult due to lack of sufficiently significant advantages of individual criteria. In this case, the lexicographic approach is also not appropriate because it does not allow to take into account only the fact of the superiority of one criterion over the other and cannot account for the degree of excellence that can lead to an unjustified narrowing set of alternative control actions. When using the method of an ideal point it must be specified the additional information in the form of a perfect solution, the receipt of which in many cases is difficult. Seems the most appropriate to use the method of aggregation (convolution) of individual criteria by constructing a generalized criterion as a scalar function [10].

Using the linear convolution of the above partial criteria let’s obtain the generalized criteria expression of ore preparation energy-efficient automated control considering ecological and economic factors as follows

$$J^{(ОПВ)}\left(\overline{\psi}(t)\right)=\left[\begin{array}{l} w_1\cdot\max\limits_{t=1\sim T}\left\{1-\dfrac{\left(\Omega_h-\Omega\left(\overline{\psi},t\right)\right)}{\Omega_h-\Omega_l}\right\}+ \\ +w_2\cdot\max\limits_{t=1\sim T}\left\{1-\sum\limits_{i=1}^{N_r}\dfrac{\psi_i(t)}{E}\right\}+ \\ +w_3\cdot\max\limits_{t=1\sim T}\left\{\dfrac{1}{N_r}\sum\limits_{i=1}^{N_r}\left(\left|\psi_i(t)-\dfrac{1}{T}\sum\limits_{\tau=1}^{T}\psi_i(\tau)\right|\Big/\dfrac{1}{T}\sum\limits_{\tau=1}^{T}\psi_i(\tau)\right)\right\}+ \\ +w_4\cdot\max\limits_{t=1\sim T}\left\{\dfrac{\left[\Theta'\left(\overline{\Omega},\overline{\psi},t\right)\right]+\sum\limits_{j=1}^{N_\Theta}\left[\Theta''_j\left(\overline{\Omega},\overline{\psi},t\right)\right]}{\sum\limits_{i=1}^{N_\Omega}\Omega_i\left(\overline{\psi},t\right)\cdot\Pr_{\Omega\,i}\left(\overline{\psi},t\right)-\left[\sum\limits_{i=1}^{N_\Omega}\Omega_i\left(\overline{\psi},t\right)\cdot E_{\Omega\,i}(t)\right]}\right\} \end{array}\right]\rightarrow\min_{t=1\sim T} \quad (6)$$

where the relative importance coefficients of individual criteria w_1, w_2, w_3, w_4 satisfy the conditions

$$\begin{cases} w_1+w_2+w_3+w_4=1; \\ w_1>0,\quad w_2>0,\quad w_3>0,\quad w_4>0 \end{cases} \quad (7)$$

The relative importance coefficient values of individual criteria can usefully be measured by the method of Saaty [11] on the basis of expert advice.

Conclusions. The proposed energy-efficient control criterion of ore preparation process considering ecological and economic factors of the mining and processing plant activities should be used at the top level of automated enterprise management system and the optimal processing amounts of ore technological varieties calculated with it is necessary to use as setpoint for the technological lines control systems.

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