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OPTIMIZATION OF TECHNOLOGICAL PROCESSES OF MINERAL WASTE PROCESSING DASHKESEN ORES

The article discusses the optimization of technological processes for the processing of mineral waste from the Dashkesen ores, taking into account the dynamics of the energy intensity of operations. Methods for estimating the parameters of mathematical models by the least-squares method are presented. It has been established that the practical search for environmentally rational technological solutions can be reduced to solving problems of linear mathematical programming. The main results of optimization of technological processes are obtained in the form of equations of the optimal time for each technological operation. To search for optimal solutions and develop physical models and mathematical descriptions of optimizing waste recycling processes, the theory of graphs is used. Structural diagrams, an oriented graph and, joint matrices of adjacency of the processes of processing of mineral technological waste of Dashkesen iron ore dressing have been constructed. It has been determined that the problem of optimization of technological processes of processing of mineral waste can be formally reduced to a problem of mathematical programming. The condition for decreasing the objective function, which characterizes the energy intensity of technological operations, shows that the minimum is achieved only with a minimum of all functions included in its composition. It is indicated that the energy intensity of production can be considered a complex indicator of the technogenic impact on the environment. Energy capacity characterizes the property of an object and acts as a sign of the internal unity of the natural system. Energy intensity as an indicator of the efficiency of technological processes takes into account the consumption of energy for the production of products and waste. A calculation scheme has been drawn up to determine the optimal vector that provides the minimum energy for processing technological waste. The dependence of the ratios of the current values of energy consumption and energy consumption on the time of waste processing has been obtained. It has been confirmed that the kinetic laws of waste processing are expressed by differential equations of the first order, where, in general, the main variables are the energy intensity of technological operations and the duration of operations. The parameters of mathematical models can be estimated by the nonlinear small squares' method. The results of theoretical analysis and numerical experiments have shown that the mathematical model of technological processes for the processing and disposal of man-made mineral waste has sufficiently high adequacy.

Keywords: *optimization, technological processes, waste processing, energy consumption, a mathematical model.*

Керімова Г.Х. Оптимізація технологічних процесів переробки мінеральних відходів Дашкесенських руд. *У статті розглядається оптимізація технологічних процесів переробки мінеральних відходів збагачення Дашкесенських руд з урахуванням динаміки енергоємності операцій. Наведено методи оцінки параметрів математичних моделей методом найменших квадратів. Встановлено, що практичний пошук екологічно раціональних технологічних рішень можна зводити до вирішення завдань лінійного математичного програмування. Основні результати оптимізації технологічних процесів отримані у вигляді рівнянь оптимального часу для кожної технологічної операції. Для пошуку оптимальних рішень та розробки фізичних моделей і математичних описів оптимізування процесів повторної обробки відходів використана теорія графів. Побудовано структурні схеми, орієнтований граф і спільні матриці*

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суміжності процесів переробки мінеральних технологічних відходів збагачення Дашкесенських залізних руд. Визначено, що завдання оптимізації технологічних процесів переробки мінеральних відходів формально можна звести до задачі математичного програмування. Умова убування цільової функції, що характеризує енергоємність технологічних операцій, показує, що мінімум досягається лише при мінімумі всіх функцій, що входять в її склад. Зазначено, що енергоємність виробництва можна вважати комплексним показником техногенного впливу на навколишнє середовище. Енергоємність характеризує властивість об'єкта і виступає в ролі ознаки внутрішньої єдності природної системи. Енергоємність, як показник ефективності технологічних процесів, враховує споживання енергії на виробництво продукції і відходів. Складено схему розрахунку для визначення оптимального вектора, що забезпечує мінімальну енергію на переробку технологічних відходів. Отримано залежність співвідношень поточних значень споживаної енергії і енергоємності від часу переробки відходів. Підтверджено, що кінетичні закономірності переробки відходів виражаються диференціальними рівняннями першого порядку, де в загальному вигляді основні змінні – енергоємність технологічних операцій і тривалість операцій. Параметри математичних моделей можна оцінити нелінійним методом малих квадратів. Результати теоретичного аналізу і чисельних експериментів показали, що математична модель технологічних процесів переробки і утилізації техногенних мінеральних відходів має досить високу адекватність.

Ключові слова: *оптимізація, технологічні процеси, переробка відходів, енергоємність, математична модель.*

Description of the problem. In the enterprises of the mining industry, the processes of processing mineral waste are carried out according to rather complex technological schemes. The efficiency of such processes depends on many factors of various kinds. Among them are technological and environmental factors, as well as indicators of the level of resource deposits [1].

Analysis of recent research and publications. To search for optimal solutions and develop physical models and mathematical descriptions of optimizing waste recycling processes, the Minsker and Pigott method was used. Structural diagrams, graphs, and joint matrices were built for the production period (Fig. 1).

It turned out that the problem of optimizing waste recycling processes can be formally reduced to a mathematical programming problem. The problem of mathematical programming in a generalized form can be represented as:

$$F(x) \to \min; \quad (1)$$

$$g_i(x) \le 0,\ i = \overline{1, m}; \quad (2)$$

$$g_i(x) = 0,\ j = \overline{m+1, m+n},$$

where $F(x)$, $g_i(x)$ functions of elements (composing) vectors – $g_j(x) - x = (x_1,\ x_2,\ x_3, ...,\ x_n)$; *m* – the amount of inequality – prohibitions; *n* – the number of equations.

If multiple elements of a vector *x* are subdivided into non-intersecting subspecies:

$$x^{(v)}, v = \overline{1, N}, \Rightarrow x = \bigcup_{v=1}^{N} x^{(v)}, x^{(v)} \bigcap x^{(v')} = \varphi, \quad (3)$$

then, for any $v = v'$ monotonic function of arguments, the objective function can be expressed as f_v (*x* (*v*)), the following tasks (1)-(2) can be formulated:

$$F\left(f_1(x_1^{(1)}),\ f_2(x_2^{(2)}),\ f_3(x_3^{(3)}), ...,\ f_n(x_n^{(N)}) \right) \to \min; \quad (4)$$

$$g_{iv}(x^{(v)}) \le 0, v = \overline{1, N}, i = \overline{1, m_v}; \quad (5)$$

$$g_{jv}(x^{(v)}) = 0, v = \overline{1, N}, j = \overline{m_v + 1, m_v + n_v}, \quad (6)$$

where m_v – the number of limiting inequalities and the levels of input in the subgroup of variable n_v – *x* (*v*). Thus, the condition of growth of the function *F* shows that its minimum can be only the function f_v (*x* (*v*)), and when the task of mathematical programming is very important at this stage is the identification of the component *x* (*v*).

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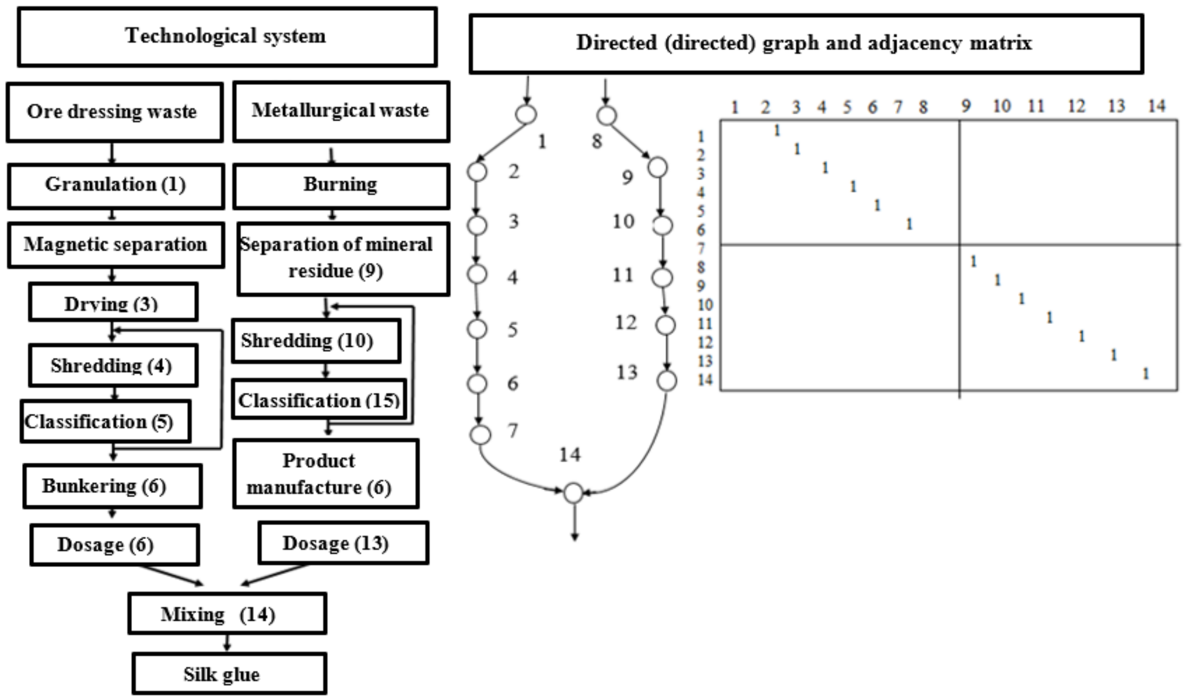

Fig. 1 – Structural schemes of technological processes of waste processing

Having studied any technological process, it is possible to confirm that, in the first approach, the speed of energy change is proportional to the difference between the speed of consumption and the speed of access from external sources. So, you can make a balance:

$$\frac{dE_i}{dt} = K_i(E_{\infty i} - E_i), \tag{7}$$

where E_i is the total amount of energy consumed to perform i – that technological operation at the moment t; K_i – coefficient of the speed of energy consumption during execution i – that technological operation; $E_{\omega i}$ – the value of the level of energy efficiency i – that technological operation.

The zero primary condition corresponds to the equation (7) for the physical meaning of the task under consideration, then by integrating the resulting:

$$\ln\left[E_{\infty i}(E_{\infty i} - E_i)^{-1}\right] = K_i t. \tag{8}$$

Solving the equation (8) concerning E_i, the dynamics of energy efficiency i – that technological operation can be expressed:

$$E_i(t) = E_{\infty i}\left[1 - \exp(-K_i t)\right]. \tag{9}$$

Purpose of the article. Optimization of technological processes in mining should be carried out taking into account the choice of several main factors of the above. This, in turn, gives rise to the need to solve complex and time-consuming mathematical problems. Due to the wide range of physicochemical properties of mineral waste, the development and optimization of various components of the system [2, 3] are required.

Obviously, the emergence of additional requirements related to information support leads to the complication of the control system. Of course, you can reduce the number of factors taken into account, and select some of them intuitively. But in this case, the loss of useful information is possible, which can lead to errors in making environmentally sound decisions [3, 4].

Presentation of the main material. The results of the calculations, calculated according to the above-mentioned relationships are presented in fig. 2. In this case, the vector x of the parameters of the objective function (8) can be expressed as the logarithm of the energy intensity present in the equation (9). Thus, the target function will consist of linear combinations of production coefficients tij. It is clear that special and general restrictions will be associated with the continuity of t_i.

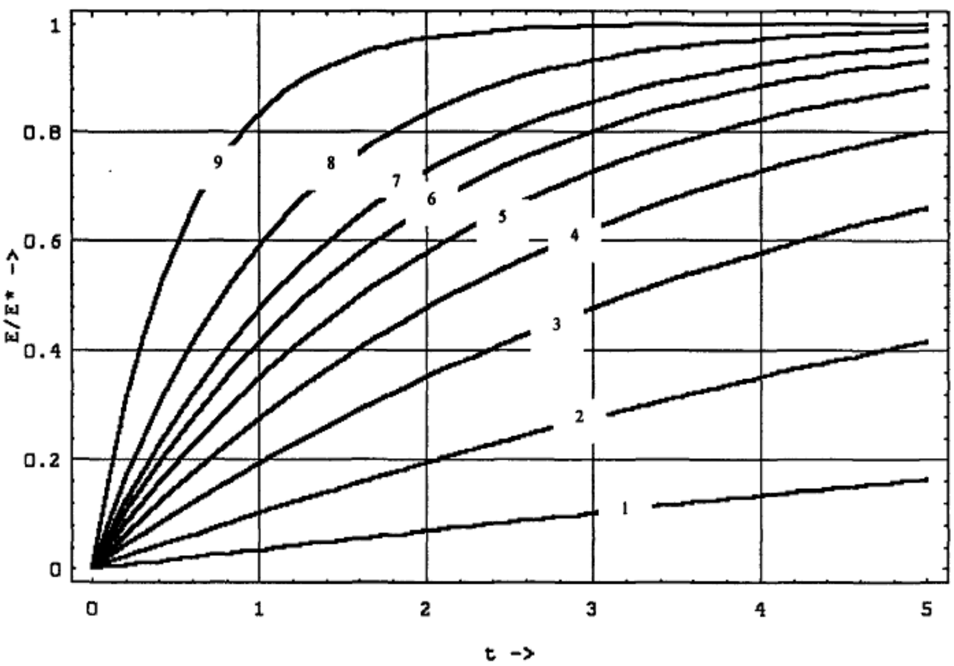

Fig. 2 – Dependence on the relationship of current values of energy consumption and energy capacity (i) from time (t)

Graphics on Fig. 2 visually demonstrate all the possible multiplicity of the solutions of the considered task of mathematical programming. The considered task of linear programming is allowed, because this task is always a minimum of one possible solution, that is, the multiplicity is not empty. The point $(t_i^0) i = 1, 2, 3, \ldots N_{on}$ (where N is the number of technological operations in the optimized process) will characterize the optimal solution of the task and will become the point of the global minimum.

In general, the task is to minimize energy consumption for the production of mineral waste:

$$K_1 t_1 + K_2 t_2 + K_3 t_3 + \ldots + K_n t_n = F \to \min\,; \tag{10}$$

$$\begin{array}{l} b_{11}t_1 + b_{12}t_2 + b_{13}t_3 + \ldots + b_{1n}t_n \geq \beta_1 \\ b_{21}t_1 + b_{22}t_2 + b_{23}t_3 + \ldots + b_{2n}t_n \geq \beta_2 \\ b_{31}t_1 + b_{32}t_2 + b_{33}t_3 + \ldots + b_{3n}t_n \geq \beta_3 \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots,\ ; \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots, \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots, \\ b_{m1}t_1 + b_{m2}t_2 + b_{m3}t_3 + \ldots + b_{mn}t_n \geq \beta_m \end{array} \tag{11}$$

$$t_1 \geq 0, t_2 \geq 0, t_3 \geq 0, \ldots . t_n \geq 0\,. \tag{12}$$

Thus, the tasks (7)-(9) are reduced to the task of linear programming with the help of the application of the whole function at the global minimum. The main results of optimization of technological processes can be obtained as the optimal timing for each operation. This approach allows the implementation of systemic principles in the integrated assessment of resources for environmentally rational use.

The availability of the proposed approach is relatively simple in solving the problem of optimizing technological processes. Numerous experiments have shown that to improve the quality of assessments of environmental forecasts in the results of the adopted decisions, it is necessary to create a local database of data related to the dynamics of energy consumption (Fig. 3).

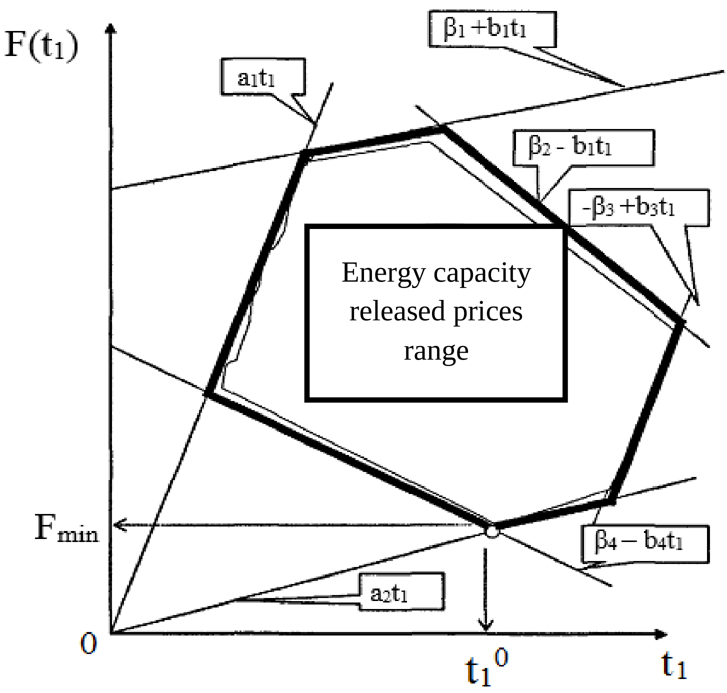

Fig. 3 – Scheme of calculation for determination of the optimal vector t_i^0 providing the minimum energy consumption for the processing of waste

It should be noted that the mathematical analysis of information about the post-processing of the waste mining industry is based on several methodological hypotheses. First of all, the means of mathematical analysis of environmental information should mimic the activity of enterprises engaged in mining. The possibility of imitation can be achieved with the help of computers.

With the help of computers, it is possible to predict the behavior of the object, depending on the conditions or other conditions that characterize the parameters of the model. It is possible to carry out some numerical experiments, changing the parameters of the model and observe the changes in the characteristics of the object.

With the help of processing the information obtained in the results of numerical experiments, it is possible to simplify mathematical models with the help of engineering formulas based on a complex primary model and a large volume of calculations.

The energy efficiency of production can be considered as a complex indicator of the impact of man-made impact on the environment, because this indicator characterizes the systemic property of the object, acting as a system, recognizing the role of recognition. A general indicator of the efficiency of technological processes – energy efficiency, because part of the energy consumed in the production of products goes to the production of waste.

The hypothesis about the possibility of interconnection between the energy capacity of technological processes and the intensity of the impact on the environment allows the use of classical mathematical apparatus for the analysis of environmental information [1].

The results of theoretical analysis and numerical experiments show that the mathematical model of the emergence and localization of waste in the mining industry is sufficiently adequate. Considering this, based on generalized indicators physically justified to use the indicator of energy efficiency for the assessment of the impact on the environment.

The kinetic regularity of output deviations is expressed with the help of differential equations of the first order. At these levels are variable – energy capacity and time. The parameters of these mathematical models can be estimated using the nonlinear method of small squares.

In the implementation of innovative technologies for repeated processing of waste, the management of the impact should be carried out with the account of real connections between all controlled factors [4].

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The practical search of ecologically rational technological solutions corresponds to the solution of the problem of linear mathematical programming. The main results of the optimization of technological processes can be obtained in the form of the optimal time for each technological operation.

Conclusions

1. The task of optimization of technological processes of repeated processing of mineral waste can be formally brought to the task of mathematical programming. As the condition shows the destruction of the whole function, which characterizes the energy capacity of technological operations, the recycling of waste, its minimum can be achieved only in that case, if there will be a minimum of all functions (v) functions.

2. It is confirmed that the kinetic regularity of processing of waste is expressed in differential equations of the first order, where in general the main variables – energy efficiency of technological operations and continuity of operations. The parameters of mathematical models can be estimated by the nonlinear method of small squares.

3. The results of theoretical analysis and numerical experiments showed that the mathematical model of technological processes of processing and utilization of solid industrial waste has sufficiently high adequacy.

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