CSITA
ISSN 2414-9055

AUTOMATION

UDC 504.55.054:622(470.6) https://doi.org/10.31721/2414-9055.2018.4.3.6

CONCEPT OF MINING DESIGN BY APPLYING INFORMATION SUPPORT

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Abstract. *The research is aimed* at developing a concept of involving off-grade metallic mineral materials into production through non-conventional mining and reprocessing methods.

Methods for solving the given task include analysis of a mining enterprise as a system of many elements, development of a complex of optimized tasks and substantiation of multi-variant automated design accompanied by step-by-step optimization of intermediate solutions.

The scientific novelty of the presented material involves generalization, systematization and statement of basic innovations in metallic ore mining and reprocessing.

Practical significance of the authors' recommendations indicates possible involvement of waste materials, which were of no industrial value before, into production in order to improve rates of subsurface resource use.

Research results: The authors substantiate complex utilization of mining waste materials after deep reprocessing and extraction of valuable components as well as reduction of chemical hazards to meet sanitary requirements. They suggest a principle of preserving the Earth's surface from destruction by mine workings through filling voids with consolidating mixtures and leaching tailings in situ in order to maintain geomechanical sustainability. There are given data on the leaching technology of producing metals in the disintegrator which is less expensive and energy-consuming, yet, much faster. The research suggests comparing technologies by a single criterion – profits factored in mineral losses in situ and tailings. It is proved that bringing waste materials of no industrial value into development facilitates capital and assets efficiency. This will also obviate the need for storing tailings on the Earth's surface and allow returning lands to the region's economic jurisdiction, ensuring profits by improving the local environment.

There are recommendations as to improving metallic deposit mining. The environmental-economic model of efficiency of offgrade materials reprocessing is suggested considering the maximum profit criterion and the region's environmental conditions.

Conclusions. The global task of bringing ore processing wastes into development facilitates indices of capital and assets efficiency. The dynamic task of forecasting and improving the mining design system cannot be fulfilled without applying information technologies. Innovations in mining operations include extraction of metals from concentration tailings and increased quality of mineral resource utilization along with optimal control of the surface condition. Absence of necessity to store tailings enables profits not only due to reprocessing products sold, but also improving the region's environment greatly.

Key words: wastes, reprocessing, the Earth's surface, leaching, metal, ore, disintegrator, losses, mineral reserves

Introduction. Provision of mankind with mineral reserves is one of the main problems of human life-support associated with other current issues. Technologists, economists and environmentalists are trying to solve this global problem which tends to intensify because of growing population and bringing new areas into mining development [1-4].

Mining is the most capital- and labourintensive industry. Return on investments starts in the long run and their efficiency can be much lower when expected mineral quantity, quality and occurrence are not confirmed.

Development of the raw-material base is aimed at meeting growing needs in minerals and increasing competitiveness of national mining enterprises.

Key points of raw-material base of the iron and steel industry include difficult mining, geological, economic and geographic conditions of mineral extraction as well as low content of some metals in natural raw materials as compared to those of countries establishing prices for metallurgical materials.

The aim of the raw-material base is to meet growing needs and increase competitiveness of national mining enterprises on the world market.

Problems of mining production should be solved at the design stage of mining enterprises. Mining is notable for a stochastic character of initial data. Most initial data necessary for designing can be defined by a set of values within the range of changes. While assessing mining systems by their efficiency, one determines an effectiveness function depending on the system capacity, total expenditures for mining and operation, damages through the system unreliability, time of operation, etc.

The main task of forecasting and improving the mining design system is simulation of future processes of mineral mining including: extraction of required quantities of ores; provision of acceptable economic indices; provision of labour and environmental safety.

At present, this task cannot be solved without applying information support.

Despite a great number of publications on this problem, issues of involving off-grade metallic raw materials into production remain understudied. The present research is aimed at developing a concept of involving off-grade metallic raw materials into production through applying nonconventional methods of mining and reprocessing
[5-8].

Materials and methods. A mining enterprise is a system of numerous elements including drifting and stoping faces, ore drawing and mucking, haulage and hoisting means, ventilation, water drainage, an ore stockpile, a sorting plant, a concentration plant, etc.

Designing of a mine as an optimal system comprises a set of optimization tasks to solve some general and specific problems.

Underground mines are referred to complicated objects due to the following factors: uncertainty of initial data; a complex character of the control structure; a dynamic character of processes; lack of time-space integration of processes; multiple choice of technical and engineering solutions including those for competitive reasons.

For underground mines, multi-variant computer-aided or automated design accompanied by step-by-step optimization of intermediate solutions makes sense (Fig. 1).

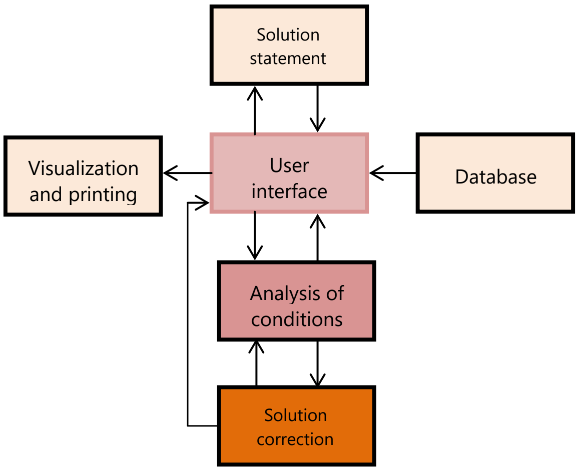

Figure 1. The flowchart of design solutions

An essential element of the design is evaluation of its compliance with natural and technogenic conditions of deposit development (Fig. 2).

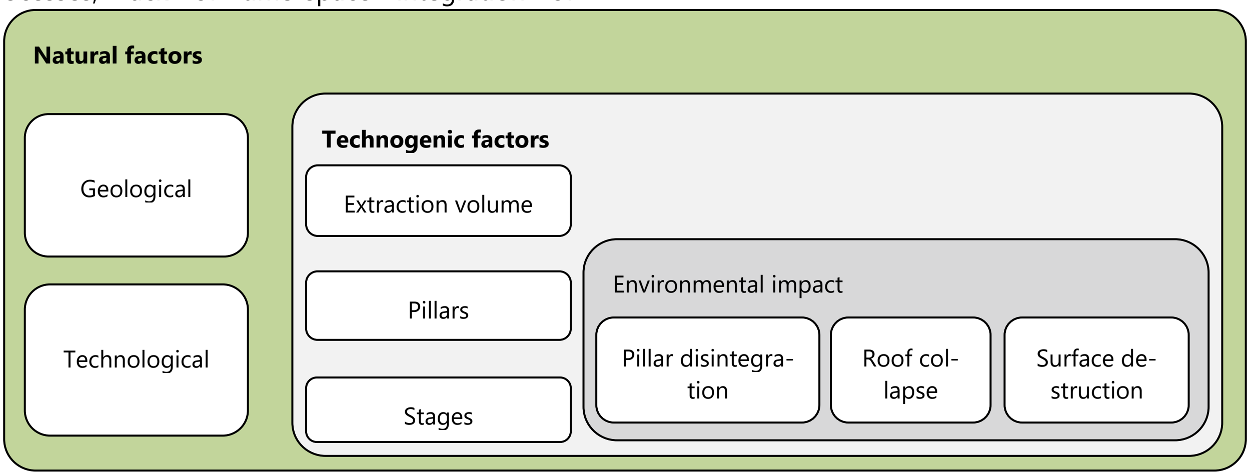

Figure 2. Factors of evaluation of natural and technogenic conditions

Data on the natural and technogenic system are used for correction on all mining stages through continuous monitoring of processes and providing solutions according to the flowchart (Fig. 3).

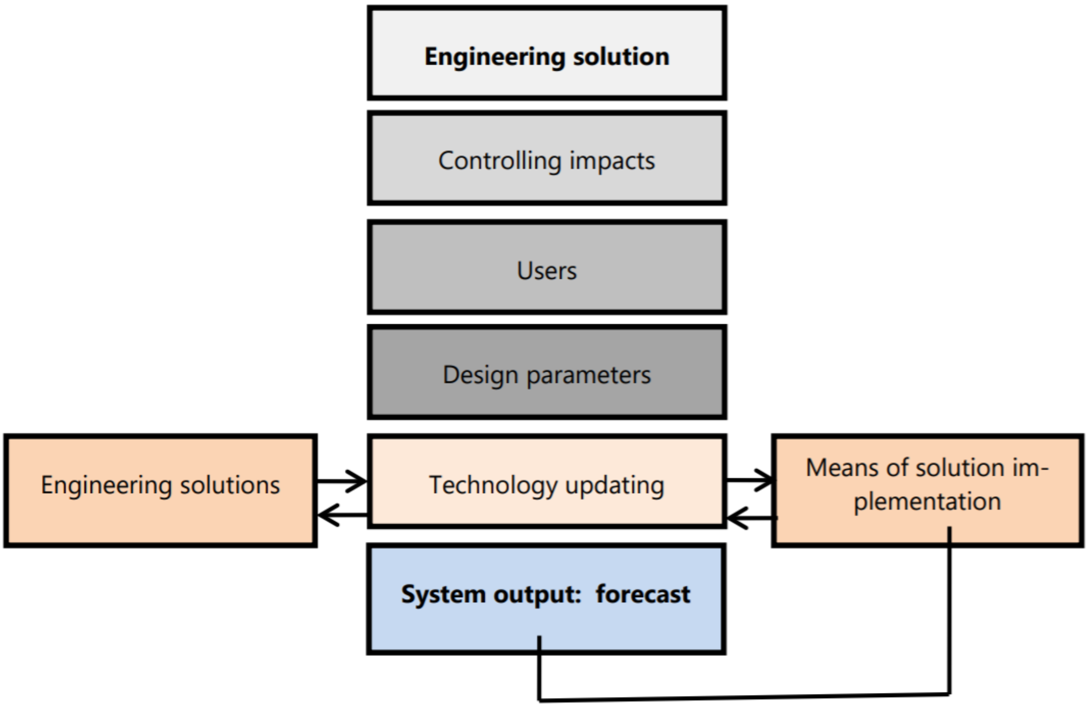

Figure 3. The structural-functional flowchart of updating the control system of mining operations

New parameters of mining and reprocessing are regarded as controlling impacts. The controlled object's internal conditions are notable for probable errors of the design while the system output is the level of mining efficiency.

The system of mining control includes mathematical models and ways to improve them. ArcView GIS characterized by powerful capabilities of working with databases is most efficient and can be used as a tool of the created system.

Mineral extraction tends to involve greater volumes and areas of mining operations to meet constantly growing needs. It leads to accumulation of corrosive wastes on all processing stages that greatly affects the environment imposing heavy expenditures on chemical pollution prophylaxis (Fig.4).

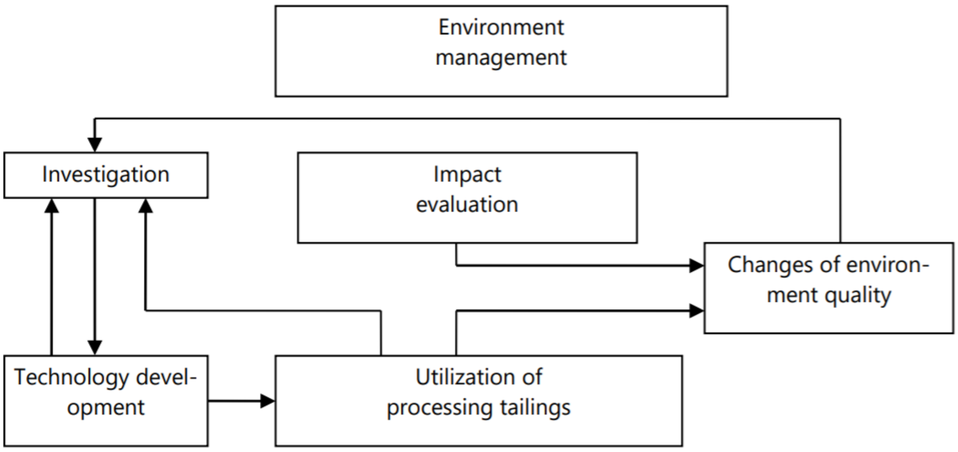

Figure 4. The flowchart of the environment control through waste management

Processing tailings are almost abandoned and hazardous resources, yet, they can become economically profitable when used efficiently [9-12].

Creation of man-made mineral formations is explained by changes in acceptable grades of marketable ore in a historical perspective and selective extraction of rich deposits as well as increased volumes of pillars without filling technological voids with consolidating mixtures.

The volume of mineral reprocessing does not exceed a few per cent of the total ore output. The basic obstacle to this is the fact that conventional technology does not allow extracting valuable components from mineral wastes. At present, each type of ore mining or processing technology has an economic grade limit established by raw material conditions.

Minerals that do not meet the conditions are discharged into the environment and become pollution generators. Only metals extracted at this very enterprise are to be filtered. Some minerals that meet conditions, but cannot be processed are dumped as there is no technological line.

According to modern ideas, waste materials comprise natural, man-made and combined natural and man-made resources including those left in support pillars.

Man-made formations are mostly created without considering possible reprocessing of tailings. Yet, there is a trend of forming such deposits to provide particular technological, geomechanical, physical and chemical parameters necessary for their future development like their piling to build geochemical barriers.

The waste-free principle of modern mining production is provided under the following conditions [13-16]: issues of extracting minerals and valuable components from natural and man-made mineral resources are regarded as a single technological complex; realizing integration of processes are determined by prioritizing the Earth's surface preservation from damage; efficiency of deposit mining is evaluated in the context of lost mined resources.

Results. Complex utilization of mining wastes implies deep reprocessing accompanied by extraction of valuable components and reduction of chemical hazards of secondary tailings to meet sanitary requirements.

Geo-saving technologies are based on preservation of the Earth's surface from destruction by mining operations through controlling geomechanical balance. New technologies provide nature-saving effects when filling voids with consolidating mixtures and tailings of metal leaching from ores in situ.

Accumulation of processing tailings is caused by the fact that most traditional technologies of concentration are limited to mechanical energy only. Leaching in percolators increases metal leaching slightly, yet, it is time-consuming. In recent years, there has appeared a leaching technology in a disintegrator.

Activation of a substance by great mechanical energy under the processing rate of 250 m/sec in the disintegrator creates electrically unbalanced charged centres and radically changes properties of raw materials. The mechanochemical technology enables manufacturing less expensive and energy-consuming products faster.

This technology offers opportunities for improving ore processing technologies.

Advantages of the technology are proved through application of information technologies in the following way: application of computer-aided methods to control the process parameters; versification of process design variants; development of computation and machine language programming; development of simulated design complexes.

When comparing technologies with different extraction volumes, ore losses should be assessed by the lost value of components determined by the limit price of the industry. It enables the single criterion of technologies - profits factored in mineral losses in situ and tailings.

Bringing waste materials into development has a considerable impact on the amount of extracted reserves and the metal content in the mined ore, thus reducing operational costs and facilitating capital and assets efficiency [17-18].

This will also obviate the need for storing tailings on the Earth's surface and allow returning lands to the region's economic jurisdiction, thus ensuring profits not only due to reprocessing products sold, but by improving the local environment as well.

Recent mining innovations are characterized by the following directions (tab. 1).

Table 1. Directions to improve metallic deposit mining

Areas of application	Directions of improvement	Methods
Underground mining	Reduction of metal losses in situ	Leaching of metals from off-grade ores using chemical solutions in mine workings
		Leaching of metals from off-grade ores using natural waters in mine workings
	Increase of mineral utilization quality by reducing ore losses and dilution	Preservation of the Earth's surface from destruction by utilizing underground leaching and concentration tailings
Open pit mining	Reduction of metal losses in reprocessing tailings	Natural leaching of metals by precipitation
		Leaching of metals in activators using combined mechanochemical impacts

The environmental and economic model of determining efficiency of off-grade materials reprocessing considering the maximum profit criterion and the region's environmental conditions looks like [19-20]:

$$П = \sum_{p=1}^{P}\sum_{o=1}^{O}\sum_{n=1}^{П}\sum_{t=1}^{T}\sum_{f=1}^{F}\sum_{n=1}^{N}\left\{\left(M_{ey}Ц_{мy} + Q_{y}Ц_{qy}\right)\right\} - \sum_{з=1}^{З}\left[K\left(1+E_{нy}\right) + E_{q} + E_{x}\right] - \left[\left(M_{e}Ц_{м} + QЦ_{q}\right) + Q_{г}Ц_{г}\right]K_{c}K_{y}K_{т}K_{б}K_{г}K_{вр}K_{г} \rightarrow \max \quad (1)$$

where P is products of tailings reprocessing; O is types of tailings; $П$ is reprocessing processes; T is time of reprocessing; F is phases of storing; N is a stage of tailings utilization; M_{ey} is quantity of metals extracted from wastes; $Ц_{My}$ is the price of metals; Q_y is quantity of restored effects; $Ц_{qy}$ is the price of reprocessed substances; E_q is the coefficient of the loan rate for reprocessing; E_x is the coefficient of the loan rate for manufacturing metals; E_{Hy} is the coefficient of the loan rate for the environment safety; M_e is quantity of metals lost; $Ц_M$ is the price of metals lost; Q is quantity of effects lost; $Ц_q$ is the price of lost valuable components; $Q_г$ is quantity of effects of the damaged environment; $Ц_г$ is expenditures to compensate global factors of damage; $З$ is expenditures for management; K is expenditures for storage management; K_c is the coefficient of self-organization of tailings; K_y is the coefficient of leaching products leak; K_m is the distance coefficient of solution leak ; $K_б$ is the coefficient of the impact on the biosphere; $K_г$ is the coefficient of the environmental impact on neighbouring regions; $K_{вр}$ is the coefficient of environmental hazards emerging over time; K_r is the coefficient of environmental damages by unaccounted factors.

Conclusion. The dynamic task of forecasting and improving the mining design system cannot be fulfilled without applying information support.

Bringing waste materials of no industrial value into development greatly facilitates capital and assets efficiency.

Innovations in mining operations include extraction of metals from concentration tailings when subjected to combined mechanochemical influence and increased quality of mineral recovery using reprocessing tailings to control the surface condition.

Absence of necessity to store tailings on the surface enables profits not only due to reprocessing product sales, but also improving the region's environment as well.

Further research in this field of study is quite promising because of growing population and depletion of ore reserves in favourable mining conditions. It also enables extraction of metals, environmentally safe construction materials and other products from mining wastes.

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