

Conference Paper

Data Support in the Choice of Mine Water Treatment Technology

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Abstract

Mathematical modeling is used in this work in the analysis of options for the implementation of acid mine water treatment technology. A technological scheme of metal-bearing mine water treatment is proposed and includes two stages. The first stage, the treatment of mine water to the required degree to extract solid insoluble sediment for further processing, is implemented in a mobile technological complex installed in places of mine water outpouring. Selective extraction of individual metal powders is delivered in a stationary complex in applying the centrifugal conversion method using plasmatron. In the first step, the metal ions contained in the mine water should be completely recovered with maximum energy-saving. The condition for complete extraction of useful components from mine waters is pH values corresponding to the beginning of precipitation of hydroxides of various metals and complete precipitation, which depend on the nature of metals, their concentration in solution, temperature, impurity content. The process regime must be manageable to ensure its adequacy in the quality of raw materials under conditions of changing mine water flow rates and concentrations of ingredients. The technological mode must be manageable to ensure its adequacy in the raw material quality under changing mine water discharges and concentrations of ingredients.

Keywords: technological complex, mine water, treatment, modeling

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Published: 31 December 2020

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TECHNOGEN-2019 Conference
Committee.

The solution to the problems of choosing the technology for acid mine water treatment is due to the need to consider a range of options. Direct pilot testing of the compared options is not possible. Accordingly, mathematical modeling tends to be the only alternative to voluntaristic decision making. It is a tool used in this work in the analysis of options for the implementation for acid mine water treatment technology.

Our proposed technological scheme for metal-bearing mine drainage treatment includes two stages. The first stage, allowing for mine water treatment to the requisite degree and to extract solid insoluble sediment for further processing is implemented in a mobile technological complex installed in points of mine water outpouring. The second stage, allowing selective extraction of individual metal powders is delivered in a stationary complex in applying the centrifugal conversion method using plasmatron

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[1]. In the first step, the metal ions contained in the mine water should be completely recovered with maximum energy-saving.

The implementation of the project will allow to organize large-scale fine powders production for powder metallurgy and nanotechnologies. The present consumption of powder metallurgy products in Japan exceeded 100 thousand tons per year, in the USA, Canada, Germany - more than 500 thousand tons.

The novelty of the proposed approach consists in the following.

1. Mine water is seen as a multicomponent thermodynamic system consisting of gases, mineral and organic matters (which differ in the degree of dispersibility and chemical composition), as well as microorganisms between which material exchange of substance and energy takes place.
2. The basis of the algorithm choice of mine water treatment technology is the existing classification of these waters, for example, into three classes: carbonate-hydrocarbonate, sulfate and chloride. Each class on the prevailing cation is divided into three groups: calcium, magnesium and sodium. In turn, each group on the prevailing component is divided into four types of wastewater to be treated in block sewage treatment plants.
3. Algorithm of planning of laboratory experiments is aimed at restoration at the stage of treatment of representative sample of mine water of its properties determining sedimentation stability of particles of solid fraction filling water. The properties of sedimentation stability are determinant for the selection of method of acting upon the water to extract heavy metals.
4. The vertices of a graph showing the decision tree on mine water treatment technology are supported by a knowledge base organized using an ontological approach. The ontology model of the subject area includes: a model of observations, a model of operating mode knowledge, a model of technological complex degradation [2].

Mobile complex as a class of technical objects refers to engineering networks, in which the target product - treated water is formed by a sequence of technology operations. The projecting of the mobile complex consists in the creation of such a scheme, which is able to deliver on its main functionality at minimum cost in the presence of destabilizing factors, technological constraints and failures of its particular elements.

1. Methods of Acid Mine Water Treatment By Process Graphs

The mobile technological complex, from a position of methods of mine waters treatment, is described by the process graph, being combination of two sets: tops of J "dividing" individual operations of mine waters treatment, and arches of F appropriate alternatives of implementation of technology operations. The sequence of arcs is determined by the valid sequence of operations. Since the elements of the set F are ordered pairs, the graph is oriented (directed graph). The directed graph presentation of the mobile complex provides visibility and maintains the amount of data necessary to assess options for the construction of mine waters treatment system and their transportation.

Arcs of the graph describe "paths" of mine water treatment, including set of technology operations, where · - mine water pumping · - purification from coarse particles with hydraulic size $U_0 = 3.0... 5.5$ mm/s, · - water pH correction; · - sludge dewatering; · - accumulation and transportation of sediment · - discharge of treated water into local terrain. Thus, the path in the graph will be understood an interleaved sequence of adjacent vertices and edges. Each path is characterized by unit resource cost for mine water treatment.

Sequence of technology operations related set of operations O and set of constructive solutions is transformed into sequence of technological units (TU) · implementing path. Each path is represented by a directional chain of arcs · including, generally, transitions through TU not participating in the path. Some vertices · may split, forming new vertices · with corresponding neighborhood splitting · by ·, which realises the introduction of some modifications of TU into the technological complex. As a result, the number of vertices of the process graph increases. The set of newly introduced vertices are denoted ·. Each arc is weighted by the performance characteristics of the concerned technology operation.

Efficiency of each technology operation is characterized by relative losses values in physical and monetary terms. Each arc is assigned weights corresponding to the cost for the implementation of operation in a particular way, the performance of that operation, and energy losses, i.e. each arc characterizes some types of relationship between vertices.

Paths differ in the presence or absence of individual technology operations, such as the ways to implement operations, the ability to monitoring process, and the associated costs and efficiencies. For example, the use of frequency controlled pumps (FC) allows controlling the volume of water consumed and used in the process cycle.

The description of constructive options is useful to establish a knowledge base (KB), which can be abstractly represented as a hierarchy of four levels:

- The level of facts which describe specific embodiments of the mobile complex contained in the database (DB);
- The level of mobile complex project classes obtained by decomposing many signs of mobile complex characteristics into meaning categories and carrying out morphological classification on multiple of interval characteristic values for each category;
- The level of a mobile complex classes-analogs received on numerous of morphological classes by an analogy relation setting between classes on different categories;
- The level of scenarios for creating and development of a mobile complex.

2. Morphological Classes Characterizing Methods of Constructive Implementation of Technological Paths

Generation of mobile complex morphological classes projects is related to selection of combinations of characteristic values according to a certain morphological scheme and with mobile complex projects grading according to the obtained morphological classes.

To describe numerous options of mobile complex construction, let's introduce morphological space characteristics M , in which characteristic values M are character or numeric interval. Each variant is matched by a point in morphological space M - a valid combination of characteristics discrete values. The result of the matching of projects by points of space M is a morphological classification.

Information technology is proposed, which allows to choose the method of mine water treatment taking into account the limited financial resources of decision-makers (DM). The preference of a solution depends on the combination of external conditions. In order to obtain information on external conditions, the (DM) has the possibility to carry out several various experiments, in particular using new technologies of processing man-made formations. In Figure 1, the decision task is graphically represented as a decision tree.

To illustrate the concepts introduced above, consider a typical branch of the tree. Moving from left to right, the DM must first either choose an experiment e_r , a cost c_r , or not carry out experiments, what is denoted by e_0 , and the relevant costs (zero) - c_0 . Subject to the selection of the experiment, an outcome is observed. The experiment leads to different outcomes, the probabilities of which are described by the distribution of conditional probabilities $p_{r,i}$. If the outcome is known, the following solution d_i should be selected. After this selection, the presence of external conditions is given by the

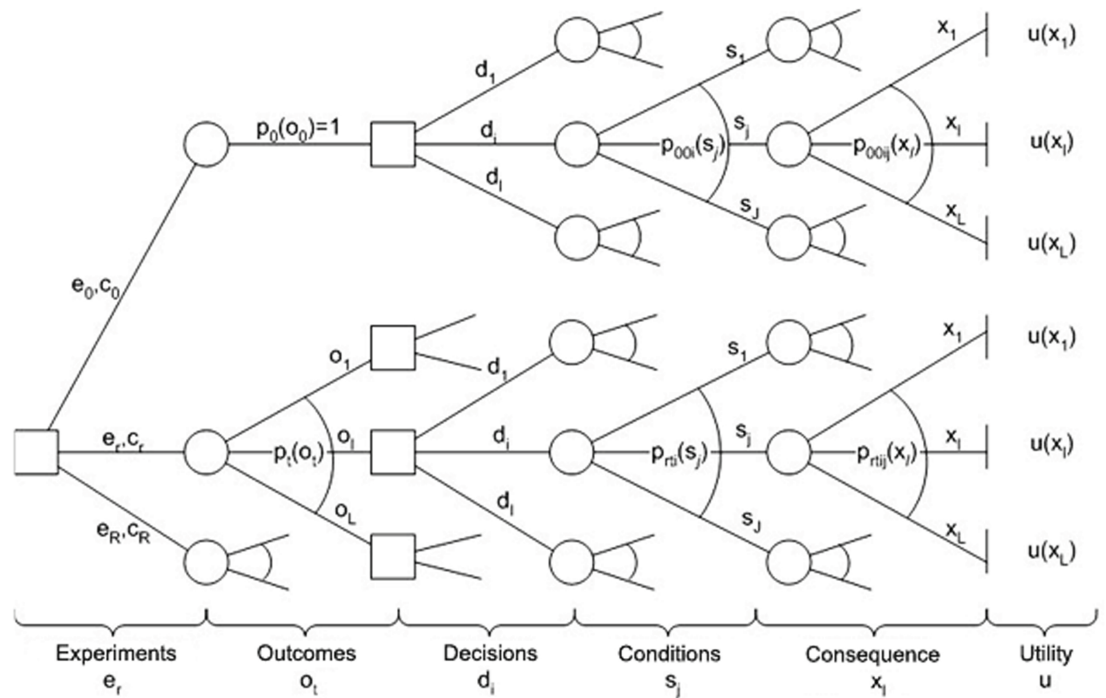


Figure 1: Fragment of decision tree.

distribution of conditional probabilities, where the index r refers to the experiment, t denotes the outcome and i - the solution. These steps result in an outcome x . The probability of different outcomes is numerically expressed through the conditional probability distribution p_{rtj} , where index j refers to external conditions. The relative preference of possible outcomes is given by utility function $u(x)$. For any solution node, the DM selects the alternative which leads to the most expected utility. In Figure 1, the decision task is graphically represented as a decision tree. System level management includes a methodology and tools for site survey, emergency and pre-emergency forecasting, failure diagnostics, assessment of existing equipment resource, maintenance planning together with production activities, increasing productivity and optimization of equipment operation, new equipment operation technology. The management at the system level is based with the use of mathematical apparatus of differential game of approach-evasion, which allows to consider the technological complex as a conflict-controlled system and to find for it a solution of dynamic optimization problem, ensuring guaranteed evasion of the system in the space of states from the prohibited area, in which the quality of the technological complex service is below the allowed [3].

The system integrates in single and consistent model information from various sources for predictive maintenance of technological complexes.

A numerical example of solving the problem of selecting a non-reactive technology for acid mine waters treatment was considered.

References

- [1] Volkov, A. E., *et al.* (2018). Innovative Technology of Metals Extraction from Technogenic Raw Materials by Centrifugal Conversion using Plasmatron. Presented at *Sci. and Pract. Conf. with the International Participation Prospects of the Development of Metallurgy and Mechanical Engineering Using Completed Basic Researches and Research and Developments*. Yekaterinburg: Publishing and Printing House Alfa Print.
- [2] Zobnin, B. B., Gorbenko, O. A. and Sorokin, S. A. (2015). Ontological Approach to the Transformation of the Technology-Related Dust into the Nanocomposites. *Novye Ogneupory (new refractories)*, issue 1, pp. 57-60.
- [3] Zobnin, B. B. and Morina, S. I. (2000). One Control Task with Limitation to the Number of Switches. *Izvestiya RAN. Teoriya i Sistemy Upravleniya*, issue 2, pp. 72-77.