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APPLICATION OF OBJECT-ORIENTED MODELING IN MINING

A. ZHAKSYLYK, T. D. IMANBEKOVA, ZH. ZH. ONGENBAYEVA

International IT University

Abstract: *The article shows the use of object-oriented modeling in mining in the open pit, given examples of creating models using block modeling. One of the main requirements for the development of mineral deposits is to increase the completeness and quality of extraction of marketable products. Therefore, making optimal decisions based on these requirements in modeling and career development is an important task. The order of mining operations during the formation of working sites was determined in the process of preparing the work, a graphical model of mining operations wascreated using the parameters of the blocks and the working area of the open-pit. According to the above formulas, calculations were made, the results are reflected in the graph of dependence of the volume of recoverable blocks by year. The given model of the working area of the field allows us to consider various optimization tasks for the annual and landmark mining positions. The methods discussed in the article are applied to solving problems of commensurate movement in the working area of the quarry, which ensures a continuous increase in the reliability and efficiency of the design of mining enterprises.*

Keywords: *blocks, career, working area of the pit, object-oriented modeling, block modeling*

ТАУ-КЕН ӨНЕРКӘСІБІНДЕ ОБЪЕКТІЛІ-БАҒЫТТАЛҒАН МОДЕЛЬДЕУДІ ҚОЛДАНУ

Аңдатпа: *Мақалада ашық карьерде тау-кен өндіруде объектілі-бағытталған модельдеуді пайдалану, блоктық модельдеу арқылы үлгілерді жасау мысалдары келтірілген. Өнеркәсіптік өнімдерді алудың сапасын көтермелеу үшін пайдалы қазбаларды өндіруге бір ғана негізгі талаптар қойылады. Оңтайлы шешімдер қабылдау үшін модельдеу және әзірлеу кезінде талаптарды есепке алу міндеттері – маңызды. Жұмысты дайындау процесінде тау-кен жұмыстарын жүргізу тәртібі анықталды, жұмыс учаскелерін қалыптастыру кезінде, блоктардың параметрлері мен ашықалаңның жұмыс аймағын ескере отырып, тау-кен жұмыстарының графикалық моделі берілген. Жоғарыда келтірілген формулаларға сәйкес есептеулер жасалды, ал нәтижелері әр жылда шығарылатын блоктар көлемінің тәуелділігі кестесінде көрсетілген. Кен орнының жұмыс аймағының осы үлгісі тау-кен өнеркәсібінің жыл сайынғы және көрнекті орындарына оңтайландырудың түрлі міндеттерін қарастыруға мүмкіндік береді.*
Мақалада талқыланған әдістер тау-кен кәсіпорындарының конструкциясының сенімділігі мен тиімділігін үнемі арттыруды қамтамасыз ететін карьердің жұмыс аймағында қозғалыстың проблемаларын шешу үшін қолданылады.

Түйінді сөздер: *блоктар, карьер, карьердің жұмыс аймағы, объективтік-модельдеу, блоктық модельдеу*

ПРИМЕНЕНИЕ ОБЪЕКТНО-ОРИЕНТИРОВАННОГО МОДЕЛИРОВАНИЯ ПРИ ВЕДЕНИИ ГОРНЫХ РАБОТ В КАРЬЕРЕ

Аннотация: *В статье показано применение объектно-ориентированного моделирования при ведении горных работ в карьере, приведены примеры создания моделей с использованием блочного моделирования. Одним из главных требований к разработке месторождений полезных ископаемых является повышение полноты и качества извлечения товарной продукции. Поэтому принятие*

оптимальных решений с учетом данных требований при моделировании и разработке карьера является важной задачей. В процессе подготовки работы был определен порядок ведения горных работ при формировании рабочих площадок, приведена графическая модель ведения горных работ с учетом параметров блоков и рабочей зоны карьера. Согласно приведенным формулам были произведены расчеты, результаты отражены в графике зависимости объемов извлекаемых блоков по годам. Приведенная модель рабочей зоны месторождения позволяет рассмотреть различные задачи оптимизации годовых и этапных положений горных работ.
Методы, рассмотренные в статье, применяются для решения задач соразмерного перемещения в рабочей зоне карьера, что обеспечивает непрерывное повышение надежности и экономичности проектирования горнодобывающих предприятий.

Ключевые слова: *блоки, карьер, рабочая зона карьера, объектно-ориентированное моделирование, блочное моделирование*

One of the main requirements for the development of mineral deposits is to improve the quality and completeness of the extraction of marketable products.

Therefore, making optimal decisions based on these requirements in modeling and developing a career is an important task. Field modeling is a prerequisite for computer-based analysis, since the models reveal the whole range of critical decisions that need to be considered when developing such a complex system as a quarry. Achieving the right decisions is impossible without analysis, a systematic approach to the process of modeling a career. Projecting system design begins with an analysis of the requirements that it will have to meet. The analysis is carried out in order to understand the purpose and conditions of operation of the system. With an object-oriented approach, the analysis of system requirements is reduced down to the development of models of this system. Currently, there are several technologies of object-oriented development of application software systems, which are based on the construction and interpretation of computer models of these systems. In this technology, the projected system is represented in the form of three interrelated models:

- an object model that represents the structural aspects of the system associated with the data;
- a dynamic model that describes the operation of individual parts of the system;
- functional model, which considers the interaction of individual parts of the system in the process of its work.

These three types of models allow us to obtain three mutually orthogonal representations of the system in one notation.

Models developed in the first phase of the system life cycle, continue to be used in all subsequent phases, facilitating further system modification. These principles of modeling can be applied to the model of the working area of the pit. It is important to choose the optimal technological parameters during field operation. These parameters of the working area should provide the minimum ratio of the volumes of the werry of the rock mass to the volume of ore of all types. The mining process is key to working with the mineral deposit, since at this stage the detailed description of the elements of the deposit is completed, its reserves are finalized, the geological model is adjusted.

These models help to test the performance of the system being developed in the early stages of its development and to make (if necessary) changes to the system design.

The general graphical model of the field and mining operations is a combination of models with various system-forming components:

$$Si = \langle Sc, M, Se, Sr, Rz, T \rangle; \quad I = 1, ..., n \quad (1)$$

Where Sc is a structural-functional model of a system of mining and geological objects; M is a math-graphic model of the system; Se is a model of a system of geological surveying symbols; Sr - model of geodesic and surveying metrics; R3 - model of the relationship between the components of the system; T - temporal characteristics of the system; n is the number of levels of detail.

Then the recalculation of reserves will be (for the integral indicators of the field) for the marked blocks (the set i I, i = {1, ..., n}) in the definition:

$$\Delta V = \sum_{i=1}^{n}(V - V), \quad (2)$$

$$\Delta Q = \sum_{i=1}^{n}(Q - Q), \quad (3)$$

where ΔV and ΔQ - changes in the volume of the mineral body occupied by the reserves of the category in question, and the amount of mineral in this category of reserves; V, V is the volume of the i-th block in the first and second variant, respectively; Q, Q - the amount of mineral in the i-th block in the first and second variant, respectively.

Similar calculations will be carried out in determining the movement of reserves during the operation of the field.

This method of presenting volumetric information also simplifies the construction of 3D images when modeling options for processing a deposit and maintaining graphic documentation when updating mining plans.

When forming work sites, mining is conducted in layers from top to bottom with a block height of 15 m. 1,2, ...6 - is the order of blocks processing (Figure 1).

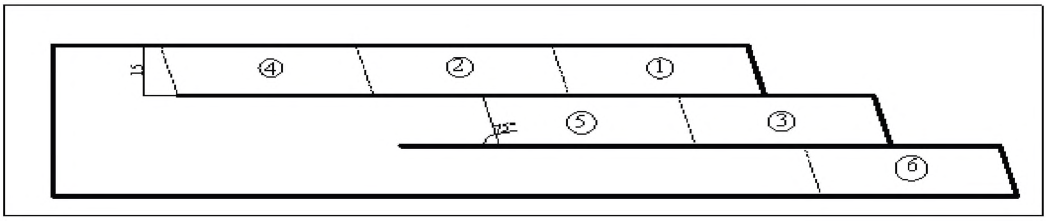

Figure 1 - The order of mining operations in the formation of working sites

There should not be too many blocks in the created model. Their number should be in the range from a few hundred to the first thousand. The block model allows, with a high degree of confidence, to estimate geological reserves, to conduct a quick calculation of the required indicators.

The considered methods are used to solve problems of commensurate movement in the working area of the quarry, which ensures a continuous increase in the reliability and efficiency of the design of mining enterprises.

One of the examples of achieving the efficiency of mining operations in the working area is the use of the following method.

When mining, each unit belongs to a specific work area. In this scheme, the position of the mining operations is described within one ledge block by block. The position of the mining operations in the block is characterized by one number — the magnitude of the displacement of the mining front.

For blocks with numbers (i, j), (i – 1, l), where l I1 (i, j), the dijl value is entered, which shows the advance of the initial position of the block (i -1, l) relative to the block (i, j) . If at the beginning of the simulated period the mining operations were not started, then the beginning of the block is taken as the initial position. In this case, the negative value of dijl is possible [1]. The permissible interposition of blocks of adjacent ledges is described by relations for all i> 1, j, l I1 (i, j):

$$X_{ij} \le X_{i-1l} + d_{ijl} - D_{i-1}$$
$$X_{ij} \le X_{i-1l} + d_{ijl} - D_z \quad (4)$$

where $l \in I_z(I-1, z)$

where xij - the displacement of the front of mining;

Dijl is a value indicating the advance of the initial position of the block (i -1, l) relative to the block (i, j);

Lij is the value that shows the advance (or lag) of the initial position of the (j - 1) -th block of the i-th step in relation to the j-th block;

I1 (i, j) is the set of overlying blocks;

D_{i-1} - horizontal projection of the escarpment of the ledge;

Z is the number of the zone to which the block belongs.

The restriction on the mutual arrangement of neighboring blocks of one horizon is written in the form:

For all i and j> 1

$$|X_{ij} - (X_{ij-1} + l_{ij})| \le D_0 \quad (5)$$

$$X_{ij} = \min\{X_{ij-1} + l_{ij} - D_0, \min X_{ij-Il} + d_{ijl} - D_{i-1}\}$$
$$l \in I_1(i, j) \tag{6}$$

where Do is a value determined by the possibilities of transport support of work.

Restrictions (1) and (2) on the form of a pit refer to blocks in which mining operations are carried out. For blocks in which work has begun, we introduce the concept of "conditional propulsion". Then this value will coincide with the real movement in the overlying blocks.

Based on relations (1) and (2) to set conditional initial positions, we have:

Graphically, this model of mining can be represented as Figure

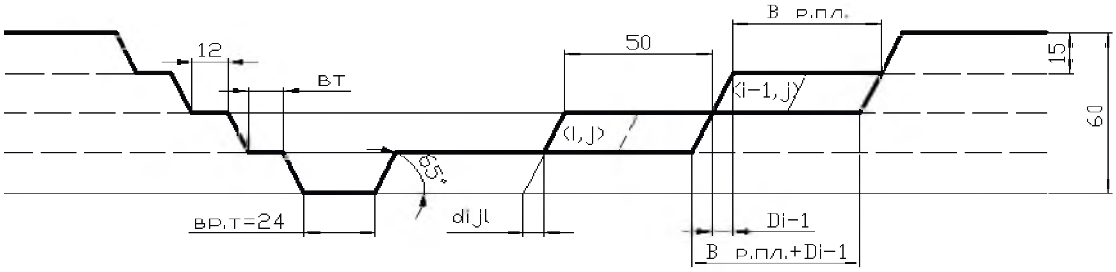

Figure 2 - Mining operations when moving rocks.

The model of the working area of the deposit site allows you to consider various tasks to optimize the annual and landmark mining provisions. These issues, as well as questions on the development system, the opening of working horizons, integrated mechanization are interrelated with economic results.

Currently, in a competitive environment, the search for methods for the economical exploitation of a field is very important. Sustainable mining at minimal costs is ensured only by a economically effective mining regime. Also, a significant factor in the assessment of economic efficiency is the time spent on investment and profit.

The profitability of the mining enterprise involves the excess of income for products sold over the costs associated with the extraction and processing of raw materials. In this case, the evaluation of design decisions is the cost of mineral from the consumer, which determines the amount of profit. The value of the cost is also influenced by many factors associated with the mining, geological, technological, technical, organizational, climatic, social conditions of mining operations. Optimization of career options also applies to other aspects of planning, for example, as the concept of cash flow.

Investigating optimization models, we can draw conclusions:

1. Optimization of a mine requires fixed costs associated with each block.

2. Discounted cash flow requires a sequence of production and production rates.

The optimal sequence of extraction of the blocks of the model is determined by the criterion: maximum NPV. This criterion determines the optimal sequence of extraction blocks. Choosing 4 years as the average cycle of price changes for products, we present a vertical section of a quarry for four years of mining.

Extraction block is adopted at a height of 15m. The width and length of the block are equal to each other and are assumed to be equal to the width of the working platform. When conducting work, the calculation of ore and rock can be made for various modifications of the counting unit.

This model and reserves will be refined and used at all subsequent stages of construction and operation of this mining enterprise. From the very first version of the model, it will use data from subsequent stages to identify economically feasible areas for the extraction of the site and to calculate the mineral reserves in them.

The dependence of the volumes of extracted blocks of ore and rock by year with a working platform width of 50 m and 35 m is shown in Figure 3.

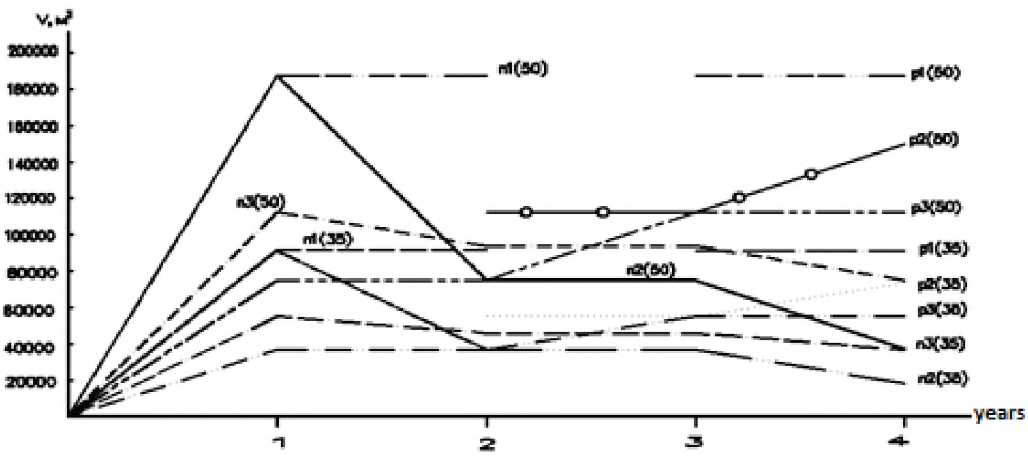

Figure 3 - Dependence of the volume of recoverable blocks by year

The compilation of several variants of the model and the need for their adjustment require the creation of universal methods for their formation. At the same time, it is necessary to ensure the possibility of a quick recalculation of mineral reserves.

Using these methods, the optimal sequence of extraction of blocks of ore and rock from different parts of the working area of the quarry is substantiated. Considered three variants of such a sequence (see Table 1). When calculating, the cost of ore blocks is assumed to be conditionally equal to 200, and rock blocks - minus 100. We give the calculation of NPV for the sequence of extraction of ore and rock blocks according to the conventional section. The calculated value is given in table 1.

Table 1 – Sequence of extraction of ore and rock blocks

Quantity of blocks	Years Variant	1	2	3	4	NPV
100/100	I	0/50	0/50	50/0	50/0	5666
100/100	II	0/50	30/20	30/20	40/10	6547
100/100	III	20/30	20/25	30/25	30/20	7508

As can be seen from the table, the best according to the NPV criterion is the third variant of the sequence of extraction of ore and rock blocks from the excavation site.

To assess the effectiveness of the options used the criterion of the net present (discounted) value of NPV:

$$NPV = SC/(1+i)^n \qquad (7)$$

where C is the cost of the extracted blocks;

$\frac{1}{(1+i)^n}$ – discount coefficient;

i – the rate of bank interest;

n – number of years of extraction of blocks.

The effectiveness of options for the development of deposits with different amounts of ore and stripping, taking into account investments and payments, it is advisable to evaluate using the following formula:

$$NPV = -PV(1) + PV(2) = -PV(1) + \sum_{n=1...15} ЧД \frac{1}{(1+i)^n} \qquad (8)$$

$$PV(1) = \sum I_n \cdot \frac{1}{(1+i)^n} \qquad (9)$$

where PV(1) is the current cost of the project (investment);

PV (2) - today’s cost of payments;

ЧД - net income.

The analysis confirms the possibility of using geo-information methods in determining the sequence of ore extraction and overburden from different areas of the quarry. The above model of the working area of the deposit site allows us to consider various optimization tasks for the annual and landmark mining positions.

A practical application of data geo-information modeling of mining obtained in the computer systems for planning opencast mining.

At the same time, the model of mining operations considered in the article is applicable for mining operations at open-pit mines engaged in controlled mining of solid minerals.

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