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CREATING AN ALGORITHM AND TECHNICAL SOLVING TO CHOOSE OPTIMAL METHOD OF OPENING FOR UNDERGROUND MINE

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ABSTRACT
One of the main stages in underground mining of deposit is their opening. The opening of mine field is described with specific features, which continuously maintains the actuality of their investigation. According to developed algorithm an object function is created and a method, for investigating the extreme value, is chosen. A suitable mathematical model is created for economic evaluation of the method of opening which is based on generating a great number of variants and multicriteria approach. The following results are achieved by means of formulating the problem for choosing the optimal method of opening: an object function for underground transport; hoisting transport; surface transport to the consumer. The problem is solved in 3 Dimension (3D).
Key words: algorithm, bed, ore, vein, minerals, mine field.

INTRODUCTION

The design and practical implementation of mine fields opening is carried out under conditions of least reliability of information about the environment. Often this information is based on data gathered while developing analogous deposits or data gathered during the process of driving prospecting workings.

The term of exploitation of the basic development workings corresponds to the period of development of the mine field and every mistake or inaccuracy made when deciding on the deposition of openings has got serious economic consequences. Their gravity may turn out to be crucial and a premature close down of the mine company be reached at a later time.

PROBLEM FORMULATION FORMING OBJECT FUNCTIONS TO SOLVE THE PROBLEM

Solving the problem of choosing a location for the opening was posed as early as the times of the first attempts to introduce strict calculation methods when deciding on the elements of the underground mining technology. For the first time the problem was treated scientifically in the works of the Russian scientists B.I. Bokiy and L.D. Shevyakov. From a modern perspective, the formulation and the solution of the problem are considered by all means three-dimensionally. In addition to the choice of a location for the main haulage gateway, another particularly important problem is the way the deposit is uncovered. In this way a general problem consisting of two mutually connected conditions is formed, the solution to which should be regarded as an example of the use of a comprehensive approach in the present day computer technology used in mining.

When determining the opening's location in the case of bedded deposits, the problem has got fairly representative solutions. They are universal, i.e. they can be used irrespective of the degree of dip and number of beds representing the deposit. Construction expenses for the openings and transport expenses along them are used as criteria published by (Vellev M. 1986). The object function is of the form:

$$w = f(x,y,z)\ , \qquad (1)$$

where x,y,z are the running coordinates of a reference coordinate system possessing pre-arranged rules for its orientation. The problem's solution is made easier if the actual earth surface is approximated with the plane:

$$z = ax + by + c\ z, \qquad (2)$$

where a, b, c are number coefficients. Then the object function w depends solely on the coordinates x and y. From the system of irrational equations:

$$\frac{\partial w}{\partial x} = 0; \qquad (3) \qquad\qquad \frac{\partial w}{\partial y} = 0, \qquad (4)$$

by means of successive approximations are determined the coordinates of the optimum location of the basic development working published by (Vellev M. 1986).

When developing ore deposits the problem is further complicated by at least three additional, but at the same time essential factors:

- Very often ore veins have got uneven distribution of useful components, they are represented by separate ore poles, which further on for convenience will be called ***geological blocks***;
- The separate geological blocks in the ore veins have got clearly identifiable inclination, which in depth has considerable influence on the dimensions and boundaries of the mine field, i. e. inclination influences the topology of the network of extraction workings for the opening and preparation of the levels;
- The thickness of ore veins (geological blocks) is uneven, which means that the amount of loads corresponding to the reserves in the separate blocks on the separate levels will be different.

To these characteristic features we should add the features of the surface terrain and the distance to the consumer. In this way premises are created for the development of a general algorithm for the choice of a technical solution for the opening of the mine field, based on the three-dimensional formulation of the problem. A reference coordinate system is introduced, oriented in such a way that the whole mine field is situated in the positive octant. The (y) axis coincides with the ore vein's strike line, while the (x) axis is oriented crosswise to the strike line, i.e. along the way of dipping.

The object function (w) is composed to measure transport work along the level haulage gateways and crosscuts, respectively w_g and w_{cr}, lifting work along the vertical shaft – w_l and surface transport work to the consumer w_c.

The authors' main claim is that geological blocks situated on the separate levels can be described very precisely in space using their indices and coordinates. In this case it is necessary to identify the centres of gravity of the geological blocks on the separate levels by means of the distance R to the origin of coordinates for the reference coordinate system, the transfer stations P on the levels and crosscuts, the amount of loads Q from each stope block within the boundaries of the level, the intersection point F, determining the intersection point of the vertical shaft with the earth surface, the location of the consumer K. The problem is considered taking for granted that the consumer's location has been determined in advance, i.e. its coordinates are known $K(x_k,y_k,z_k)$. The problem thus formulated necessitates the introduction of triple indexation - i, j, k where:

i = 1..n – the index showing the sequential number of the geological blocks (poles), located on the level, and situated along the ore veins' strike line;

j =1..m – the index showing the location of the following vein, determined crosswise to the strike line;

k =1..t – the index showing the level's sequential number within the mine field.

In this case, when the stope block's geometry is predetermined (length L_{bl} and height $H_{bl} = H_l$, where H_l is the level's height) it is possible to calculate the amount of reserves, respectively amount of loads Q[ijk], to be transported to the surface and then to the consumer.
Clearly

$$\sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{k=1}^{t} Q[ijk] = \frac{z_{bal}(1-a_e)}{1-b}, t \tag{5}$$

where: z_{bal} – is the balance reserve in the mine field; a_e – exploitation losses; b – ore dilution. In this case z_{bal}, a_e, b are constants, i.e. the influence of the mining technology is not taken into account.

When the geological blocks' coordinates on the separate levels are known it is possible to calculate the geometrical dimensions, the amount, the productivity and the location on the separate levels by means of three angles (fig.1):

- The angle of dip α of the vein or the geological block in the plane 0xz, α varying on the interval $0 \le \alpha \le 180°$;
- Angle of inclination φ of the geological block on the separate levels in the plane 0yz, φ varying on the interval $0 \le \varphi \le 180°$;
- The angle of azimuth β of the geological block on the separate levels in the plane 0xy, β varying on the interval $0 \le \beta \le 360°$.

The calculation of parameters such as geometrical dimensions, amount, productivity, takes place once the angles α, β, φ have been determined by means of the geological blocks' coordinates on the separate levels (fig.1):

Projected length (S) of the [ijk]-th geological block on the separate levels as the remainder of the maximum and minimum (y) coordinates:

$$S[ijk] = y^{max}[ijk] - y^{min}[ijk], m \tag{6}$$

Actual length (S_r) of the [ijk]-th geological block on the separate levels as the remainder of the maximum and minimum (y) coordinates:

$$S_r[ijk] = (y^{max}[ijk] - y^{min}[ijk]) / \cos(\beta[ijk]) = S[ijk] / \cos(\beta[ijk]), m \tag{7}$$

* *actual thickness* (m_r) of the [ijk]-th geological block on the separate levels as the remainder of the maximum and minimum (x_r) coordinates:

$$m_r[ijk] = x_r^{max}[ijk] - x_r^{min}[ijk], m \tag{8}$$

* *projected thickness* (m) of the [ijk]-th geological block on the separate levels as the remainder of the maximum and minimum (x) coordinates:

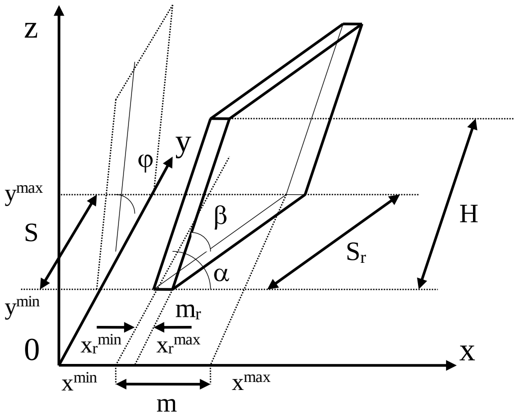

Figure1. Geological block on a separate level in (3D) space

* *actual thickness* (m_r) of the [ijk]-th geological block on the separate levels as the remainder of the maximum and minimum (x_r) coordinates:

$$m_r[ijk] = x_r^{max}[ijk] - x_r^{min}[ijk], m \quad (8)$$

* *projected thickness* (m) of the [ijk]-th geological block on the separate levels as the remainder of the maximum and minimum (x) coordinates:

$$m[ijk] = x^{max}[ijk] - x^{min}[ijk] = S[ijk].\cos(90 - \beta[ijk]) = = S[ijk].\sin(\beta[ijk]), m \quad (9)$$

* *the distance from the origin of coordinates to the centre of gravity* of the projected [ijk]-th geological block on the respective level along the (y) axis:

$$R[ijk] = (y^{max}[ijk] + y^{min}[ijk]) / 2, m \quad (10)$$

* *the distance from the origin of coordinates to the centre of gravity* of the projected [ijk]-th geological block on the respective level along the (x) axis:

$$R_x[ijk] = (x^{max}[ijk] + x^{min}[ijk]) / 2, m \quad (11)$$

* *productivity* per square metre ($1m^2$) of the geological blocks on the separate levels:

$$p[ijk] = m_r[ijk].\gamma, t/m^2 \quad (12)$$

where γ - is the density of the deposit, t/m^3.

In the case of inhomogeneous deposits $\gamma[ijk]$ is used to determine the productivity of each geological block on the separate levels.

- *Quantity of reserves* in each [ijk]–th geological block on the separate levels:

$$Q_r[ijk] = S_r[ijk].H[ijk].p[ijk] = S_r[ijk].H[ijk].m_r[ijk].\gamma, t \quad (13)$$

where H[ijk] – the inclined height of each of the [ijk]-th geological blocks on the separate levels. That height is constant, when α stays constant. It is determined by the location of horizontal workings.

* *The projected quantity* along the (y) axis is:

$$Q[ijk] = Q_r[ijk].\cos(\beta[ijk]), t \quad (14)$$

* *The projected quantity* along the (x) axis is:

$$Q_x[ijk] = Q_r[ijk].\cos(90 - \beta[ijk]) = = Q_r[ijk].\sin(\beta[ijk]), t . \quad (15)$$

The optimum work of *underground transport* along horizontal workings solely (drifts, crosscuts) without vertical transport is represented by an object function. The object function is divided into five global intervals along the respective axis of study, one of the global intervals being subdivided. If y is taken as a running coordinate on the interval [0, R_y] depending on the intervals studied for the function we get:

interval $0 \le y \le y^{min}[1jk]$ (formula 16):

* interval $y^{min}[1jk] < y < y^{max}[1jk]$ (formula17)

$$w_1(y) = \sum_{j=1}^{m}\sum_{k=1}^{t}\sum_{i=1}^{n}\{Q[ijk].(R[ijk] - y)\}, t.m \quad (16)$$

$$w_2(y) = 0.5\sum_{j=1}^{m}\sum_{k=1}^{t}\{\{(y - y^{min}[1jk])^2 + (S[1jk] - y)^2\}.H[1jk].p[1jk]\} + \sum_{j=1}^{m}\sum_{k=1}^{t}\sum_{i=2}^{n}\{Q[ijk].(R[ijk] - y)\}, t.m \quad (17)$$

- interval $y^{max}[1jk] \le y \le y^{min}[njk]$ (formulas18 and 19):

On this interval, divided into two subintervals, it is necessary to introduce the following additional conditions:

i = 1…n; r = 2...(n-1); 1 < r < n; When i = r,

where r shows the location of the fixed element i as an ore body or a geological block on a separate level. The running coordinate y (or x) either intersects or does not intersect the projection of the i^{-th} element. This element is called - r :

- irst subinterval $y^{max}[ijk] \le y \le y^{min}[i+1jk]$ from the global interval $y^{max}[1jk] \le y \le y^{min}[njk]$, where y does not intersect the projection of the $i^{-тия}$ element (formula 18):
- second subinterval $y^{min}[ijk] < y < y^{max}[ijk]$ from the global interval $y^{max}[1jk] \le y \le y^{min}[njk]$, where y intersects the projection of the i^{-th} element (formula 19):

* interval $y^{min}[njk] < y < y^{max}[njk]$ (formula 20): * interval $y^{max}[njk] \le y \le R_y$ (formula 21);

$$w_{31}(y) = \sum_{j=1}^{m}\sum_{k=1}^{t}\sum_{i=1}^{r-1}\{Q[ijk].(y - R[ijk])\} + \sum_{j=1}^{m}\sum_{k=1}^{t}\sum_{i=r}^{n}\{Q[ijk].(R[ijk] - y)\}, t.m \quad (18)$$

$$w_{32}(y) = \sum_{j=1}^{m}\sum_{k=1}^{t}\sum_{i=1}^{r-1}\{Q[ijk].(y - (R[ijk])\} + 0.5\sum_{j=1}^{m}\sum_{k=1}^{t}\{\{(y - y^{min}[rjk])^2 + (S[rjk] - y)^2\}.H[rjk].p[rjk]\} + \sum_{j=1}^{m}\sum_{k=1}^{t}\sum_{i=r+1}^{n}\{Q[ijk].(R[ijk] - y)\}, t.m \quad (19)$$

$$w_4(y) = \sum_{j=1}^{m}\sum_{k=1}^{t}\sum_{i=1}^{n-1}\{Q[ijk].(y - (R[ijk])\} + 0.5\sum_{j=1}^{m}\sum_{k=1}^{t}\{\{(y - y^{min}[njk])^2 + (S[njk] - y)^2\}.H[njk].p[njk]\}, t.m \quad (20)$$

$$w_5(y) = \sum_{j=1}^{m}\sum_{k=1}^{t}\sum_{i=1}^{n}\{Q[ijk].(y - R[ijk])\}, t.m \quad (21)$$

$$w(y) = w_1(y) + w_2(y) + w_{31}(y) + w_{32}(y) + w_4(y) + w_5(y), t.m . \quad (22)$$

The optimum work of underground transport has got the same form if the other x axis is taken as a running coordinate on the interval 0 to R_{xx} in order to study the function. This may be obtained under the following conditions: $Q[ijk] = Q_x[ijk]$, $R[ijk] = R_x[ijk]$, $S[1jk] = m[1jk]$, $S[njk] = m[njk]$ and $R_y = R_{xx}$.

In the isolated case of parallel running veins which do not exhibit considerable variability along the strike line, the optimum work of transport along the horizontal workings – drifts and crosscuts, taking into account vertical transport along the z axis and transport to the consumer could be represented by the object function:

$$w(x,y,z) = 0.5\sum_{j=1}^{m}\sum_{k=1}^{t}\{\{(y - y^{min}[ijk])^2 + (S[ijk] - y)^2\}.H[ijk].p[ijk]\} + \sum_{j=1}^{m}\sum_{k=1}^{t}\sum_{i=1}^{n-1}\{Q[ijk].|(y - R[ijk])|\} + \sum_{j=1}^{m}\sum_{k=1}^{t}\sum_{i=1}^{n}\{Q[ijk].|\{x - (R_x[ijk] \pm \Delta x)\}|\} + \sum_{j=1}^{m}\sum_{k=1}^{t}\sum_{i=1}^{n}\{Q[ijk].(t.H - k.H + H)\} + \sum_{j=1}^{m}\sum_{k=1}^{t}\sum_{i=1}^{n}\{Q[ijk].H_p\} + \sum_{j=1}^{m}\sum_{k=1}^{t}\sum_{i=1}^{n}\{Q[ijk].\Delta z\} + \sum_{j=1}^{m}\sum_{k=1}^{t}\sum_{i=1}^{n}\{Q[ijk].\sqrt{(x - x_k)^2 + (y - y_k)^2 + (z - z_k)^2}\}, t.m \quad (23)$$

where Δx is the correction of coordinates along the x axis, due to the non-coincidence between the coordinates of the centre of gravity of each [ijk]-th body and the crosscut transfer station;

H – constant vertical height of the level;

H_p– height, measured from the highest point of the closest to the surface level to the lowest elevation of the surface (the terrain);

Δz – vertical height, measured from the lowest elevation of the surface to the highest elevation of the surface (topography relief);

x_k, y_k, z_k – consumer's fixed coordinates on the surface;

x, y, z – running coordinates.

GENERALIZED ALGORITHM FOR LOCATING INTO SPACE THE OPEN HOLE OF A BASIC DEVELOPMENT WORKING. ALGORITHM FOR THE 3D PROBLEM

The whole procedure for choosing a deposition for a vertical mine shaft and determining the optimum opening plan is in itself the algorithm, represented by means of a flow chart in fig.2. The main elements of the algorithm have been developed. The algorithm is an open structure allowing the unhindered addition of new elements pertaining to its improvement when additional limiting conditions are introduced.

CONCLUSION

The elaborated algorithm and the results obtained while solving the problem of choosing an optimum location for the deposition of a basic development working show that the object function has got a clearly identifiable minimum which facilitates its formalization. At the same time the functions describing the work of transport are in themselves curved surfaces, and this fact necessitates looking for an optimum solution in three-dimensional space.

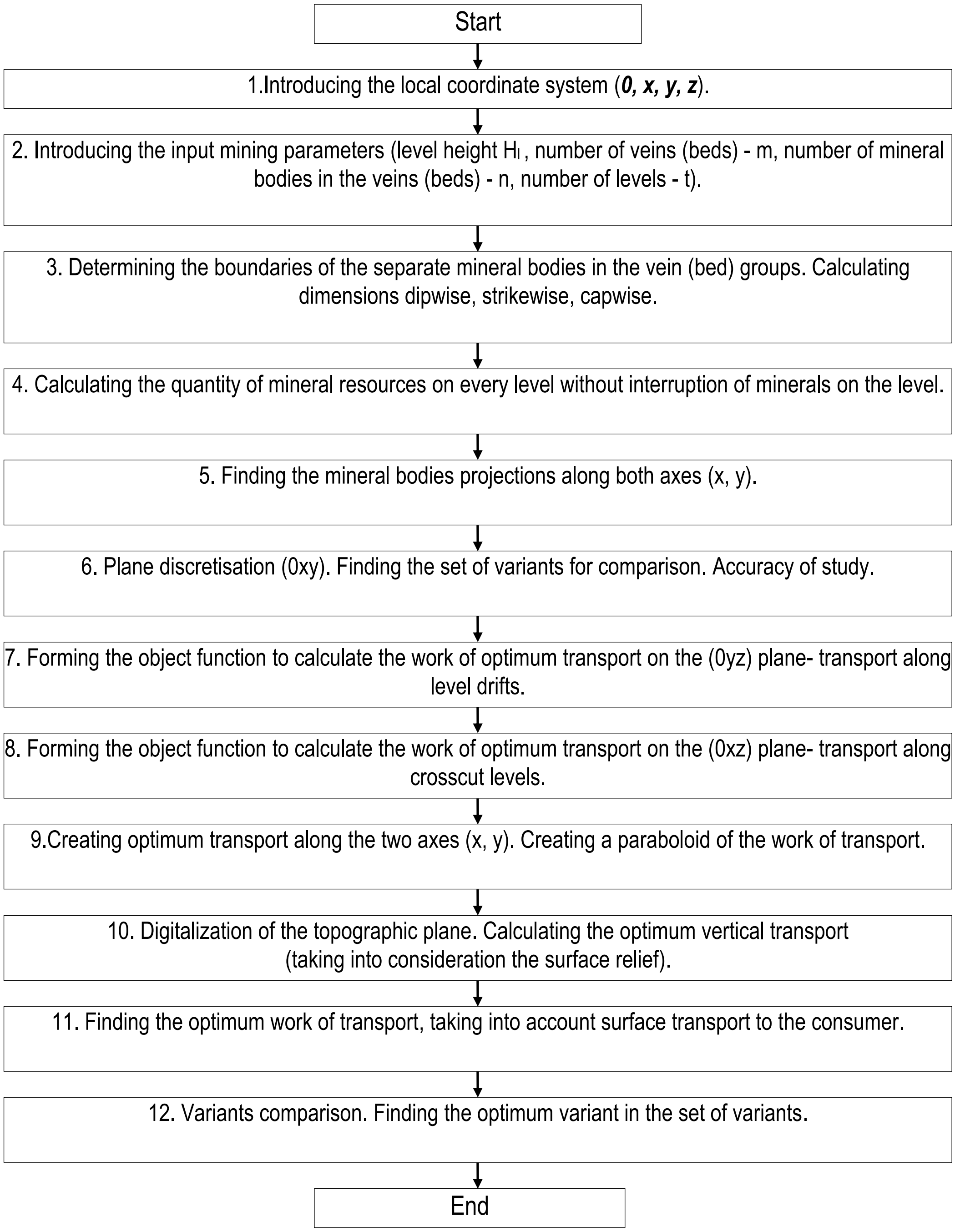

Figure 2

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