Defining the optimal point of opening and developing a surface pit mine

Ivo Galić [1]***, Dragan Krasić*** [2] and ***Tihomir Knežiček*** [3]

Contemporary methods of projecting surface pit mines are applicable exclusively by means of computing technique and specified-purposed programs. One of the developed methods is The ***Method of movable slopes*** *has been confirmed by the test on the "Kongora" open pit. The process of projecting surface open pit mines includes the defining of the digging block sequences. The optimal pit opening position and pit development determined by the* ***Method of uniformed ratio****.*

Key words*: open surface pit, optimal point of opening, development, contemporary methods.*

Introduction

Optimalization of the contours of the "Kongora" open surface pit, applying the Method of movable slopes (l) has been elaborated in the Master thesis "Projecting in the mining by applying application programs" [10]. In the basic proposition of the Method of movable slopes, fix values of the energy market prices and the elementary prices of mineral raw material digging, have been taken into consideration for the reason of simplified procedure in verifying the method in the course of elaborating the algorithms [9,10]. According to the algorithms of contemporary methods, a process of projecting surface pit mines includes also determination of blocks digging seguences [14]. It includes an exact defining of optimal opening point and the direction of developing surface pit.

The change of the exploitation price is considerably influenced by the factors such as - the place of opening, the way of digging, direction of advancing and some additional investments [1]. Formerly determined final contours of the surface pit might serve as an ultimate goal of optimalization. An exact sequence of technological operations should be determined to be able to reach the established goal [4,5].

The point of opening and developing of the surface pit is greatly influenced by the following factors: value of the mineral raw material (economic factor), shape of ore body, quality of the mineral raw material and the quantity of the overburden (natural and technological factors) as well as the morphology of the ground. Inside any surface pit mine there is tendency of continuity in sense of profit but also with regard to really possible technological solutions. It means that a crucial problem is to achieve constant quality of mineral raw material, quality of overburden and the form of mining works [2,3,6]. Following these propositions, a contemporary method of determination an optimal point of opening and developing of the surface pit has been elaborated, primarily for the stratified deposits as well as for the other types of deposits, nominated as the Method of uniformed ratio (MUR). This method has been tested on the representative example of the "Kongora" coal mine pit.

Theoretical model of the method of uniformed ratios

Basic propositions of the Method of uniformed ratios (MUR)

Existing algorithm of the Method of movable slopes (MMS) represents the basis of the contemporary method in projecting surface mine pits [9,10,11].

In optimization of the contours of a surface pit, it is doubtless that MMS resulted as an effective method. However, projecting a surface pit is a large scale and long lasting process so that the segment of determination an optimal point and developing of a surface pit has remained unsolved.

To determine an optimal point of opening and developing surface pits, various criteria should be scientifically explored and taken into consideration.

[1] Ivo Galić, Ph.D.,University Of Zagreb, Faculty Of Mining, Geology and Petrol, Croatia
[2] Dragan Krasić, Ph.D., Ministry Of Economy, Labour and Entrepreneurship, Zagreb, Croatia
[3] Tihomir Knežiček, Ph.D., University of Tuzla, Faculty of Mining, Geology and Civil Engineering, Bosnia and Herzegovina

They are as follows:

- Natural: basis of geological, hydrogeological, hydrologic, geomechanical and other data;
- Technological-exploitative: basis of mining data;
- Technological with specified purpose: basis of the data for specified-purpose objects;
- Economic: the basis of economic models.

Taking into consideration that above said data have been elaborated or they could be delt by the method of movable slopes, a research is directed to certain relation terms by means of which a number of influencing factors can be reduced to minimum [4,8,15]. Using this method of research, one can achieve an issue value that would illustrate a requested goal, in other words, it might determine the point of opening and the sequence of blocks digging [17,18].

Following this, factors which have the greatest influence on the point of opening and developing the digging blocks on the surface pit, should be clearly pointed out. They are as follows:

- An utmost possible profit
- The shortest transport ways
- Constant quality of mineral raw material
- Uniform coefficient of overburden

Profit as a positive value and the length of transport ways as an expense, represent a pure economic factor, where the profit is being increased by reducing transport expenses and reversely. It is understood that for the sequence of exploitation, the most suitable are the blocks and/or the zones of blocks of (surface pits which have the highest profit and the shortest distancev [21,22].

However, the problem becomes complex when technological requests for a constant quality of mineral raw material and a constant coefficient of overburden is added. Quality .of mineral raw material is oscillating even in the most homogenous deposits so that it is obligatory to determine the mode of exploitation, i.e. development of a surface pit which should secure a definite constant quality of mineral raw material. [3]. In this case it should be taken into consideration that the point of opening is only the zone of maximum where the development of surface pit will be initiated. The plan and the quality of overburden is uneven and usually it becomes thicker and grows as the pit gets deeper.

According to above stated problems, an algorithm for equalizing coefficients has been worked out; it expressed the most convenient relation between factors of influence for determing the opening point and developing the surface pit, nominated as the Method of uniformed ratios (MUR).

Numerical expressions of the Method of uniformed ratio (MUR)

The basic starting point for numerical expressions of the Method of uniformed ratio (MUR) are the given criteria and the factors of influence, as well as the reciprocal connection with numerical expressions of the Method of movable slopes (MMS) [23]. The elaborated data from the economic method obtained by the MMS [12] are used as entry data.

According to the Method of movable slopes, the value (profit) of the blocks is obtained with the expression:

$$B_{i,j,k} = C_t \cdot E_{i,j,k} - T_{i,j,k} \qquad (1)$$

C_t - price of the mineral raw material on the world market, (money unit/ equ.)
$E_{i,j,k}$- equivalent value of the block $b_{i,j,k}$, (equ.)
$T_{i,j,k}$- expenses of the exploitation of the block $b_{i,j,k}$, (money unit)

Expression for constant quality of mineral raw material:

$$k_q = \frac{|\Delta q| + q_{av}}{q_{av}} \qquad (2)$$

Δq - difference between quality of mineral raw material in the block i,j,k and an average quality (for coal: thermal value) in optimal contour (from 1 to 2)

$$\Delta q = q_{i,j,k} - q_{av}$$

$q_{i,j,k}$- quality of mineral raw material in the block i,j,k
q_{av} - average quality of the mineral raw material in the whole deposit

Expression for the coefficient of the overburden quantity:

$$k_{ko} = \frac{O_{i,j,k} + O_{av}}{O_{av}} \tag{3}$$

$O_{i,j,k}$- quantity of the overburden in the block i,j,k
O_{av} - average quantity of the overburden by a block

Unifying the coefficients of uniformed quality of mineral raw material and quantity of overburden in any block, we get a technological coefficient of uniformity for an observed block:

$$k_u = k_q \ x \ k_{ko} \tag{4}$$

However, for every contour of the surface pit, on any position of the block bi,j,k, it is necessary to define an average or middle coefficient of the overburden which would practically include the substance of all the blocks which should be digged above the lowest observed block.
Average (middle) coefficient of uniformity (Ks) is obtained
by the expression:

$$K_s = \frac{\sum_{i=1}^{n} k_u}{N_b} \tag{5}$$

$\sum_{i=1}^{n} k_u$ -amount of technological coefficients of uniformity in the contour of the pit $S_{i,j,k}$

N_b - number of the blocks in the contour of the pit Si,j,k

The contour of the surface pit, in geometric symmetrical forms, can be approximated, i.e. observed as an inverted cone.

The number of blocks in 3D in an inversed cone can be observed in two ways:

a, For the case when the level i=n, there is a minimal number of blocks, i.e. one block is used for the fallowing expression:

$$\mathrm{N_b} = \sum_{i=1}^{n} (2 \cdot \mathrm{i} - 1)^2 \tag{6}$$

Correctness of the expression (6) is confirmed by the example in the Table 1.

Tab. 1. Defining the number of the blocks in 3D in an inversed cone when i=n, and Δj=1 and Δk=1 on the lowest level.

Σi	**Δj=2i - 1**	**Δk=2i - 1**	**N_b**
1	1	1	1
2	3	3	10
3	5	5	35
4	7	7	84
5	9	9	165
6	11	11	286
7	13	13	455
..	..	..	..
n	2 x n -1	2 x n -1	N_n

b, For the case when on the level i=n e.g. 3, there are jxk blocks, e. g. 2x3, the following expression is used:

$$\mathrm{N_b} = \sum_{i=1}^{n} (\Delta \mathrm{j} \cdot \Delta \, \mathrm{k}) \tag{7}$$

The expression (7) is confirmed by the example in the Table 2.

Tab. 2. Defining the number of the blocks in 3D in an inversed cone when i=n, and Δj≠1 and/or Δk≠1 and/or on the lowest level.

Σi	Δj	Δk	N_b
1	2	3	6
2	4	5	26
3	6	7	68
4	8	9	140
5	10	11	250
6	12	13	406
7	14	15	616
...	...	...	...
n	m	l	N_n

When the expressions (4) and (6) are included into the expression (5) one gets an average coefficient of uniformity which usage is simplified.

$$K_s = \frac{\sum_{i=1}^{n} k_q \cdot k_{ko}}{\sum_{i=1}^{n} (2i-1)^2} \tag{8}$$

And, finally, when the technological coefficients are uniformed one can come to a relation connection between these coefficients and economic factors. Here, one should have in mind that value of the block (profit) falls with the increase of transport distance.

Optimal point of opening and the most appropriate sequence of blocks digging will be obtained by determing the maximum, i.e., the order of the blocks from the highest to the lowest value [4].

The most appropriate order, i.e. the sequence of the blocks digging, in other words, the formation of the series of the surface pits is obtained by the expression:

$$I_O = B_{i,j,k} - (T_e \cdot K_s) \tag{9}$$

I_v - index value of the sequence of digging
$B_{i,j,k}$ - value of the block $b_{i,j,k}$ (it can be positive or negative)
T_e - transport expanses, from the position of the block till the deposit, (money unit)

$$T_e = Q_t \cdot L_t \cdot C_t \tag{10}$$

Q_t - total amount which is transported from the pit contour, m3
L_t - distance of transport, from the position of the block till the deposit, m
C_t - unit price of the transport, (money unit/m^3 m')
K_a - average coefficient of the uniform quality m.s. and the quantity of the overburden in the contour of the pit $S_{i,j,k}$

The sequence of digging the blocks, i.e. the series of surface pits will be obtained by the principle of maximal value, it means that the pit with greater index will have priority value, thus:

$$S_D = \left\{ I_{O(\max)}; I_{O(\max-1)}; I_{O(\max-2)}; \ldots; I_{O(\min+1)}; I_{O(\min)} \right\} \tag{11}$$

The sequence of digging is practically the sum of all the index values in the optimal contour of the surface pit with a falling seria, i.e. the order from maximal to minimal value [17,18].

According to the expression (11) we obtain pure mathematical values, but practical solutions for an optimal point of opening and developing a surface pit will be achieved by the interpretation of treated amount of data and after defining zones of maximum and submaximum. Such an approach is the result of technological criteria which having taken into consideration theoretically obtained sizes, presume that real solutions are achieved on the ground. They are, for example, possibility of forming digging open-pit benches, traffic ways and other objects on the surface pit. Their main features are dynamism and continuity of fhe works.

Procedure in applying the Method of uniformed ratio

Elaboration of geological and economic model of a deposit is the basic presumption for applying the method of uniformed ratio (coefficients), i.e. for defining an optimal point of opening and sequence of blocks digging [4,7,15]. Here, it is also necessary to determine, previously, an optimal contour or any contour of the surface pit for which we want to determine the place of opening and the sequence of digging the blocks, what practically means that MMS (Method of movable slopes) precedes the application of the Method of uniformed ratio (coefficients). The order of the working operations according to MUR is as follows:

1. Defining the order of the blocks and starting point in space; [7,10,19]
2. Elaboration of an economic model of MUR on the basis of the MMS model;
3. Transformation of the data of economic MUR model into the model for working out the relation data basis;
4. Development of relation data basis;
5. Interpretation of exit results;
6. Determination of optimal point of opening and developing of a surface pit.

TESTING THE METHOD OF UNIFORMED RATIO (COEFFICIENTS) ON THE "KONGORA" SURFACE PIT

Basic data about the "Kongora" deposit

"Kongora" lignite deposit is situated in the Republic Bosnia and Hercegovina, cca 8 km south-east from the municipal centre, Tomislavgrad, and cca 100 km from the town Split in Croatia. The results of investigation digging show that the deposit "Kongora", in its structure, creates brachysyncline stretching in the direction east-west in the length of 4 km and 2 km in width (Fig. 1 and 2) [13,16]. Four coal layers have been developed which are named on the basis of their position in the deposit or their significance according to determined reserves (Tab. 3).

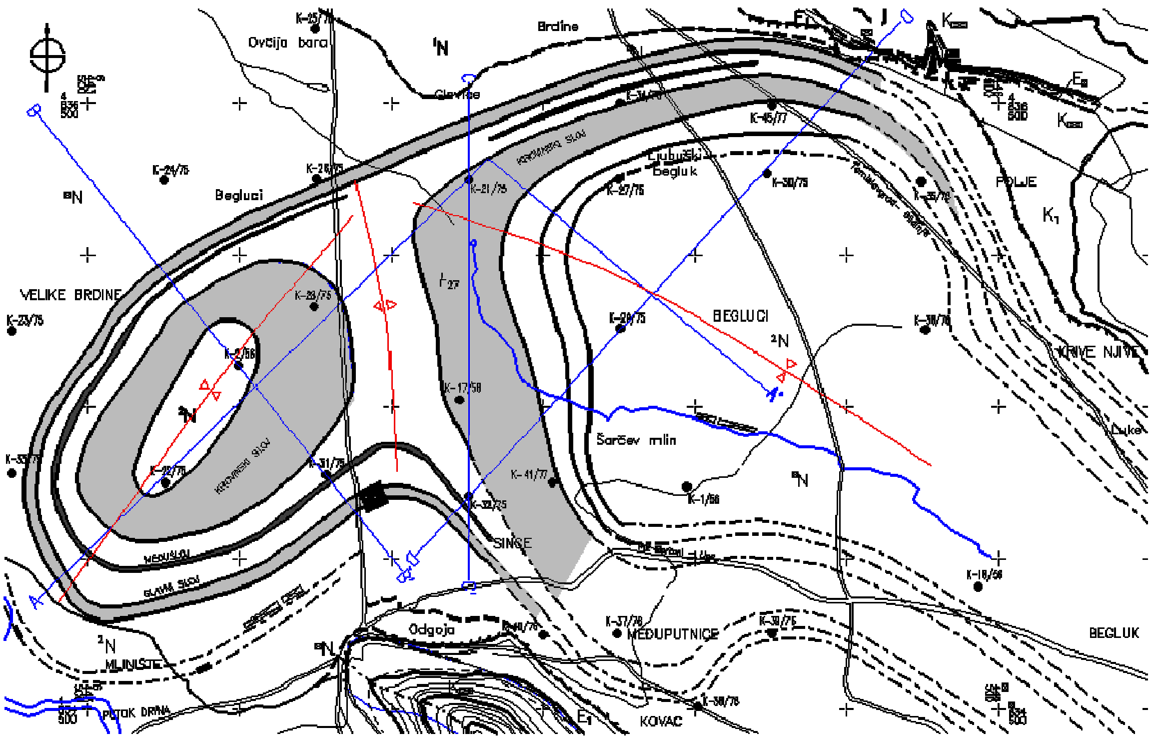

Fig. 1. Situation map of the "Kongora" deposit, M1:25,000 [11].

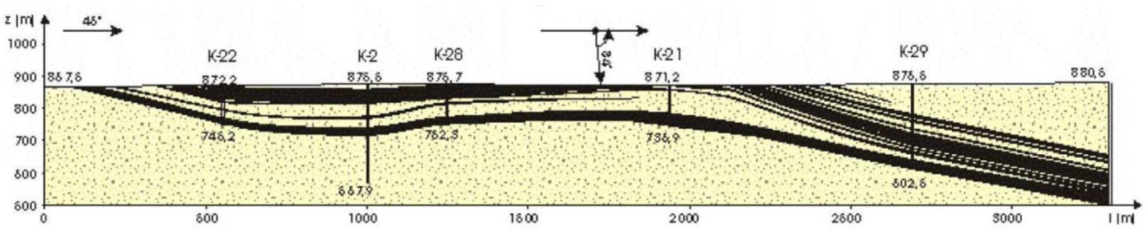

Fig. 2. Profile A-A' of the "Kongora" deposit, M1:25,000 [11].

Tab. 3. Proved reserves of the coal in the "Kongora" deposit [11,13].

RESERVES OF COAL, t		
CATEGORY	**Geologic reserves**	**Balance reserves**
B	135,568,000	129,831,000
C_1	80,333,000	76,582,000
TOTALLY	215,901,000	206,413,000
C_2	57,888,000	57,888,000

Determination of the order of blocks and starting point in space

The first step in the application of MUR on the "Kongora" deposit was to define the order of blocks and starting point in space. Taking into consideration that block model had been previously positioned in space, the working task was to define x,y,z coordinates, for each block in the model (Fig. 3).

The second step was to position the starting point, i.e. defining x,y,z coordinates, of the place to which the mineral raw material (coal) would be transported. Position of the block i,j,k =1,1,1 was chosen as a starting point as there was practically supposed the location for depositing coal,i.ef the industrial zone of the thermoelectric plant.

The third step in th

e preparation of the Method of uniformed ratio (MUR) was more particular and demanded task, i.e., to elaborate estimation of the distance of each block from the starting point.

The data about the space order and the distance of the blocks from the starting point were recorded in the estimation tables and afterwards used in economic models.

Elaboration of economic model of the MUR on the basis of the model of MMS (Method of movable slopes)

Starting point for elaboration of the model MUR were the expressions defined in the point 2 (from 2 to 11) as well as formerly worked the economic model of MMS which matrix is shown on the Fig. 4.

In the model MMS each block is consisted of 3 cells, i.e. links which represent definite parameters of the optimalization of the surface pit contours.

However, the application of MUR, i.e. defining the starting point of opening and developing of the surface pit can be worked out only by introducing new parameters which were elaborated and stated in the expressions from (2) to (11).

Thus, the existing model of MMS was used as a form, therefore the economic model of MUR with 13 cells in each block was elaborated (Pict.5). Here, it is essential to know that by means of economic model we stimulate the space order of blocks in nature.

By means of economic model of MUR one of the chosen contours of the surface pit to which we want to come through the best order of blocks digging is being observed.

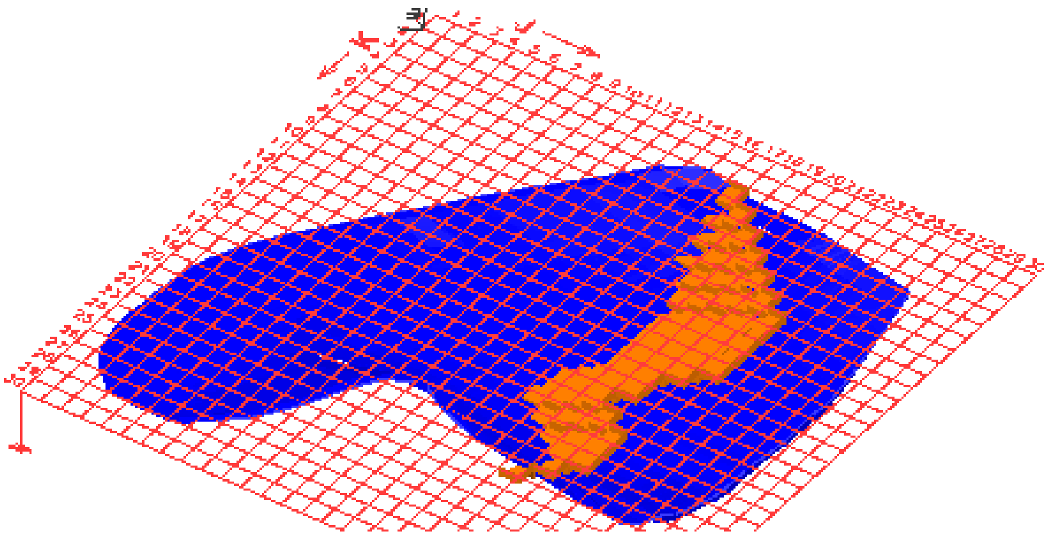

Fig. 3. Block model of the "Kongora" deposit.

In this example an optimal contour of the "Kongora" surface pit which contains 1235 blocks of coal and overburden is given. The whole block model contains 6300 blocks (30 coloumn x 30 pillars x 6 files) of which a considerable number of blocks (5065) is not taken into consideration when making estimations of parameters but a zero value and space order is added to them.

Estimation of parameters of the opening and developing point according to expressions for MUR

Using the expressions of the algorithm of MUR and entry data (quantity of coal, overburden and energy, specific heat, expenses of exploitation and profit) the other factors which influence the choice of opening and developing of surface pit are elaborated. In each cell for a belonging factor there is formed a relation (mathematical and programming) by means of which an automatized elaboration of the data is made possible, of those internal and external ones. Such a way of elaborating data and obtaining exit results produces a great number of reciprocal links between cells, what often makes difficulties to an operator. However, users may see this economic model as an amount of settled values of regular order, as it is shown on the Fig. 5.

$j \rightarrow$	11	12	13	14	15	16	17	18	19	20	21	22	23	24
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	62.586 17.608 141.744	855.493 121.411 959.148	1.952.026 68.531 512.595	2.018.829 153.701 1.048.726	2.018.828 151.945 1.033.228	2.018.812 65.589 446.007	2.018.808 40.402 274.733	2.018.804 21.205 144.196	2.018.800 0 0	2.018.800 0 0	2.018.800 0 0	2.018.800 0 0	2.018.800 0 0
2	0	0	92.073 5.604 44.274	1.005.360 94.576 728.238	1.891.628 67.175 488.770	2.018.816 85.037 578.785	2.018.836 194.064 1.319.635	2.018.829 156.335 1.063.079	2.018.816 83.825 570.013	2.018.812 65.302 444.052	2.018.801 7.763 52.786	2.018.800 0 0	2.018.800 0 0	2.018.800 0 0
3	0	0	0	51.198 6.286 48.401	851.870 64.955 474.174	1.490.693 67.318 484.687	2.018.805 25.825 182.585	2.018.811 60.270 409.834	2.018.834 184.202 1.252.574	2.018.831 165.661 1.126.497	2.018.818 95.632 650.296	2.018.806 33.009 224.461	2.018.800 0 0	2.018.800 0 0
4	0	0	0	0	21.995 2.348 17.138	702.819 47.561 342.436	1.720.526 18.744 133.082	2.013.587 3.559 24.204	2.018.804 20.902 142.136	2.018.812 63.616 432.589	2.018.819 101.028 686.992	2.018.813 71.189 484.087	2.018.813 67.666 460.127	2.018.802 9.807 66.691

Fig. 4. Display of one column from the economic model of MMS.

By introducing 12 factors-cells, influential factors are reduced to one value, i.e. on the index of digging (I_o) which is stated on the last, lowest place in the block.

Transformation of the data of the economic model into the model for elaboration of the relation basis data

After all the data in the economic model MUR were entered and worked out, it is necessary to perform certain transformation. Economic model which simulated also space order on the blocks in the surface pit contours is not appropriate for sorting the data for the reason that all the variables are also given in the 3D field. Therefore, it is necessary to transform variables from the 3D field into. 1D field.

The basic principle of the relation basis of the data is that the variables are in accordance with the columns, to be able, after the client's demand, to perform any search i.e. sorting the data. According to the stated rule, rotation of the parameters order was performed in a way that to each parameter one column was given. (Fig. 6).

k=19, $i \downarrow$ / $j \rightarrow$		01	02	03	04
0					
01	O		13.733	213.401	316.000
	G		81.233	82.352	0
	T		358.048	1.369.749	1.594.852
	E		568.634	576.467	0
	q		7.000	7.000	0
	T_e		29.048	91.082	98.232
	L_t		1.910	1.924	1.942
	ΣT_e		29.048	91.082	98.232
	B		1.404.718	417.298	-1.594.852
	k_c		1,1059	2,0009	4,7125
	S		1.404.718	417.298	-1.594.852
	K_s		1,11	2,00	4,71
	Io		1.372.593	235.051	-2.057.773
02				11.500	190.000
				118.113	170.910
				477.862	1.566.416
				826.789	1.196.373
				7.000	7.000
				40.954	115.083
				1.974	1.992
				259.317	430.216
				2.085.184	2.142.340
				1,0959	1,8960
				2.312.349	-1.054.014
				0,89	1,40
				2.048.673	1.980.730

Legend:

O	QUANTITY OF OVERBURDEN
G	QUANTITY OF COAL
T	EXPENSES OF EXPLOITATION OF A BLOCK i,j,k
E	EQUIVALENT OF THE VALUE OF MINERAL RAW MATERIAL
q	PARAMETER OF THE MINERAL RAW MATERIAL VALUE - FOR COAL SPECIFIC HEAT
T_e	TRANSPORT EXPENSES FROM THE BLOCK i,j,k
L_t	LENGTH OF TRANSPORT
ΣT_e	TOTAL EXPENSES OF TRANSPORT FROM THE PIT TO THE POSITION OF THE BLOCK i,j,k
B	VALUE - GROSS PROFIT FROM THE BLOCK EXPLOITATION i,j,k
k_c	COEFFICIENT OF THE CONSTANT QUALITY OF THE MINERAL RAW MATERIAL ON THE BLOCK i,j,k
S	VALUE - GROSS PROFIT FROM THE SURFACE PIT EXPLOITATION ON THE POSITION OF THE BLOCK i,j,k
K_s	COEFFICIENT OF THE CONSTANT QUALITY OF MINERAL RAW MATERIAL IN THE SURFACE PIT ON THE POSITION OF THE BLOCK i,j,k
I_o	INDEX OF THE DIGGING SEQUENCE

Fig. 5. Example of forming the economic model MUR for the "Kongora" deposit.

i	j	k	overburden	coal	expense of digging	equivalent	spec. heat	transp. expenses	distance	sum of the transport	profit block	coeff. of uniformity	profit pit	avarage coeff.	I_o
2	8	11	5.867	69.940	278.205	601.482	8.600	17.115	1.410	388.015	1.586.388	1,20	7.293.494	1,85	1.554.690
2	9	11	121.895	156.706	1.172.202	1.347.673	8.600	65.626	1.471	652.816	3.005.583	1,79	1.614.737	2,92	2.813.633
2	10	11	351.387	69.031	2.018.813	593.666	8.600	103.428	1.537	834.322	-178.448	2,94	-9.653.623	3,79	-570.629
2	11	11	377.595	31.816	2.018.806	180.987	5.689	105.245	1.606	995.817	-1.457.747	3,21	-1.629.166	3,57	-1.833.432
2	12	11	252.902	208.880	2.018.839	1.117.760	5.351	124.048	1.678	1.093.754	1.446.216	2,65	6.105.780	3,03	1.069.924
2	13	11	189.882	298.367	2.018.856	1.790.202	6.000	137.025	1.753	1.186.975	3.530.772	2,14	12.346.343	2,47	3.191.639
2	14	11	218.866	257.210	2.018.848	1.723.309	6.700	139.516	1.830	1.205.739	3.323.411	2,10	2.706.014	2,56	2.965.902
2	15	11	270.666	183.654	2.018.834	1.377.407	7.500	138.934	1.910	1.242.674	2.251.128	2,21	-4.548.699	2,88	1.851.343
2	16	11	338.657	87.107	2.018.816	675.083	7.750	135.759	1.992	1.273.890	73.941	2,60	-12.222.967	3,50	-400.741
2	17	11	395.911	5.806	2.018.801	44.998	7.750	133.442	2.075	1.308.203	-1.879.308	2,86	-18.278.953	4,38	-2.463.392
2	18	11	400.000	0	2.018.800	0	0	138.293	2.159	1.356.652	-2.018.800	5,43	-19.776.727	5,17	-2.733.304

Fig. 6. Display of a transformed economic model of MUR from 3D into 1D field.

Development of the relation data basis

Data pool of the relation data basis was formed by original estimation tables in a way that by means of direct links the relation between the operations in EXCEL and ACCESS programs was formed. Insertion of the data has an interactive meaning, namely, each change of value in original data files causes an automatic change in all the other data files.

By application of certain modules the imported or independently created data files can be displayed in a reduced form, according to the user's necessity, as for example, if one wants to give only quantity (sum and similar) of coal by the blocks.

Sorting of the data enabled us to arrange the estimated index values of blocks digging according to the expression (11) and thus to obtain a falling sequence of value, from maximum to minimum. In this way, for each file (from 1 to 7) and for all collective, an order of blocks digging was worked out. By ordering to sort one file, for instance, by falling series, an order for a parallel transfer of the other variables in the same file is also given. Sorting of the data can be performed simultaneously for more variables, but with regard to formerly reducing the number of factors to one value, this operation seems to be contradictory.

Display of the results in numerical form

A numerical form of presenting the results is a display of mathematical (theoretical) correct sequences of falling or increasing, depending on a functional order. It is certain that such a series is hardly possible in practice, what means that certain aberrations should take place even in the most detailed calculations. Technological solutions are in fact modified theoretical solutions which might be carried out in determined space and time.

Display of numerical values in the form of a table is shown on the Fig. 7.

According to the Fig. 7, a falling index of digging is seen, from the highest to the lowest value, obtained on the basis of the expression (11). In the last file (F21) the ordinal numbers of the blocks digging are presented.

expense transport	distance	sum of trans. expenses	profit block	uniformed coeffic.	profit pit	average	Y	X	Z	I_o	F21
133.365	1.979	2.082.145	11.330.911	1,50	7.684.106	2,57	6.444.324	4.835.718	760	10.987.650	1
108.526	1.938	1.569.927	9.728.104	1,41	9.343.660	1,95	6.444.236	4.835.765	760	9.516.786	2
175.848	2.112	2.708.325	9.548.199	1,26	-2.262.761	2,40	6.444.365	4.835.582	760	9.125.457	3
142.598	2.185	18.969.984	9.008.926	1,50	55.035.752	2,85	6.444.859	4.835.659	680	8.602.667	4
170.624	2.070	2.182.972	8.820.933	1,23	6.092.420	1,83	6.444.277	4.835.629	760	8.508.488	5
116.223	1.778	7.528.652	8.512.743	1,43	25.887.972	2,87	6.444.824	4.836.018	720	8.179.040	6
143.953	2.110	18.875.382	8.306.306	1,64	60.844.082	2,84	6.444.906	4.835.747	680	7.898.091	7
130.479	1.969	18.664.684	8.252.826	1,35	70.026.092	2,82	6.445.000	4.835.924	680	7.885.366	8
139.738	2.038	18.782.931	8.234.913	1,56	67.610.493	2,82	6.444.953	4.835.836	680	7.840.260	9

Fig. 7. Display of numerical values (sequence of digging) in the form of table.

Display of the results in graphical form

Graphical form of displaying the results is definitely the form with certain aberrations from theoretical values, though it is more true to real shape of surface pit in some phase of works. To be able to clearly illustrate the difference between mathematical order of size, and geometric - possible model of the point of opening and sequence of digging (development), on the Fig. 8 theoretical values and practical solutions are being displayed.

DETERMINATION OF THE OPTIMAL POINT OF OPENING AND DEVELOPING OF THE "KONGORA" SURFACE PIT

Extensive preparatory operations and various kinds of elaborating the data are in the function of the final goal, that is, defining an optimal point of opening and developing of the surface pits [20]. A complete series of factors of influence, even a reduced index of digging, should result, in the end, in technologically realizable solutions [22].

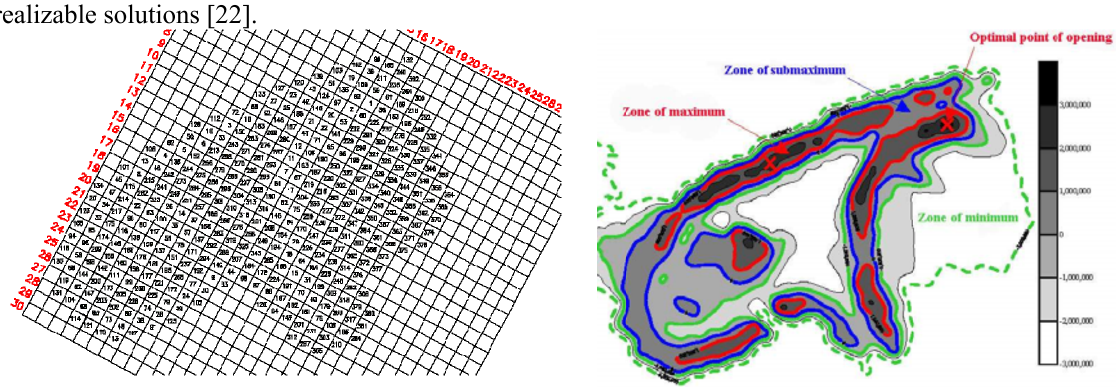

Fig.8. Graphic display format of surface mining, blocks first order.

Determination of the optimal point of opening the surface pit

According to the Fig. 8, certain zones in which the blocks of definite index values are concentrated are clearly evident. If we observe the most appropriate blocks, it can be stated that the zones of maximum are in question. Therefore, for the "Kongora" surface pit the two distinct zones with the highest values (dark shadows on the Fig. 8) can be determined. An optimal point of opening represents the most appropriate place for starting the mining works. Mathematically observed, there is only one maximum, but, technological demands are of different significance, namely, we observe the zones in which the blocks of definite, in this case, of maximal values, are concentrated. Therefore the "Kongora" deposit imposes a solution with two points of opening, or more explicitly, forming the two fronts of mining works, as it is shown on the Fig. 10 [11].

Determination of developing a surface pit

Development of a surface pit represents, in the first place, defining the front and progression of mining works. Against the definition, the front represents the form of developing the face of files (e.g., longitudinal, cross or circular) and progression represents the direction and form of moving the mining works fronts (e.g., parallel, fan-shaped, radial and similar).

According to the solution from the Study "Integrated Lignite Mining and Power Project", elaborated by the firm Reinbraun Engineering and Wasser GMBH, Germany (1998), the optimal point of opening of the "Kongora" surface pit is situated on the middle part of the north side of the deposit. A circular form of the front with radial progression of mining works was proposed, as shown on the Fig. 9 [12].

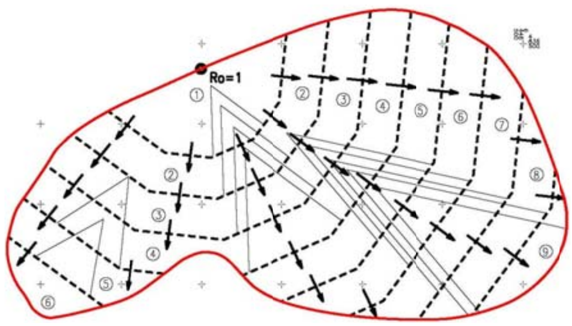

Fig. 9. Chosen variant of opening and developing the "Kongora" surface pit, M 1:40 000 [12].

However, according the investigations of applying the method MUR, it is evident that the order of mining works is influenced by a number of factors. Reducing all these factors to one index of digging, a possibility of making selections and arranging the blocks according to definite zones is created.

Linking the blocks by a method of kriging, with different space order and close indexes of opening, in the same tonality, practically the models of the most appropriate development of mining works were elaborated. Tonalities denote the blocks, i.e. the zones which, against the MUR, should be digged simultaneously (Fig. 10).

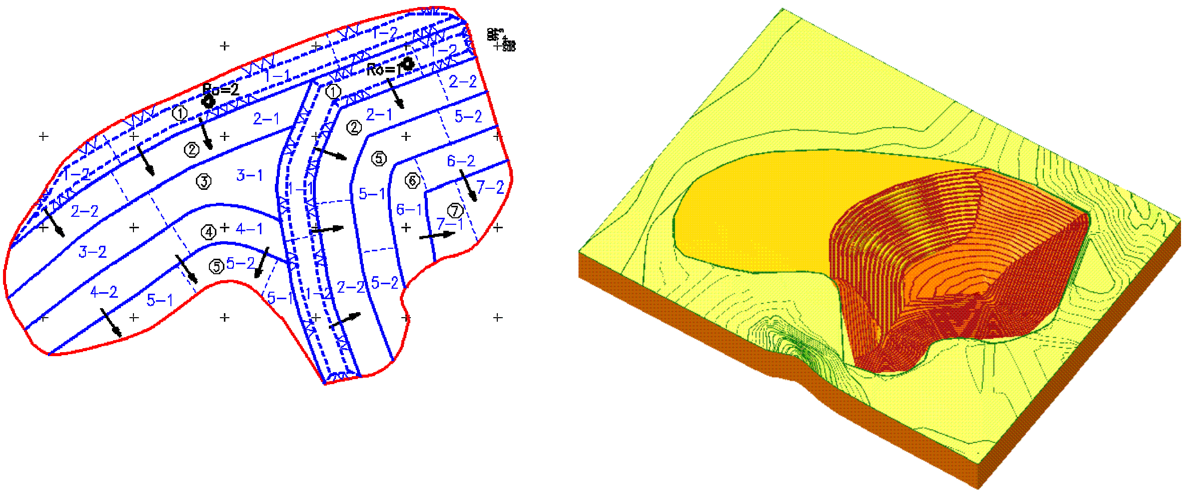

Fig. 10. Points of opening and developing of the "Kongora" surface pit, according to MUR [11].

According to the Fig. 10, it is obvious that the "Kongora" surface pit will be developed by the combination of longitudinal and circular-fold front of the mining works, on the basis of results obtained by the MUR. Circular-fold front of the mining works will be formed on the roof layer of the chilometric synclinal. The sign Ro = 1 denotes the first point of opening the surface pit and the place from which the development of the circular-fold front with radial progression will start. Longitudinal front of mining works will be formed on the main layer in the chilometric and hectometric synclinal. The sign Ro = 2 denotes the second point of opening the surface pit and the place from which the development of the longitudinal front with parallel progression will start. On the Fig.10, the order of forming the positions of the fronts is seen.

CONCLUSION

In this work the conception of opening and developing the surface pits on the stratified deposits have been investigated and therefore a method named Method of Uniformed Ratio (MUR) has been proposed. On the "Kongora" coal deposit the effects of this method is confirmed.

Quality of the mineral raw material oscillates even in the most homogenous deposits. Therefore, it is necessary to define a way of exploitation (development) of the surface pit which will ensure a certain constancy of quality. Here, it should be taken into consideration that the order and quality of overburden is uneven.

On the basis of the results of the MUR method, the "Kongora" surface pit will be developed by combination of longitudinal and circular-fold front of the mining works, thus achieving the utmost profit from the coal exploitation on the "Kongora" deposit.

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