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OPTIMIZATION OF MAIN TECHNOLOGICAL PARAMETERS AFFERENT FOR THE MINING METHODS

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Abstract: *Utilization of mining methods with undermined coal bank in the case of thick coal seams in Jiu Valley coal basin has lead to the increase of efficiency obtained and to significant decrease of production costs, but the establishment of coal fields has been made without performing an accurate analysis regarding the influence of main technological parameters' variation of this method (length of face line „l_{ab}", length of face field „l_p", and the thickness of undermined coal bank „h_b") onto the achieved technical and economical indexes.*

Key words: *optimization, model, methods, coal, costs.*

1. CONDITIONING

Establishment of optimum values of above mentioned parameters should take into account the following criteria:

1. Establishment of optimum dimensions of coal field length „l_{ab}" , „l_p" , „h_b" according the criteria of minimum mining costs.
2. Variation of advancing speed depending on the face length („l_{ab}"), the undermined coal bank's thickness (h_b) and working technology in that face.
3. Influence of geo – mechanical characteristics of coal onto the thickness of undermined coal bank.
4. Establishment of undermined coal bank thickness in accordance with the criteria of minimum dilution.

2. METHOD USED

Establishment of optimum dimensions for the coal field length (l_p), coal face length (l_{ab}) and height of undermined coal bank (h_b), in accordance with the criteria of minimum mining costs. In order to solve the optimization problem it will be used the criteria of minimum cost *(c)* onto the product unit, as the following relationship:

$$c \to \min, \text{ with restriction } P \geq P_{plan}, \quad \text{P- output,} \qquad (1)$$

Establishment of economical and mathematical model that has to lead to solution of the optimization problem starts from identification of sub – systems that are components of total mining costs system, but only those costs with significant importance in the total mining costs's value. Starting with the above presented, the costs afferent for mining the coal field can be expressed with following formula:

$$C = \sum C_i , \qquad (2)$$

Where: C - represents the costs afferent for mining the coal field;

$\sum C_i$ – sum of partial costs of afferent subsystems

The analysis of costs system afferent for the technological unit to be optimized lead to identification of subsystems of partial costs (fig.1). In this case:

$$\sum C_i = C_p + C_i + C_u + C_m + C_e + C_a , \qquad (3)$$

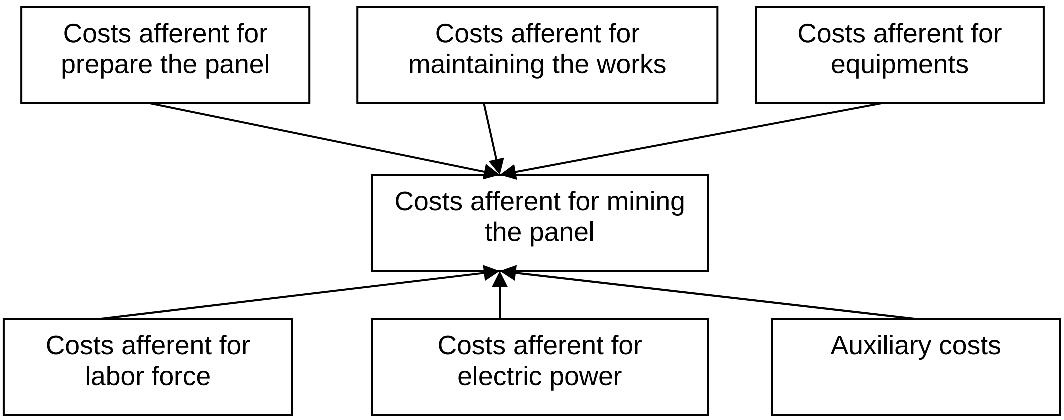

Fig.1 *System of costs afferent for mining the coal field and afferent subsystems [1]*

Where: C_p - costs afferent for preparatory works;

$C_{\hat{i}}$- - costs afferent for maintaining the preparatory works;

C_u- costs afferent for equipments (supporting, transporting, cutting, etc.);

C_m- costs afferent for the labor force needed for mining the coal panel;

C_e- costs afferent for electric power;

C_a- auxiliary costs (repairs, materials, etc.).

In the same time the production unit costs are expressed by the relationship, relationship that express the production costs afferent for the mining method with undermined coal bank used for mining the coal field reserve:

$$c = \frac{C}{R_p} = \frac{C_p + C_i + C_u + C_m + C_e + C_a}{1{,}2 l_p l_{ab}\left(h_{ab} + h_b\right)}, \qquad \text{(ROL/tones)} \qquad (4)$$

Where: c - unit costs;

C - total mining costs;

R_p- industrial reserve of coal panel: $R_p = S_p H_p h_{ex} \gamma k_1$, (5)

Where: S_p - coal field dimension on direction;

H_p - coal field dimension on declivity;

h_{ex} –thickness of mined coal slice;

γ - specific gravity of coal;

k_1 - coefficient that depend on the recovery degree and dilution: $k_1 = \dfrac{\eta}{1-\rho}$; k_1=0,8;

$\tilde{\eta}$ - recovery degree;

$\tilde{\rho}$ - dilution.

In order to establish the economical and mathematical model based on relationship (4), it is required to establish the calculation relationship depending on the three considered parameters, for every of partial costs, as follows:

- *Costs afferent for preparatory works,* [2]:

$$C_p = 2 l_p c_g + \left(c_p + c_{pa}\right) l_{ab}, \qquad \text{(ROL)} \qquad (6)$$

Where: c_g - unit cost for drilling and supporting one linear meter of underground gallery;

c_p - unit cost for drilling and supporting one linear meter of inclined plane;

c_{pa}- unit costs for drilling and supporting one linear meter of inclined plane of attack.

- *Costs afferent for maintaining the preparatory works*

In this case certain specifications should be made, as follows: the costs afferent for maintaining the preparatory works shall represent a percentage from the total value of preparatory works, as follows:

$$C_i = k_i C_p, \qquad \text{(ROL)} \qquad (7)$$

Where: k_i - coefficient representing the ratio between annual value of maintaining works in comparison to initial value of works, ki=0,15.

$$C_i = 0{,}15 C_p, \qquad \text{(ROL/year)} \qquad (8)$$

relationship that express the value of maintaining works carried out during one year.

In order to express the costs afferent for maintaining the preparatory works for entire mining period of the coal field, starting from the restriction $P \geq P_{plan}$ and considering the planned daily advancing speed V_z as main parameter influencing the daily output, it is established the mining period of that coal field:

$$T_p = \frac{l_p}{V_z}, \quad \text{(days)} \qquad \text{or} \qquad T_p = \frac{l_p}{256 V_z}, \quad \text{(years)} \tag{9}$$

It should be taken into consideration the fact that the length of the two direction underground galleries it is continuously reduced as result of mining the coal field. Under these circumstances:

$$C_i = \frac{0.15 c_g}{256 V_z} l_p^2 + \frac{0.15 c_p}{256 V_z} l_p l_{ab}, \quad \text{(ROL)} \tag{10}$$

$$C_i = 0.0006 l_p \left(l_p c_g + l_{ab} c_p \right) \frac{1}{V_z}, \quad \text{(ROL)} \tag{11}$$

- *Costs afferent for equipments*

$$C_u = \frac{l_p}{256 V_z} \left(\frac{C_{ut}}{T_{A1}} + \frac{C_{us}}{T_{A2}} + \frac{C_{uT}}{T_{A3}} \right) k_m, \quad \text{(ROL)} \tag{12}$$

Where: C_u - costs afferent for equipments;

C_{ut} – costs afferent for transportation equipments;

C_{us} - costs afferent for supporting equipments;

C_{uT} - costs afferent for cutting equipments;

T_{A1} - depreciation period of transporting equipments;

T_{A2} - depreciation period of supporting equipments;

T_{A3} - depreciation period of cutting equipments;

k_m - coefficient that takes into account the equipments' assembly costs: k_m=1,1.

$$C_u = 0{,}004 l_p \left(\frac{n_1 c_{ta}}{T_{A1}} + \frac{n_{uT}}{T_{A3}} \right) \frac{1}{V_z} + 0{,}004 l_p^2 \frac{c_{tg}}{l_u T_{A1} V_z} + 0{,}004 l_p l_{ab} \frac{c_{us} d}{T_{A2} V_z}, \quad \text{(ROL)} \tag{13}$$

Where: n_1 – number of transportation equipment in coal face n_1= 1 or 2;

n_2 – number of transportation equipment in underground gallery:

$$n_2 = \frac{l_p}{l_u} \qquad n_2 \text{ is integer number} \tag{14}$$

l_u - length of transportation equipment (catalog data);

c_{ta} – cost of one transportation equipment for coal face;

c_{tg} – cost of one transportation equipment for the underground gallery;

c_{us} - cost of supporting unit;

d - supporting density (number of supporting units onto the coal face length unit), having the value of d = 1.25 for individual supporting;

n_{uT} - number of cutting equipments;

c_{uT} – unit cost of cutting equipment.

- *Costs afferent for labor force*
  - *Costs afferent for the labor force involved in transporting the mined output*

$$R_{mt} = 2l_p^2 \frac{c_{mt}}{l_u V_z}, \quad \text{(ROL)} \qquad (15)$$

where c_{mt} represent the average wages of transport workers (ROL/man – shift).

$$R_{mt}^1 = 3{,}098 l_p^2 \frac{c_{mt}}{l_u V_z}, \quad \text{(ROL)} \qquad (16)$$

$$C_{mt} = 4{,}46 l_p^2 \frac{c_{mt}}{l_u V_z}, \quad \text{(ROL)} \qquad (17)$$

Where: R_{mt} – direct wages for transport activity;

R_{mt}^{1} - direct wages and bonuses for transport activity;

C_{mt} - total costs for transport activity.

  - *Costs afferent for the labor force involved in mining the underground coal field reserve*

Establishment of these costs' volume can be made only after analyzing the production system. In this case was established following relationship [1]:

$$C_{ma} = c_{ma}\left(1{,}89 l_p l_{ab} + 0{,}08 l_p l_{ab} h_b + 0{,}55 l_p h_b + 12{,}8 l_p\right) \qquad (18)$$

- *Costs afferent for electric power* are expressed by following relationship:

$$C_e = c_e l_p l_{ab}\left[\frac{h_{ab} + \eta h_b}{k_u}\left(\frac{l_p P_{tg}}{2 l_u Q_{tg}} + \frac{n_1 P_{ta}}{Q_{ta}}\right) + \frac{P_t}{vb} + \frac{P_s t_1}{dbk_s}\right], \text{(ROL)} \qquad (19)$$

Where: c_e - price of electric power;

k_u - coefficient of utilization the conveyor's technical flow;

Q_{tg}; Q_{ta} - technical flow of gallery, respectively face conveyor;

P_{tg}; P_{ta} – nominal powers of gallery, respectively face conveyors;

v - cutting speed of shearer;

b - depth of the kerf cut by the shearer;

d - supporting density;

t_1 - operation time of hydraulic unit required for performing necessary moves by a supporting unit;

k_s - simultaneity coefficient at the stride of supporting system.

- *Auxiliary costs*
  - *Costs afferent for repairs, C_{ar}:*

$$C_{ar} = 0{,}1C_u ;$$

$$C_{ar} = 0{,}0004 l_p \left(\frac{n_1 c_{ta}}{T_{A1}} + \frac{n_{uT} c_{uT}}{T_{A3}} \right) \frac{1}{V_z} + 0{,}0004 l_p^2 \frac{c_{tg}}{l_u T_{A1}} \frac{1}{V_z} + 0{,}0004 \frac{c_{us} d}{T_{A2}} \frac{1}{V_z} \quad \text{(ROL)}, \qquad (20)$$

  - *Costs afferent for materials (metallic wire, wood, explosives and detonators)* it surprised in paper [1].

Based on above presented relationships, the function of unit costs (4) can be written as follows:

$$c = \frac{A + El_p h_b + Fl_p + Kh_b}{1{,}2 l_{ab}(3{,}2 + h_b)} + \frac{B}{1{,}2 l_p (3{,}2 + h_b)} + \frac{Cl_p + Dl_p h_b + Gl_{ab} + Hl_{ab} h_b + Ih_b + J}{1{,}2(3{,}2 + h_b)} + \frac{L}{1{,}2 l_p l_{ab}(3{,}2 + h_b)} \quad (21)$$

Where, the coefficients A, B …. L, result from calculation.

Establishment of absolutely minimum point of the costs function (which establishes the optimum values for considered technological parameters) can be made by solving the equation system obtained by making equal the partial derivatives of the costs function depending on the three variables considered with zero, respectively:

$$\frac{\partial c}{\partial l_p} = 0 ; \qquad \frac{\partial c}{\partial l_{ab}} = 0 ; \qquad \frac{\partial c}{\partial h_b} = 0 , \qquad (22)$$

3. CONCLUSION

Establishment of absolutely minimum value of the costs function based on relationships (21) can lead to values of parameters that are outside the limits imposed by the real conditions of coal deposit, or at values that do not comply certain technological restriction. In this case, by applying the criteria 2, 3 and 4, there are established the values of parameters complying all geological and mining restrictions, and the costs function allow the estimation of mining cost afferent for the coal reserve located in pre – established conditions. In this case the value of costs will be decisive in making the decision afferent for mining respective coal field.

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