STRIP MINING AND UNDERGROUND MINING

INFLUENCE OF RATE OF COAL GETTING AND RATE OF DEVELOPMENT WORKINGS ON OPTIMAL DIMENSIONS OF A MINE PANEL

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The traditional point of view of Russian specialists in the coal-mining industry has been that the efficiency of coal getting operations increases with increasing length of the excavation district in the mine [1, 2]. Reference is usually made here to the lag of the indicators of the Russian coal industry relative to the corresponding indicators of foreign coal industries; for example, in 1991, the mean length of the excavation district in mines in the Russian Federation amounted to 600-650 m versus 1219 m in mines of the Federal Republic of Germany. For this reason, it is believed that increasing the length of the excavation column to 1.2-1.5 km [1] and even to 3-4 km [2] is one of the principal ways of improving the technology of stoping operations. The low effective rates of coal getting and development operations, the significant time lags* between the start of development operations and initiation of the stoping face into operation as well as inflationary processes in the Russian Federation are not taken into account here.

There is virtually no analysis in any published study of the way these factors influence the efficiency of coal getting operations or, in particular, the dimensions of the excavation district and mine panel. Existing techniques of optimization of the dimensions of the excavation district and mine panel are based on the use of the minimal coal extraction costs or the relative costs as optimality criterion [4] and suffer from the drawbacks inherent to these factors. Among these drawbacks is the fact that the range of practically equivalent optimal solutions is quite broad, that neither of these two criteria may coincide with the optimal solutions obtained on the basis of general criteria (e.g., profit, income), and so on. Significantly fewer reports have been concerned with the solution of the analogous problem based on the criterion of maximal profit, and the optimization problem based on the criterion of maximal gross income has, for all practical purposes, not been investigated.

Let us consider as an optimality criterion the gross profit of a mine, expressed in the form of a functional dependence on the building lag† $T_b$ and service period $T$ of a mine panel:

$$ P(T_b, T) = \sum_{t = T_b}^{T} \left( w(t) - c(t, A_t) \right) A_t (1 + E)^t \rightarrow \max, \quad (1) $$

where $A_t$ is the volume of coal extracted in the panel in the $t$-th year, expressed in terms of wholesale price $w(t)$; $c(t, A_t)$, time trends** in the variation of the wholesale price and coal getting costs, respectively, with both determined from the following relations [4, 5]:

*A time lag is an economic indicator that reflects a delay or temporal advance of one economic phenomenon by comparison with other economic phenomena [3].
†The term, "building lag," represents the mean construction period for a production facility [3], in our case, the mean length of development of the panel.
**The notion of "time trend" refers to a long-term tendency in the variation of an economic indicator.


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Here \( w_0 \) and \( c_0 \) are the wholesale price and coal getting costs, respectively, in the base time period; \( \varphi_{w} \) and \( \varphi_{c} \) the annual rates of growth of the wholesale price and coal production cost, respectively; and \( E \) is the annual bank rate of income, determined as a function of the real rate of income \( E_r \) and the rate of inflation \( E_i \) on the basis of the following formula [6]:

\[
1 + E = (1 + E_r)(1 + E_i).
\]

Let us carry out some algebraic transformation in order to represent the optimality criterion (1) in the form of a functional dependence on the dimensions of the mine panel.

We specify the dimensions of the panel by the length of the excavation column \( L_e \) and the length of the incline or slope \( L_s \). The building lag, assuming a standard system for development of the mine panel and the excavation column (i.e., by sinking two inclines and the entries of two faces that are operating simultaneously), is given as

\[
T_b = L_s v_s^1 + n_f L_f v_f^1 + n_f L_f (v_o^1 + v_m^1),
\]

where \( n_f \) is the number of stoping faces in the panel that are operating simultaneously; \( L_f \) is the mean length of the stoping face; and \( v_s, v_e, v_o, \) and \( v_m \), the annual rates of development of the inclines, the entries of the excavation column, the open-pit working, and erection of the stoping face, respectively.

The mean service period of a panel is determined from the formula

\[
T = \frac{Q}{n_f} = \frac{k L_e L_s}{n_f v_f L_f},
\]

where \( Q = k g m k_1 L_e L_s \) are the commercial coal reserves in the case of a unidirectional (\( k = 1 \)) or bidirectional (\( k = 2 \)) panel and \( A = g m k_1 v_f L_s \) is the mean annual output of the stoping face. [\( k_1 \) is not defined in the original — trans.]

Let us represent the optimality criterion (1) to reflect formulas (4) and (5) and the transformations given in [6] in the form of a time trend model thus:

(a) under the condition of constant profit (\( w_0 - c_0 = p \)):

\[
\max_{n_f, L_e, L_s} \left\{ \frac{p n_f A}{E} ((1 + E)^{-T_b} - (1 + E)^{-T_b}) \right\},
\]

(b) in general form, to reflect the time trends (2):

\[
\max_{n_f, L_e, L_s} \left\{ E^{-1} \left( (w_0 - c_0) n_f A - c_1 + (\varphi_{w} - \varphi_{c}) n_f A \left( 1 + \frac{E}{E} \right) (1 + E)^{-T_b} - (1 + E)^{-T_b}) + \left( (1 + E)^{-T_b} - (1 + E)^{-T_b} + T_b (1 + E)^{-T_b} - (1 + E)^{-T_b} \right) \right\},
\]

Evidently, the objective function (6b) constitutes a complex, nonlinear, multi-extremal dependence on the two dimensions of the panel \( L_e \) and \( L_s \) and the number of stoping faces that are simultaneously in operation. In the special case (when \( c = 0 \)), the optimality criterion (6b) constitutes the gross income of the mine.

An analytic solution of the problem (6) is possible in the simplest case in which an element of the excavation column panel is selected as the object, with optimized length \( L_e \) assuming a constant profit condition:

\[
P(L_e) = p A E^{-1} ((1 + E)^{-L_e v_e^2 + L_e (v_o^2 + v_m^2)} - (1 + E)^{-L_e v_e^2 + L_e (v_o^2 + v_m^2)}).
\]

The objective function (7) is represented as the difference between two decreasing exponential dependences and possesses a maximum point relative to the length of the excavation district. An optimal value of the length of the excavation district is generated under the influence of the following mutually contradictory factors: with increasing length of the excavation district, on the one hand, the coal reserves in the excavation column increase, and the gross profit of the mine grows;