



Rational Combination of Capital Mining and Construction Mining Operations in Coal Cuts

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Abstract

The purpose of the construction of a coal open-cut should be an achievement in the shortest possible time of an access to the mineral deposit and creation of favorable mining conditions for achieving the specified performance. In the context of investment restrictions during the construction of the mine, the volume of preparatory work should be minimized (preparation of the surface of the quarry field, organization of the field drainage system, creation of a system of tracks, construction of installation sites, power lines, electrical substations, warehouses, and other infrastructure facilities).

The main reason for the failure to comply with the deadlines for the commissioning of coal mines is the un-preparedness of the mining front, so the priority in determining the sequence of putting infrastructure facilities into operation is their influence on the development of the mining front.

Justification of the sequence of input of mining sites in the development should be carried out based on the analysis of mining and geological conditions, as well as take into account the location of mining sites relative to the systems of transport and energy communications.

The creation of the necessary infrastructure should be carried out in stages with the transfer of costs to the later periods of operation of the mine, when conditions for reinvestment from the company's profits will be created.

Keywords: coal open-cut, capital mining operations, construction mining operations, construction of mines, mining and transport equipment, mining block, deposit.

1. Introduction

When conducting construction mining operations, to increase the investment attractiveness of projects for the construction of new coal mines, it is necessary to increase the efficiency of capital expenditures. Improving the efficiency of capital expenditures is achieved by minimizing the volume of capital mining operations and the timing of their implementation, choosing the optimal construction complex of mining and transport equipment and technological schemes for the production of capital mining operations in accordance with the volume and specified construction time and taking into account the development of the company's infrastructure in this period.

During the construction of large coal mines, a phased sequence of commissioning production capacities is effective, allowing for the concentration of investment, material and labor resources in the primary mining block to ensure its commissioning in the shortest possible time.

The creation of subsequent mining blocks can be carried out by reinvesting the profits from the sale of coal mined in previous sites. With a shortage of assets of the enterprise, additional investments from external sources of financing may be attracted.

Analysis of the experience of mining of coal deposits by open-cut mines allows concluding that the division of the open-cut field into mining lines is often conditional and is a consistent involvement in the development of new coal reserves.

2. Purpose of study

A limited number of stages for the input of production capacity of coal mines and a considerable period (up to 7 years) of capital mining and construction mining operations within the boundaries of each of them testify to the irrational organization of mining operations leading to destabilization of cash flows. At the same time, the created mining front is not developed for a long time and is not involved in mining. The number of stages usually corresponds to the number of commissioned complexes of the main mining and transport equipment [19-20].

In modern conditions, in the construction of coal cuts, as a rule, the main mining and transport equipment is used, which is inefficient in the production of capital mining and construction mining operations because of the low equipment utilization over time, as mining works are carried out in cramped conditions (driving entry and cutting trenches, and excavators operating in mining faces).

3. Methods

According to the studies [7, 10, 12, 18], the generally accepted norm of compliance with the high level of investment potential of a field development project, which contributes to the intensive attraction of investments from internal and external sources, is an internal rate of return of more than 18% and the

payback period of investments, not exceeding 3 years, while the 5-6 year payback period already characterizes projects as average in terms of the level of investment potential.

In practice, it usually takes a long period to prepare a coal deposit for mining.

The pace of construction of large mining enterprises does not allow for the timely return on investment. For the implementation of construction projects of coal mines for the development of large field deposits, reducing the time it takes for the company to become self-sufficient is the most urgent task, even if its implementation entails a reduction in net discounted income (NDI) for the entire period of mining the geological reserves of the field [8, 11].

In accordance with the norms of technological design [1, 19], the construction of coal mines of small production capacity is carried out without division into stages, and with large coal production, construction is carried out in stages. Moreover, the performance of the open-pit mine of the first stage should be at least 50% of the design capacity of the open-pit mine. This procedure for the implementation of capital mining construction requires significant investment in construction and leads to an increase in its payback period.

The construction of new open-pit mines should be combined with the operation of already constructed areas, which will reduce the need to attract foreign investment. At the same time, all or part of the profits from the sale of coal can be reinvested in construction, offsetting part of the costs of these mining operations. The need for investment is inversely proportional to the volume of operational work performed during the construction of the mine, that is, with greater degree of combining capital mining and operational works, the cost of loan payments will tend to a minimum.

In numerical terms, the degree of combination of construction and operational works can be estimated using the coefficient of combination [9], determined by the ratio of the volume of stripping developed during the construction of the open-pit mine to the volume of all stripping work performed during the same period. It can be expressed as a fraction of a unit, and as a percentage.

The combination of construction and operational works at coal deposits developed by the group implies time-related parallel maintenance of processes and operations in individual open-pit mines of the group, or in adjacent mining blocks of one of the open-cut mines of the group.

The opening of new sites will be financed by profits from operating sites; therefore, the amount of funds allocated for opening new mining stages and the intensity of these works (P_n) will be directly dependent on the speed of mining faces $v_{mng(n-1)}$ [16]:

$$P_n = f(v_{mng(n-1)}) \tag{1}$$

The speed of mining operations, according to the regularity of the dynamics of mining operations, cannot exceed the speed of advance opening of the site under consideration; the work on opening the field also depends on the timely capital mining operations at the newly commissioned field. Therefore, the work on opening in new areas will be the greater, the greater will be the speed of capital mining operations in the first open-cut mine:

$$v_{mng(n-1)} \leq v_{ovb(n-1)} = f(v_{m-i})_{(n-2)} \tag{2}$$

If The speed of opening and preparation of the mining block for operation is determined by many factors. At the stage of construction of a new mine, it is necessary to ensure the mining allotment with an appropriate infrastructure, prepare the surface of the open-cut field, carry out measures to drain the field, bring

transport and energy communications, deliver and install the main mining equipment, and provide enterprise personnel with conditions for safe labor. Infrastructure arrangement should be carried out in stages with the transfer of the most capital-intensive work possible during the operation of the mine, when appropriate economic conditions will be created for reinvestment from the company's profits.

To organize the effective combination of construction mining and operational works, it is necessary to synchronize these processes in time, i.e. the speed of operational work on the block should be equated to the speed of preparatory work on the following block. The block opening speed is the first-time derivative of the opening (t_{ovb}) of the block opening length (t_{ovb}). If one considers the rate of advancement of the mining and overburden face to be equal, then

$$v_{mng} = v_{ovb} = \lim_{t \rightarrow 0} \frac{dL_F}{dt_{ovb}} \tag{3}$$

At the same time, the speed of mining operations will be as follows:

$$v_{m-i} = f(t_n), \tag{4}$$

where t_n is the total time spent on operations to prepare a new production site for the opening; it depends on the volume of capital mining operations that cannot be attributed to the operation of the open-cut

$$t_n = f(V_{m-i(const)}) \tag{5}$$

Thus, the proportionality of the mining and operational works will depend on the organization of work, which will allow equalizing the speed of work on preparing the site for development with the speed of operation on the block being worked adjacent to the considered block

$$t_{mng} = t_{ovb} = t_n \rightarrow \lim_{t \rightarrow 0} \frac{dL_F}{dt_{ovb}} = f(V_{m-i(const)}) \tag{6}$$

When conducting mining and construction mining works at the same time [17], the coefficient of combination is as follows:

$$K_M = \frac{\sum_{i=1}^n \sum_{j=1}^m V_{mng\ ij}}{\sum_{i=1}^n \sum_{j=1}^m V_{mng\ ij} + \sum_{i=1}^n \sum_{j=1}^m V_{VB\ ij} + \sum_{i=1}^n \sum_{j=1}^m V_{MI\ ij}} \tag{7}$$

Updating where $V_{mng\ ij}$ is the operational overburden volumes performed during the construction period at the stage i of the open-cut mine j , m^3 ; $V_{MB\ ij}$ is the construction mining overburden volumes performed at the stage i of the open-cut mine j , m^3 ; $V_{MI\ ij}$ is the capital mining overburden volumes, performed at the stage i of the open-cut mine j , m^3 ; n is the number of stages of construction; m is the number of mining sites.

The value of the coefficient of combination $K_c = 0.5$ means that half of the volume of stripping work performed during the construction of the mine is accounted for operational work.

Construction mining and capital mining operations in the case under consideration differ in the way they are financed: capital mining operations are carried out at the expense of investments, funds raised, refinancing, and construction mining operations are

carried out at the expense of the main activity from the company's own funds; as part of the cost price.

The combination factor can be determined by the ratio of the volume of overburden removed or the volume of operational and total (including byproduct) coal mining. In evaluating the technology and the complex mechanization of mining at coal open-cuts, an operational block was adopted as a structural unit, within which one set of equipment was used. The number of such blocks in the open-pit mine can vary from one to several and is determined by the production capacity of the open-cut, mining, technical, and geological conditions of development. The technology of capital mining operations, in the first place, will be determined by the sequence of construction of blocks or their open-cut mines and the order of commissioning.

When determining the parameters of the blocks, their rational and minimum lengths were distinguished. This makes it possible, when carrying out capital mining operations, initially to build an open-pit mine of minimum length and, after the start of operational work in this block, to build up its length to a rational value. Such an approach to the planning of capital mining operations increases the number of possible variants of technological schemes for conducting these works, combined with the operation of individual blocks [2-6].

The increase in the output of the mine determines the timing of commissioning of blocks or their open-cut mines into operation, the growth rate of production volumes and, consequently, the level of income from the sale of coal, the effectiveness of investment in the development of a coal deposit [13].

Evaluation of the effectiveness of investment in the development of a coal field, worked out by a group of open-cut mines, can be carried out according to the following objective function [14-15]:

$$NPV_{coal} = \sum_{j=1}^T \sum_{f=1}^m \left[(NC_{ff} \cdot G_{ff}^{-n}) - \sum_{t=1}^{T_c} \sum_{f=1}^m (K_{ft} \cdot G_{ft}^{-n}) \right] \rightarrow \max \quad (8)$$

$$j \in k_1, f \in k_2, t \in k_3, \\ k_1 = \{1,2,3,\dots,T\}, k_2 = \{1,2,3,\dots,m\}, k_3 = \{1,2,3,\dots,T_1\}$$

modernization where $k_1 = \{1,2,3,\dots,T\}$ is the duration of the mine development, years; $k_2 = \{1,2,3,\dots,m\}$ is the number of open-cut mines included in the group; $k_3 = \{1,2,3,\dots,T_1\}$ is the duration of investments, years; NC_{ff} is the current profit from the development of the open-cut mine f in the j -th year after taking into account the interest rate and taxes – net current profit; $G_{ff}^{-n} = (1+i)^{-n}$ is the discounting factor of the net current profit of the open-cut mine f in the j -th year; G_{-nft} is the discounting factor of investment in the open-cut mine f in the t -th year; K_{ft} is the amount of investments in the design, construction and operation of the open-cut mine f in the t -th year; i is interest rate (interest); n is the serial number of the year of assessment.

Standards and terms of development of the design performance of the open-cut mines are presented in Table 1.

Table 1: Standards and terms of development of the design performance of the open-pit mines

Capacity of the coal open-cut mine, mln t/year	The period of development of the design capacity, months	Coal production, % of production capacity		
		1st year	2nd year	3rd year
Up to 3 3-15	9	85	100	-
	15	70	98	100

Data on the capacity of the first start-up stage of the open-pit mine are presented in Table 2.

Table 2: Open-pit mines' starting capacity

Indicator	Unit	Value of the indicator		
Coal open-pit mine	mln t/year	Up to 3	3-15	> 15

capacity				
Open-pit mine starting capacity, % of the total	%	100	50	30

4. Results

According The necessary intensity of increasing the productivity of the mine can be ensured mainly in the conditions of combining capital mining and operational work through technological and organizational-technical solutions. The technical solutions include an increase in the total capacity of the main mining equipment used in the construction of priority areas (blocks). Such an increase can be achieved due to the almost simultaneous (or in a short period of time) com-missioning of several complexes of the main mining equipment, including complexes intended for construction and (or) operation of adjacent blocks.

During the construction of the open-cut mine, the length of the mining front is usually insignificant and the possibilities for commissioning a large amount of mining and conveyor equipment are limited. In order to accelerate the buildup of the front and the opening and preparation of new horizons, mining should be carried out most intensively due to the high concentration of excavators and the rational organization of work of vehicles.

The length of the mining blocks is minimized. Road transport has special advantages during the construction of the open-pit mine, as it provides the possibility of multilateral extraction of rock mass on the upper ledges and interbeds opened by temporary tracks, allows concentrating a large number of excavators on the horizons and developing a high speed of movement of the work front.

The combination of mining and operational works during the construction of the open-cut and the high intensity of their production provide the most favorable mode of mining operations compared to the regime typical of traditional construction technologies — with consistent construction and alternate commissioning of operational blocks (sites, stages, commissioning complexes, etc.).

Figure 1 shows the graphs of changes in the current stripping ratio during the construction of a coal open-cut mine using different technological schemes of capital mining operations and the intensity of their maintenance.

As a result of the research, the following characteristic patterns of the mining regime during the construction of the open-cut mine have been identified:

- For almost all the considered capital mining management schemes, the mining regime schedules are un-stable, especially in the first half of the construction period of the mine, when most of the blocks and stages are put into operation;
- The maximum excess of the current stripping ratio during the construction period of the mine in relation to its average value for the period of commissioning of the blocks reaches 120% for a number of technological schemes;
- The most uniform distribution of the volume of overburden operations by construction year and the smallest calendar volumes are options for which intensive growth in coal production is achieved due to the accelerated construction of the first blocks and the maximum possible combination of capital mining operations;
- For the traditional technology of construction of the open-pit mine with the sequential introduction of blocks into operation, an uneven distribution of the volume of stripping work in time is characteristic;
- With an increase in the degree of combining capital mining and current mining operations, the average value of the stripping factor over the construction period of the open-cut decreases, which indicates a trend to reduce costs in this period.

1 – in case of sequential construction of the blocks and their alternate commissioning (the traditional construction scheme of the open-cut mine);

2 – in case of intensive rates of construction of the blocks and combining construction mining and operational works between the blocks and inside the blocks;

3 – in case of an average rate of construction of the blocks and combining construction mining and operational works between the blocks.

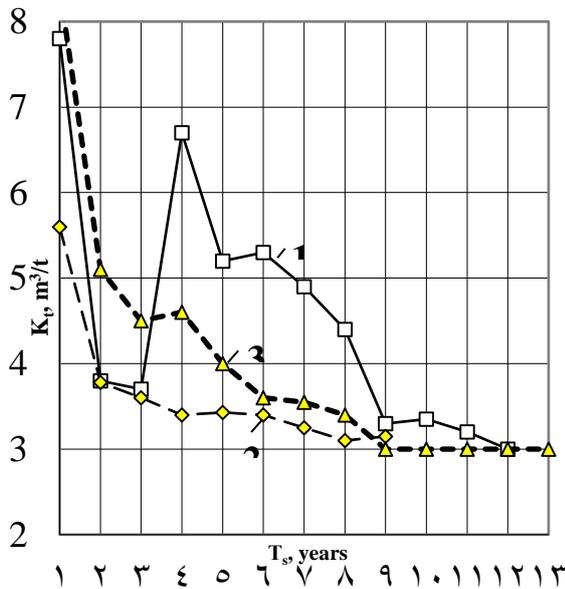


Fig. 1: Graphs of changes in the current stripping ratio in the process of construction of the open-cut mine using various technological schemes of capital mining operations and the intensity of their maintenance.

5. Conclusion

For coal mines engaged in the development of deposits in the current economic conditions, the developed requirements and preliminary recommendations for capital mining and construction operations should be fulfilled, based on the analysis of the results of the open-cut mines, as well as the experience of the construction of the mines, taking into account the peculiarities of investment in mining projects:

1. Construction of open-cut mines of large production capacity should be carried out in stages when rationally combining capital mining operations with operational ones, which will allow reinvesting part of capital expenditures at the expense of profits from the sale of coal mined during the construction period.
2. Development of quarry fields should be carried out by separate adjacent mining blocks with the creation of a unified front of mining operations and the formation of a general scheme for the opening of working levels. The exploitation of coal begins after the completion of the first stage of the mine and the further expansion of production capacity to the design value is carried out gradually due to the phased commissioning of the newly built adjacent production blocks of the mine. Moreover, the volume of the worked-out space of the working zone of the first stage open-cut mine should be minimal.
3. Construction and commissioning of new operational blocks should be carried out by reinvesting the profits derived from the operation of previously developed operational blocks.
4. An open-cut mine of the first stage and the first operational blocks should be located in the section of the career field with the most favorable mining and geological conditions with the maximum approach to external transport and energy communications. This will reduce the cost of construction and the need for investment and contribute to ensuring the profitability of the mine in the first years of operation.
5. For each stage of field development, the most effective mining equipment for the mining conditions of the mine should be justified. During the construction of primary blocks, the main equipment of adjacent mining blocks may also be involved, or additional equipment may be introduced to reduce the commissioning time of these blocks.

6. In order to reduce the duration of construction of the open-cut mine of the first stage, when mining and construction works are carried out, it is advisable to use operatively mounted mobile mining equipment, including diesel-driven one. This will allow the construction of the mine to begin before the supply of power communications and the installation of the main mining equipment. In the future, this mobile equipment can be used on a permanently operating construction site, providing advanced construction of operational blocks.

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