Substantiation of equipment complexes for the development of brown coal deposits in the mode of coal quality management

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Abstract. The choice of equipment complexes, development technology is a task influencing the technical, economic, environmental, social and other indicators of the mining enterprise. The world known companies having long traditions in the production of mining construction machines and excavators are flexible companies that easily adjust to constantly changing market, this is the equipment that can be used in the current situation. The interrelation of the equipment complex parameters with the production capacity of the open pit is since the productivity of the first must be a multiple of the second value, and the costs for all types of mining and investment are minimal with the selected technological complex variant. The article studies the influence of the mine production and the bucket capacity of a hydraulic excavator (for which the corresponding variant of the technological complex was formed) on the technical and economic indicators of the mine operation for the conditions of a valid research object.

1. Introduction

Currently, the Russian market has a large selection of excavators with a wide range of characteristics from domestic and foreign manufacturers of mining and construction equipment, the manufacturers emphasize significant differences between their equipment and other products.

HITACHI competes by developing and bringing to the market equipment with a wide range of technical capabilities, using microprocessors, and with a well-thought workplace for the operator. Traditionally, the strength is the simpler service technology and reasonable price.

An example of a qualitative embodiment of the above principles is KOMATSU excavators. Work equipment is optimized for durability/reliability. Automation allows you to perform four operations (digging, leveling horizontal surfaces, slopes and their tamping) at high speed, and, if necessary, quickly switch to short-term work in a mode of increased power by 10%. The operator's cab meets the requirements of EU standards. Komatsu paid special attention to the design of devices for a quick change of buckets, and the operator can do it without leaving his cabin [1, 2].

More recently, excavators appeared in the list of equipment produced by the British company JCB. Despite the short history of excavator production, the JCB models fully meet the standards of English quality.

The advantages of Caterpillar excavators are modern design, a wide range of interchangeable end-of-arm tooling, booms and arms of various configurations and lengths. The hydraulic system provides increased torques and operating speeds of the hydraulic cylinders of the boom, arm, and bucket. Caterpillar pays special attention to increased cabin comfort: it has an automatic climate control system,
filtration of circulating air, and maintaining overpressure inside the cabin. The complexity of the service is reduced due to the availability of all units requiring daily maintenance.

The German corporation Liebherr pays special attention to full-rotating construction and open-pit mining excavators. They have the following features: a hydrostatic drive for tracked vehicles, automatic gearbox with power shift transmission for wheeled vehicles; Litronic electronic, hydraulic control system of a new generation with auto diagnostics of units; own production diesel engines, designed specifically for earthmoving equipment. These engines are characterized by an increased working volume, direct injection, high torque, and, consequently, increased engine life and lower exhaust toxicity.

The US corporation Case is well known for its Case-Poclain full-rotation excavators. There are three standard modes of operation: normal, high-precision and maximum power. They are powered by their own production diesel engines. Optimization of engine operation is provided by electronic regulation of hydraulic flows. The layout of the working tools on the rotating platform provides easy access to each of them.

The Fiat-Hitachi trademark is well known in the field of excavator manufacturing. The excavators of this company are equipped with an Isuzu power unit, which is equipped with a button system of switching to idle mode. The starting preheating system provides the preparation of excavator units for launch and operation at low temperatures. The push-button electronic system adapts engine speed and hydraulic pump performance to working conditions, allowing one to combine high performance with good fuel economy in any of four programmable modes.

O&K is a registered trademark of the products of the German company Orenstein&Koppel AG. The company was founded in 1876, and during this time, O&K products have gone from steam excavators on a rail track to an 800-ton tracked giant. O&K plays a prominent role among the trendsetters of the "excavator fashion."

The main advantage of the O&K hydraulic rotary excavators is the 3rd generation electronic control system that automates many processes. The company equips its machinery with O&K patented units: track cleaners that increase their lifespan and prevent the track chain from jumping off - for tracked excavators, multi-disc brakes, ensuring smooth braking - for wheel excavators.

South Korean company Daewoo is a dynamic participant of the earthmoving machinery market. The range of their excavators is extensive, but the key attention is given to tracked vehicles. Daewoo designers have managed to gain an advantage over competitors in several areas. Among them is the increased platform rotation speed; increased digging force and reach ground level; optimum parameters of a working zone for operating in constrained space. This provides pre-start monitoring of oil level in the engine and hydraulic systems, as well as engine temperature.

The Swedish company Volvo claims that their machines have distinguished high performance. It is achieved with traditional methods: automatic selection of digging modes and engine operation regimes, increased working area due to boom geometry and usage of long-stroke hydraulic cylinders, usage of less high-speed diesel engines with increased torque and reduced exhaust toxicity, placement of daily maintenance units to easily accessible areas.

The open joint-stock company “Tyazheks” is the main producer and supplier of heavy earth-moving equipment in Russia — excavators of the V and VI size groups (six modifications) with various replaceable tools. Depending on the configuration the excavators can be equipped with a front or back shovel and other interchangeable equipment - drilling tools, ripper, and hydro hammer. All excavators are equipped with engines of the Yaroslavl plant.

The hydraulic excavators have the following advantages compared to power shovels:
- due to the hydraulic system, the working equipment has an independent rotating bucket, skipper arm, and boom. Hydraulic excavators can adjust the digging force at any height of the face, and it is 1.5 times higher than the digging force of the power shovels with the same bucket capacity, and the shear thickness varies up to 0.2 ± 3 m;
- with the same bucket capacity, the weight of hydraulic excavators is 1.8÷2.5 times less than the power shovels, thanks to this, the purchasing cost of hydraulic excavators and the operating costs are
reduced, due to the smooth and soft movement of the working parts of the hydraulic excavator, driver's working conditions are improved too;
- the possibility of the horizontal movement of the bucket creates conditions for compacting the material inside the bucket, while the loosening coefficient decreases to 10% and the filling ratio increases by 10-15%, which results in productivity increase by 25 ÷ 30%;
- hydraulic excavator has high mobility, movement speed (2.2-5-4.5 km/h) is 4-8 times higher than power shovels, pressure on the ground is 2.5 times less than that of a power shovel with the same bucket capacity. A hydraulic excavator can draw up to 8-10m below the level of its placement, which makes it possible to carry out an advanced trench with a width of 2 ÷ 3m;
- due to the ability of the bucket to move with any trajectory, the hydraulic excavator can clean the working site, the lower site and the face without a bulldozer;
- the minimum time for an overhaul of a power shovel is three months, and a hydraulic excavator is two weeks.

Hydraulic excavators can be used for trenching, sump and mining operations in the presence of groundwater, as well as for the selective development of low and complex coal seams.

At the same time, not only the loss of mineral resources can be drastically reduced, but its dilution due to the lack of advanced drilling and blasting loosening of the rock mass and a selective excavation, which will lead to an improvement in the quality of coal.

Also, a reasonable reduction in the amount of standard quality coal will allow an increase in its balance reserves for enterprises of open coal mining by 10÷15%.

2. Materials and methods

The choice of options for mining complexes is based on the recommendations [3-7] for a rational combination of the capacity of the excavator bucket and the dump truck and the recommendations of equipment manufacturers [8]. The choice of optimal parameters of drilling and blasting operations in the development of deposits by the opencast is given in the literature [9-14].

Currently the “Methodological guidelines for evaluating the effectiveness of investment projects ...” define the efficiency of an investment project [15].

Guidelines contain a system of indicators, criteria, and methods for evaluating the effectiveness of investment projects in the process of their development and implementation applied at various management levels [16, 17, 18].

When evaluating the effectiveness of an investment project, the comparison of different-time indicators is carried out by reducing (discounting) them to the value at the time of evaluation.

To bring multi-time costs, results and effects, the discount rate standard (E) is used, it equals the investor's rate of return on capital.

Comparison of various investment projects (or project options) and the selection of the best one is recommended based on various indicators including the following:
- net present value (NPV) or integral effect;
- profitability index (PI).

Net present value (NPV) is defined as the sum of the current effects for the entire billing period, reduced to the initial step, or the excess of the integral results over the integral costs [19, 20].

If during the billing period there is no inflationary change in prices or the calculation is made in base prices, then the NPV value for the constant discount rate is calculated using the formula:

\[ E_{int} = NPV = \sum_{t=0}^{T} (R_t - E_t) \cdot \frac{1}{(1+E)^t} \]  \hspace{1cm} (1)

where \( R_t \) – results achieved at the t-th calculation step, rub; \( E_t \) – costs incurred in the same step, rub; \( E \) – discount rate standard; \( T \) – evaluation period, years.

The profitability index (PI) is the ratio of the sum of the reduced effects of the amount of capital
investment:

\[ PI = \frac{1}{R} \sum_{t=0}^{T} \left( R_t - E_x \right) \cdot \frac{1}{(1+e)^t}. \tag{2} \]

The calculation of mining work includes the following cost items: auxiliary materials for technological purposes; energy for technological purposes; mineral extraction tax; fuel for technological purposes; basic wages of production workers; additional wages of production workers; unified social tax; depreciation; expenses for maintenance and operation of auxiliary equipment; shop expenses; coal mining stripping work.

In the economic evaluation of equipment complexes, they first established the relationship between the profitability index and the net present value at a various production capacity of the mine (Figure 1).

![Figure 1](image)

**Figure 1.** The dependence of the profitability index and net present value from the mine productivity: \((\bullet - PI, \square - NPV)\).

From the graphs presented in Fig. 1, it is obvious that there is a linear relationship between the profitability index and the net present value. It allows using any of these indicators during justification of the mining complex.

Therefore, further calculations are made of the profitability index for various values of the mine production and excavator bucket capacity, the results of which are used to plot the graphs shown in Figure 2. Their analysis suggests that the corresponding dependencies have a parabolic shape, with an extremum, which position depends on the production capacity of the mine.
Based on these data, graphs have been built that allow us to recommend the equipment complex for the capacity of the excavator bucket and to establish some economic indicators for the mine operation with a known production capacity (Figure 3) [21].

Figure 2. The impact of bucket capacity on the profitability index at different values of mine production capacity.

Figure 3. Influence of the production capacity of the mine on the optimum capacity of the excavator bucket, the cost of coal mining and the investment profitability index.
3. Conclusion
For the development of lignite deposits with small capacity mines, it is advisable to use equipment complexes with hydraulic excavators for mining operations.

As a result of analyzing the experience of using various models of mining equipment at the respective enterprises of the Krasnoyarsk territory, it was found that it is most rational to use excavation, loading and transport machines of the Japanese company for the development of brown coal deposits.

The economic evaluation of the equipment complexes, in the combinations recommended by KOMATSU and according to the developed methodology showed that the dependence of the profitability index on the parameters of the complex (excavator bucket capacity) has the form of a parabola, the extremum position of which is predetermined by the production capacity of the mine.

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