OPTIMUM CONTROL OF ROTOR EXCAVATORS
AT QUARRIES OF REFRATORY RAW MATERIALS

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Rotor type stripping excavators of a capacity of 1250 m$^3$/h are the principal equipment used for stripping and transporting the rock to the dump at quarries of refractory raw materials. The main types are the ERG-400 17/1.5, ERG-350/1000 or ER-1250. The average resistance to stripping in vertical cuts was determined experimentally and proved to be 1.2-2.3 kg/cm$^2$. The productivity of a rotor excavator is not limited by the power of the drive of the rotor wheel or by the handling capacity of the conveyors.

The performance of stripping equipment during the period 1965-1972 was carried out* at the Donetsk Scientific-Research Institute of Ore Mining on the basis of the average monthly technical ($Q_{tech}$) and operational hourly ($Q_h$) productivities:

\[ Q_{tech} = \frac{V_m}{T_{h,t}} \text{ m}^3/\text{h} \]
\[ Q_h = \frac{V_m}{(T_c - T_{ov})(T_d - T_{loss})} \text{ m}^3/\text{h} \]

where $V_m$ is the theoretical solid volume of soil excavated per month, m$^3$; $T_{h,t}$ is the actual excavation time per month, h; $T_c$ are the working days per month, $T_{ov}$ is the day of the monthly overhaul; $T_d$ are the working hours per day; $T_{loss}$ is the loss to between-shifts servicing and dinner breaks, h.

The analysis showed that neither productivity is constant in magnitude. The rms deviation of the technical productivity from the arithmetic mean for the months of a year is as high as $\pm 209.5$ m$^3$/h. The histogram of the distribution of the technical productivity shows that the most likely value with a repeat frequency of 0.348 is 400-500 m$^3$/h and the minimum with a repeat frequency of 0.012 100-200 m$^3$/h. The peak productivity of rotor excavators in the quarries of refractory raw materials in the Ukraine is 700-800 m$^3$/h with a repeat frequency of 0.06. The technical productivity depends on the properties of the rock being worked and on the control parameters which are in turn influenced by the weather conditions. The significance of seasonal variations is influenced by the results of a single-factor analysis of the standard deviation.

The histogram of the distribution of $Q_h$ of rotor excavators shows that the most likely value with a repeat frequency of 0.319 is 200-300 m$^3$/h, the minimum value with a repeat frequency of 0.074 50-100 m$^3$/h, and the peak productivity with a repeat frequency of 0.06 500-600 m$^3$/h. The fact that the most likely hourly productivity is low can be attributed to the low technical productivity and the low coefficient of machine utilization. The results of a single-factor analysis of the standard deviation shows that, like $Q_{tech}$, $Q_h$ depends on the season.

The results of the aforementioned statistical performance analysis of the rotor excavators in the Ukrainian quarries of refractory raw materials illustrate the unordered state of the optimization object (i.e., the process of operating the excavator) with productivity

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Fig. 2. Block diagram of the strategy in the search for optimum parameters for the process of pillar-working with a rotor excavator: MIK-1M is a small-scale analytical unit.

Fig. 3. Block diagram of a program for determining the optimum values of the technological factors with an MIK-1M.

as criterion, and the technical necessity and economic advantages of optimizing the process control.

The above technological parameters of the quarrying process are produced by the drivers of all excavators operating in quarries of refractory clay and kaolin where the loading of the conveyer depends on the driver's judgment. The productivity varies within wide limits as a result of the subjective choice of the cutter position at the face by the driver. The skill of the driver as a factor in the stability of the work process of the excavator was investigated in a single-factor experiment.

The level of the base factor, i.e., the driver's skill, is qualitative and fixed. The results of the single-factor analysis of the variance of the experimental data showed that the performance of an EHRG-400 17/1.5 excavator is in fact influenced by the degree of skill of the driver. Other productivity analyses of this type furnish grounds for stating with a probability of 0.95 that the linear dimensions of the pillars being worked do not significantly influence excavator productivity.

With manual control the dimensions of the excavator cut cannot be maintained on the prescribed level. An analysis of the distribution histogram of the thickness of the cut (Fig. 1) shows that during the working of a single pillar the thickness of the cut varies 0.1-0.7 m. In manual control the main parameters of the process of excavating are unstable.

In the optimization of the excavator performance the working process and the input factors are known. It is necessary to determine process parameters which will give the extremum if the latter lies within the investigated region of factorial space, or the minimax of the optimality criterion. These values of the input factors are known as the optimum parameters of the work process.

The work process expressed in terms of the interaction of the excavator with the quarry face is complex and multifactorial since the mechanism of the phenomenon is not fully understood. The relation between the input variables and the function of the yield is described by a figurative equation:

\[
Y_{1m}(t) = f\left[T_I(t), K_j(t), O_m(t), Z(t), \varphi, W(t)\right],
\]

where \(T_I(t)\) are the controllable technological factors; \(K_j(t)\) are the controllable design factors; \(O_m(t)\) are the organizational factors; \(Z(t)\) are the uncontrollable but monitored factors in the complex work process of the excavator; \(\varphi\) are operators which are effective for certain ratios and limitations concerning \(T_I(t), K_j(t), O_m(t), Z(t)\); \(W(t)\) are variables corresponding to noise type disturbances.