Impact of the number of blades of the geokhod cutting body on the energy intensity of the rock destruction

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Abstract. The article presents the sequence of calculating the energy intensity of the rock destruction with the blade of the geokhod cutting body. The influence of the number of cutting elements of the geokhod body on the energy intensity of rock destruction is determined. To substantiate the relevance of the study, features of the new class of mining machines – geokhods and the main provisions of geokhod technology are presented. The main research stages are formulated, based on the method for determining the energy intensity of the destruction of the rock face with the blade of the geokhod body. Geometrical features and power parameters of the geokhod blade cutting body that affect the energy intensity of rock destruction are identified. To determine the influence of the number of blades of the geokhod body on the energy intensity of the destruction of the rock face, the geometrical parameters of the blade body and the parameters of the mining and technical conditions of the mine working are substantiated. For carrying out mathematical calculations, an algorithm has been developed for calculating the energy intensity of the destruction of a rock face with a blade body a geokhod. As a result of the study, it was revealed that the energy intensity of the destruction of rock with the blade cutting body increases unevenly with increasing number of blades.

1. Introduction
Existing mining systems and technologies of mine workings are poorly adapted, and in most cases are not able to solve the problem of cavity formation in the underground space at small depths [1–4].
A promising direction for the development of cavity formation technologies in the underground space is the use of geokhod technology, the basic element of which is the geokhod. This is an apparatus designed to carry out the excavation of underground workings for various purposes and location in space [6–9].

When developing technical and structural solutions for devices and elements of a geokhod, it is necessary to take into account the complex, helical movement of the machine to the bottom of the mine. In addition, the developed methods for determining the power parameters of devices and elements of geokhod, which interact with the external environment and between themselves, should take into account the complex nature of geokhod movement.

One of the main devices of the geokhod that has a direct impact on the power characteristics of the underground apparatus is a cutting body. In turn, the methodology for determining the power parameters of the body is influenced by its technical and design parameters.

The main indicator for evaluating the effectiveness of the geokhod cutting body is the energy intensity of rock destruction [10]. Therefore, the research aimed at improving the methodology for calculating the energy intensity of the rock face destruction, as well as determining the influence on it of the design parameters of the blade cutting body is relevant.

2. Research methodology

From the previous studies [11–16], the energy intensity of the destruction of the rock face with the blade cutting body of geokhod will be determined by the expression

\[ p = \frac{p_{cd}}{F_{mid}}. \]  

(1)

where \( R_{cv} \) — projection of the total force of the resistance of the soil to cutting, on a plane perpendicular to the axis of geokhod rotation, H;

\( F_{mid} \) — cross section of the slot area, mm².

For a geokhod blade cutting body, the total projection of the resistance of the soil to cutting on a plane perpendicular to the axis of rotation is equal to [14–19]

\[ R_{cb} = n(R_{cb,cv} + R_{cb,side}), \]  

(2)

where \( n \) — the number of blades of the geokhod body;

\( R_{cb,cv} \) — projection of the component of the force of soil resistance to cutting, depending on the width of the cut, on the plane perpendicular to the axis of rotation of the geokhod (figure 1), H;

\( R_{cb,side} \) — projection of the component of the force of soil resistance to cutting, not depending on the width of the cut, on the plane perpendicular to the axis of rotation of the geokhod (figure 1), H.

Projection of the component of the force of soil resistance to cutting, depending on the width of the cut, on the plane perpendicular to the axis of rotation of the geokhod [14–19]

\[ R_{cb,cv} = \frac{\alpha m_{c} h_{B}}{2 \pi n \cos \gamma} \left[ \frac{\sin \beta_{2} - \sin \beta_{1}}{\sin \beta_{1} \sin \beta_{2}} + \cot g(\delta + \varphi_{fr}) \ln \left| \frac{t g \beta_{1}}{t g \beta_{2}} \right| \right]. \]  

(3)

Projection of the component of the force of soil resistance to cutting, not depending on the width of the cut, on the plane perpendicular to the axis of rotation of the geokhod [14–19]

\[ R_{cb,side} = \frac{h_{B}}{n} \left( m_{side} h_{B} + m_{side,mid} \right) \left[ \frac{\sin (\delta + \varphi_{fr} + \beta_{1}) + \sin (\delta + \varphi_{fr} + \beta_{2})}{\sin (\delta + \varphi_{fr})} \right]. \]  

(4)
Figure 1. The areas of action of the components of the sharp blade cutting force.

From [14, 15, 16, 17, 18, 19] and Figure 1, the cross-sectional area of the slot will be determined

\[ F_{mid} = bh + k_{side}^2 h^2 \cot \gamma, \]  

(5)

where \( b \) – the blade width, m;
\( h \) – depth of cutting, m;
\( k_{side} \) – the depth ratio of the expansion part of the slot;
\( \gamma_{lim} \) – angle of inclination of the expansion part of the slot to the horizon, degree.

During one full turn geokhod moves a distance equal to the pitch of the helical blade \( h_B \). Therefore, if we assume that there is only one blade on the cutting body, it should destroy the cut of thickness equal to \( h_B \). When installing several knives on the geokhod cutting body, the cut thickness \( h \) will be equal to:

\[ h = \frac{h_B}{n}, \]  

(6)

Taking into account the expression (6) the cross-sectional area of the slot with one blade of the geokhod cutting body

\[ F_{mid} = b \frac{h}{n} + k_{side}^2 \left( \frac{h}{n} \right)^2 \cot \gamma_{pr}, \]  

(7)

Putting expressions (2) and (7) in expression (1) we get

\[ p = \frac{n(R_{cb.cv}+R_{cb.side})}{n\left(b \frac{h}{n} + k_{side}^2 \left( \frac{h}{n} \right)^2 \cot \gamma_{lim} \right)}, \]  

(8)

We simplify expressions (8)

\[ p = \frac{R_{cb.cv}+R_{cb.side}}{b \frac{h}{n} + k_{side}^2 \left( \frac{h}{n} \right)^2 \cot \gamma_{lim}}, \]  

(9)

From the expression (9) it can be concluded that the value of the energy intensity of the destruction of the rock face with the blade cutting body of the geokhod will be the same both for one blade and for the entire blade cutting body of the geokhod with several blades.
3. Results
To determine the influence of the number of blades of the geokhod blade cutting body on the energy intensity of the destruction of rock, we chose the parameters of the mining conditions of the mine workings and the geometrical parameters of the blade cutting body. The values of these parameters are presented in table 1.

Table 1. Mining conditions of working with geokhod and the geometrical parameters of the blade cutting body.

| Name                                                   | Symbol | Unit of measurement | Value |
|--------------------------------------------------------|--------|---------------------|-------|
| Geokhod radius                                         | $R_g$  | m                   | 0.3   |
| Central nozzle radius                                  | $r_o$  | m                   | 0.025 |
| External propulsion step                               | $h_B$  | m                   | 0.3   |
| Coefficient taking into account the influence of the cutting angle | $\varphi$ |               | 0.59  |
| Specific cutting force in the frontal part of the slot at a cutting angle of 45° | $M_{cv}$ | H/m²               | 97000 |
| Strength of the destruction of the soil in the side parts of the slot | $M_{side}$ | H/m²               | 36000 |
| Specific cutting force of one of the side edges of the blade | $M_{side,mid}$ | H/m               | 8490  |
| Angle of inclination of the radial blade to the plane perpendicular to the axis of rotation of the geokhod | $\gamma$ | deg                | 0     |
| Cutting angle                                          | $\delta$ | deg                | 25    |
| Friction angle                                         | $\varphi_{fr}$ | deg | 31.4  |
| Depth ratio of the expansion part of the slot           | $K_{side}$ | deg               | 0.9   |
| Angle of inclination of the expansion part of the slot to the horizon | $\gamma_{lim}$ | deg | 30    |

According to expression (9), we determined the dependence of the energy intensity of the destruction of the face rock with the blade cutting body of geokhod on the number of blades on the geokhod cutting body.

The procedure for calculating the geokhod blade cutting body is shown in figure 2. The developed algorithm was applied when designing a computer program for determining the energy intensity of the destruction of the face rock with the geokhod blade cutting body.
Figure 2. Algorithm for calculating the energy intensity of the face rock destruction with the geokhod blade cutting body.

A fragment of the calculation of the energy intensity of the face rock destruction with the geokhod blade cutting body with a varying number of blades using a computer program is shown in figure 3.

![Algorithm Diagram](image)

On the basis of the obtained values, a graph of the dependence of the energy intensity of the rock destruction with the blade cutting body of the geokhod on the number of blades was plotted (figure 4).

![Graph](image)

**Figure 3.** Calculation of the energy intensity of the face rock destruction with the geokhod blade cutting body with a varying number of blades using the Microsoft Excel program.

On the basis of the obtained values, a graph of the dependence of the energy intensity of the rock destruction with the blade cutting body of the geokhod on the number of blades was plotted (figure 4).
The ordinate axis of the presented dependence shows the value of the energy intensity of the rock destruction with the blade cutting body of the geokhod (MJ/m³), and the abscissa axis shows the change of the number of blades on the geokhod cutting body (pcs.).

![Figure 4. Dependence of the energy intensity of the face rock destruction with the blade cutting body of the geokhod on the number of blades.](image)

4. Findings

From the graph presented in figure 4, it follows that:
- the value of the energy intensity of the rock destruction with the blade cutting body of the geokhod changes nonlinearly upwards with an increase in the number of blades on the cutting body of geokhod;
- with an increase in the number of blades n > 3 pcs., the energy intensity of the destruction of rock with blade cutting body continues to increase, but less intensively;
- the energy intensity of the destruction of the rock increases as a result of a relative decrease in the side expansions of the slot, within which the resistance of the rock is less than that in front of the frontal edge of the blade.

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