The Geokhod Bar Working Body With a Diameter of 1.8 m Characteristic Point Determination

Vladimir V Aksenov 1,a, Vladimir Yu Sadovets 2b, Elena V Rezanova 2, Dmitriy A Pashkov 3,c

1Research Center "Siberian NPO", 650000, Russia, Kemerovo, Sovetsky Avenue, 56.
2Kuzbass State Technical University named after T.F. Gorbachev, 650000, Russia, Kemerovo, Vesennyaya Str., 28.
3Siberian Branch of the Russian Academy of Sciences Federal Centre for Coal and Coal Chemistry Studies Coal Institute, 650610, Russia, Kemerovo, Leningradskiy Avenue, 10.

E-mail: a 55vva42@mail.ru b vsadovec@yandex.ru c pashkov.d.a@inbox.ru

Abstract. In the article the geokhod bar working body characteristic point with a graphical method is determined. The research relevance has been considered. The information about the geokhods’ working bodies operating peculiarities is given. For the research objectives and tasks setting the geokhod bar working body characteristic point condition is defined. The 1.8 m diameter geokhod with a bar working body use conditions have been determined. On the ground of the research results the graph of changes of the geokhod bar working body cutting force axial projection ($P_{OCC}$) was constructed depending on the distance $x$ by which the point is remote from the axis of rotation, as well as the geokhod bar working body cutting force radial projection ($R_{OCC}$) dependence on the range from $x$ to $R_g$. The geokhod bar working body characteristic point has been found in a graphical manner, i.e. it is the interception point of graphs of changes in the cutting force axial projection ($P_{OCC}$) in the range from 0 to $x$ at a distance from the point rotation axis over a distance $x$ and the cutting force radial projection ($R_{OCC}$) within the range from $x$ to $R_g$ at a distance from the point rotation axis over a distance $x$.

1. Introduction

One of the priority directions in the development of science, technology and equipment in the Russian Federation is the need for effective use of space, including underground space [1]. However, the underground workings are laborious and expensive process in which the most urgent problems are increasing the speed of penetration, labor productivity and safety, reducing the cost of work [2,3,4].

A promising direction that addresses these issues is the application of geokhod technology for making hollow in the underground space where the basic element is geokhod [5,6,7].

Geokhods belong to a new class of tunneling equipment. A distinctive feature of geokhod is screwing of the hull into the rock array, which fulfills the function of the mobile support. In this way, pressure forces are created as a result of the introduction of propulsion elements into the contour array and the use of a normal reaction that occurs when the elements of geokhod interact with the rocks array. Early developments in this area led to the creation of the first samples of geokhods - screw-boring penetrator units (VPA) ELANG-3 and ELANG-4 (Fig. 1) [8,9,10]. At present, a prototype of geokhod with working body for destructing rocks of medium strength has been created (Figure 2) [11,12].
Fig. 1. Experimental samples VPA ELANG-3 (a) and ELANG-4 (b)

Fig. 2. Experimental sample of geokhod with drum-like working body

At the current stage of development of the elements of geokhod technology, there are no variants with a variable number of cutting elements depending on the center of geokhod’s rotation.

Therefore, the works aimed at developing technical solutions for the location of cutting elements relative to the center of rotation of geokhod for destructing rocks with a strength up to 1 of Protodyakonov hardness are topical.

Nowadays new technologies in the field of robot automation are being introduced at rapid pace. However, the sphere of creating devices that can form cavities underground is less studied [1,2].

For this reason, the tasks appear connected with the development of new approaches, technologies, and machines that allow robotically perform all processes for cavity formation underground [3,4].

The use of geokhod technology is one of the areas that allows an underground robot to form cavities underground.

Currently, to develop the elements of geokhod technology, it is necessary to develop constructive and technical decisions for the working bodies capable of forming cavities in the underground spaces in rocks with hardness up to 1 according to M.M. Protodiakonov scale [5-7].
Thus the work aimed at the substantiation of geokhods’ working bodies parameters for rocks destruction with hardness of up to 1 is relevant.

2. The geokhod working body features
The geokhod original movement to the face involves the formation of complex surface geometry both of the face and of the working body. The surface of the mine at tunnel boring with the geokhod takes the form of several benched helicoid surfaces.

Point A (figure 3), located on the bar periphery, upon the given pitch distance of the external drive screw blade \( h_b \), passing the track \( 2\pi R_g \), in one complete turn around the circumference, moves to the face at an angle \( \beta_1 \) to the plane perpendicular to the axis of geokhod rotation [8], wherein

\[
\beta_1 = \arctg \frac{h_b}{2\pi R_g},
\]

where \( R_g \) is the geokhod head section radius.

Any point of the bar located at a distance of \( x \) (figure 1) from the geokhod axis of rotation moves to the face at an angle [8]:

\[
\beta_x = \arctg \frac{h_b}{2\pi x}.
\]

3. Methods of research
From the previously made research, one of the characteristic points of the geokhod bar working body is the point at which the projection of the component ground resistance to cutting, depending on the width of the cut, on the axis of the geokhod rotation \( P_{0, CV} \) in the range from 0 to \( x \), will be equal to the projection of the component ground resistance to cutting, depending on the width of the cut, on the plane perpendicular to the geokhod axis of rotation \( R_{IO, CV} \) within the range from \( x \) to \( R_g \), i.e.

\[
\int_0^x P_{0, CV} \, dx = \int_x^{R_g} R_{IO, CV} \, dx.
\]

The projection of the component ground resistance to cutting, depending on the width of the cut, on the geokhod axis of rotation \( P_{0, CV} \) in the range from 0 to \( x \) will be equal to [8-10]

\[
P_{0, CV} = \frac{qm_{cv} h^2 + h_n P_{in}}{2\pi \cos \gamma} \left[ \ln \left( \frac{1}{\sin \beta_x} \right) - \frac{h_n}{2\pi} \left( \frac{qm_{cv}}{n} \frac{\cot \phi_{TP}}{\cos \gamma} - \frac{\cot \phi_{TP}}{\cos \gamma} \right) \frac{1}{\sin \beta_x} \right]
\]

where \( \phi \) - coefficient that takes into account the influence of cutting angle;

\( m_{cv} \) - specific cutting force to overcome resistance of soil by the front at the cutting angle of \( 45^\circ \), Pa;
h - depth of cutting, m;

$P_{zn}$ - additional force of cutting which is to be exerted upon the bar section with a worn place or bluntness;

$\gamma$ - angle of a bar slope to the plane perpendicular to the geokhod rotation axis, degree;

$\delta$ - angle of cutting, degree;

$\varphi_{tp}$ - angle of friction, degree.

Projection of the component ground resistance to cutting depending on the width of the cut, on the plane perpendicular to the geokhod axis of rotation ($R_{IO,CV}$) within the range from $x$ to $R_g$, will be equal to [8-10].

$$R_{IO,CV} = \frac{\varphi m_{cv} h_x^2 + h_x n P_{zn}}{2\pi \cos \gamma} \cdot \sin \beta_x - \sin \beta_1 +$$

$$\frac{h_x}{2\pi} \left( \frac{\varphi m_{cv} h_x \cotg(\delta + \varphi_{tp})}{\cos \gamma} - \frac{\cotg(\delta_1 + \varphi_{tp})}{\cos \gamma} P_{zn} \right) \left( \frac{\tan \beta_1}{2} \right)$$

One of the ways to solve equations is a graphical way. It is based on the construction of function graphs and determination of their intersection points. Thus, to find the characteristic point under condition (3) it is necessary to construct graphs of changes in the axial projection of the cutting force ($P_{0,CV}$) in the range from 0 to $x$ at a distance from the point axis of rotation over distance $x$ according to formula (4) and the radial projection of the cutting force ($R_{IO,CV}$) in the range from $x$ to $R_g$ at a distance from the point axis of rotation over a distance $x$ according to formula (5).

4. Results

On the basis of the mining conditions for underground workings by the geokhod with a bar working body presented in the table, there the cutting force axial projection ($P_{0,CV}$) in the range from 0 to $x$, where the variable $x$ varies from 0 to $R_g$, as well as the cutting force radial projection ($R_{IO,CV}$) in the range from $x$ to $R_g$, where the variable $x$ varies from 0 to $R_g$ in increments of 0.01 m were calculated according to formulas (4) and (5).

On the basis of calculations the graphs (figure 4) of changes in the axial projection of the cutting force ($P_{0,CV}$) in the range from 0 to $x$ at a distance from the point rotation axis over a distance $x$ and radial projection of the cutting force ($R_{IO,CV}$) within the range of $x$ to $R_g$ at a distance from the point rotation axis over a distance $x$.

There are the geokhod bar working body cutting force projections values (H) on the Y-axis of the represented graphs of changes, and on the X-axis there is a distance $x$ by which the point from the axis of rotation is remote.

Table – Mining conditions for underground workings by the geokhod with a bar working body.

| Unit name                        | Designation | Unit of measurement | Unit value |
|----------------------------------|-------------|---------------------|------------|
| The geokhod radius               | $R_g$       | m                   | 0.9        |
| The screw blade pitch distance   | $h_g$       | m                   | 0.5        |
| Coefficient taking into account the angle of cutting influence [11] | $\varphi$ |                      | 0.74       |
| Specific cutting force in the front of the slot at a cutting angle of 45°[11] | $m_{cv}$ | n/m$^2$ | 3000000    |
| Angle of slope of radial blade to the plane perpendicular to the geokhod rotation axis | $\gamma$ | degree | 0          |
| Parameters characterizing the material resistance to elastic-plastic compression [11] | $P_0$ | n/m | 11300      |
| | $P_{usl}$ | n/m | 61900      |
| | $h_{usl}$ | m | 0.639      |
| Angle of cutting                 | $\delta$   | degree | 35         |
| Angle of friction[12]            | $\varphi_{app}$ | degree | 31.4       |
5. Conclusion

The graphs in figure 2 show that the characteristic point for the geokhod bar working body with a radius of 0.9 m will be located at a distance of 0.76 m from the geokhod axis of rotation.

With an increase in the cutting width by more than 0.57 m from the center of rotation the projection value of the cutting force on the geokhod axis of rotation begins decreasing. This is due to the change in the angle between the cutting force vector and the direction of the projection axis. Therefore it can be said that at a certain value of the cutting width from the geokhod axis of rotation $x$, the geokhod working body will be self-sumping.

At a value of $x>0.1$ m the radial projection cutting force value is reducing in proportion to the distance from the geokhod axis of rotation.

References

[1] Nishi S., Seiki T. Planning and design of underground space use. // Mem. Sch. Eng. Nagoya Univ. - 1997. №1.
[2] Maidl, B. Hardrock Tunnel Boring Machines / B. Maidl, L. Schmid, W. Ritz, M. Herrenknecht. Berlin: Ernst& Sohn, 2008. 343 p.
[3] Wighman T. Think deeps – go underground // ENR: News Rec. 1998. №4.
[4] Aksenov V., Sadovets V., Pashkov D. The influence of parameters on the generatrix of the helicoid form guide of geokhod bar working body// E3S Web of Conferences The Second International Innovative Mining Symposium. 2017.
[5] Aksenov V.V., Efremenkov A.B., Sadovets V.Yu., Rezanova E.V. The geokhod structural portrait forming //Bulletin of the Kuzbass State Technical University. 2010. No. 01. p. 35-41.
[6] Beglyakov V.Yu. The geokhod working body with the face wasteinteraction surface parameters substantiation. Thesis of candidate of technical Sciences. - Yurga, 2012.-139p.
[7] Koperchuk A.V., Beglyakov V.Yu. The geokhodstarting device circuit design choice //Mining machinery and electromechanics. -2016. -№ 8 (126).-P. 15-18.
[8] Determination of the geokhod bar working body power parameters for rocks of little hardness breaking/ V.V. Aksenov, V.Yu. Sadovets, D.A. Pashkov // Bulletin of the Kuzbass State Technical University. - 2017. –No.3. – P. 116-126.
[9] Machinery for underground work / under Volkov D.P. general editorship – Moscow: Mechanical engineering, 1992. 187 p.
[10] Vetrov Yu.A., Bladinskiy V.L. Machinery for special underground work. – Kiev: Publishing office of Kiev University, 1980. 308 p.
[11] Vetrov Yu.A. Calculation of cutting forces and soil digging. – Kiev: Publishing office of Kiev University, 1985. 251 p.
[12] Zelenin A.M., Balovnev V.I., Kerov I.P. Machinery for underground work // Textbook for universities – Moscow: «Mechanical engineering», 1975. 424 p.