Analysis of cross-sectional shapes of borehole

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Analysis of cross-sectional shapes of borehole

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Abstract. The studies are known to indicate the effect of the shape of a bore-hole cross-section on the results of the explosion including elliptical, square, triangular cross-sectional shapes as well as bore-holes with stress raisers applied to their side surfaces. The parameters of the indicated shapes can affect not only the process of crushing by explosion, but also the design of the drilling tool. Therefore, it is necessary to carry out generalization of the parameters of the cross-sectional shapes, and the article proposes criteria for estimating the shapes of the cross-section of a cavity completely filled with an elongated charge of an explosive. The criteria are considered from the point of view of the effectiveness of the explosive impact on the rock and can be used to create and justify the design of the drilling tool. The analysis is made of the geometric shapes of the cross sections of the explosion cavity using examples of biangular, triangular, and quadri-angular shapes. The specific value of the criteria can be determined for the existing designs of the drilling tool. The interrelations of the considered criteria are shown.

1. Introduction

The conventional form of the cross section of a well is the circular shape obtained by rotation of the tool since the transfer of mechanical energy to the face can occur both by creating an axial force and torque. The creation of a cavity in rock with a non-circular cross section is possible both without the rotation of the tool [1] and with its rotation.

One of the main tasks on the way to increasing the effectiveness of the explosion is to reduce the over-grinding of the rock near the explosion cavity [2, 3]; at this, the feature of its geometric parameters is important [4].

Along with the change in the location and shape of the charge within the boundaries of the circular cross-section, the usage of elongated charges with explosive that fill in the cavity with a non-circular cross section affects the results of explosive shattering of the rock. In particular, the results of theoretical and experimental studies on the effect of charges with a stress raiser applied to the wall of the bore-hole are known [5-8], showing the effect of the cross-sectional shape on the result of the explosion. Thus, it is possible to distinguish significant parameters of the cross-section of an elongated cavity (well or borehole), such as a shape and its elements that create stress raisers.

2. Materials and methods

The peculiarity of the action of the charge when the shape of a cavity does not have pronounced angles of conjugation of its walls, such as, for example, an elliptical shape, is based on the difference in the lengths of its small and larger axes; while the peculiarity of the action of the charge when the shape of a cavity has pronounced angles of conjugation of its walls, is determined, in addition, by the presence of stress raiser. The increase in the difference in the lengths of the axes of the cavity in the cross section leads to an increase in the degree of difference from the circular cross section and promotes an increase in the concentration of tensile stresses along longer axes. And a decrease in the angle of conjugation of its walls contributes to a local increase in the concentration of tensile stresses near it.

The change in the shape of the cross-section of the explosion cavity filled with explosive material leads to a change in the amount or volume of the explosive material per unit area of the side surface of the explosion cavity. Such effect of changing the shape of the cross-section can be estimated relative to the circular cross section, provided that the volume of the explosion cavity is equal, which is equivalent to the condition of equality of their cross-sectional areas. With the same cross-sectional area and an equal amount of explosive, it is possible to obtain a different area of the side surface affected by this amount of explosive.

Thus, as indicators which characterize the influence of the shape of the cavity cross-section on the shattering process due to explosion, it is suggested to take into account the difference in the lengths of its axes in the cross section, the presence and severity of the stress raisers in the form of the angle of conjugation of its walls and an increase in the area of the side surface of the cavity upon transition to the non-circular form of its cross-section.

It is suggested to use the following criteria assessed in quantity.

1. The relative range of the radii of the cavity:

$$R_o = \frac{R_{max} - R_{min}}{R_{max}}, \qquad (1)$$

where R_{max} – the maximum radius of the circumscribed circumference of the cavity cross-section (Fig. 1);

R_{min} – the minimum radius of the inscribed circumference of the cavity cross-section (Fig.1).

2. The angle of conjugation of the cavity walls: ε (Fig. 1).

3. Increase in the area of the cavity side surface, %:

$$S = \left(\frac{L}{L_o} - 1 \right) \cdot 100, \qquad (2)$$

where L – perimeter of the contour of the non-circular cross-section of the cavity;

Lo – perimeter of the contour of the circular cross-section with the area equal to the area of the non-circular cross-section of the cavity.

These criteria can be used for any shape of cross-section.

3. Results & Discussion

In using stress raisers created with the help of narrow and shallow slots made on the side surface of a circular cavity cross-section, the values of the criteria R_o, S are insignificant. If the conjugations of the walls of the cavity form angles, for example, in the case of a triangular, square cross-sectional shape, the process of explosion crushing is affected by all the above-mentioned criteria, and when drilling, the process of creating such shape coincides with the formation of a stress raiser.

In roller drilling, it is possible to ensure the length of the contact line of rock cutting elements with the borehole bottom variable by the angle of rotation. To do this, the cone bits must have a variable length of the generating lines of their circular conical surface (Fig. 2), and therefore their rolling along the face will result in the reproduction of the radius of the bore-hole with a length that is dependent on the angle of rotation, forming a cross-sectional shape in the form of a regular figure (Fig. 3).

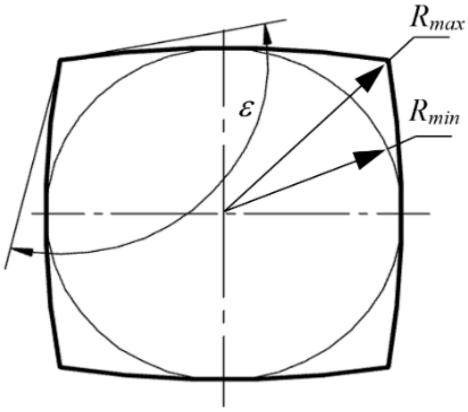

Figure 1. The parameters of the cross-sectional shape of the elongated cavity.

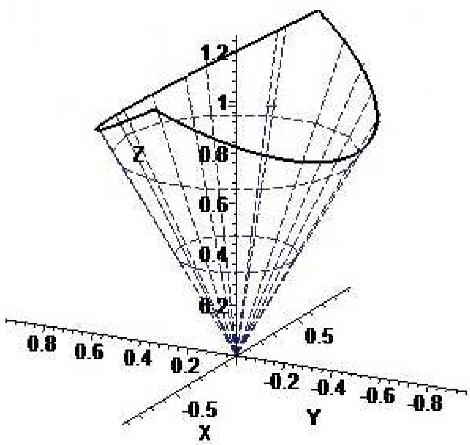

Figure 2. The shape of the surface of the cone bit for the square cross-section of the borehole.

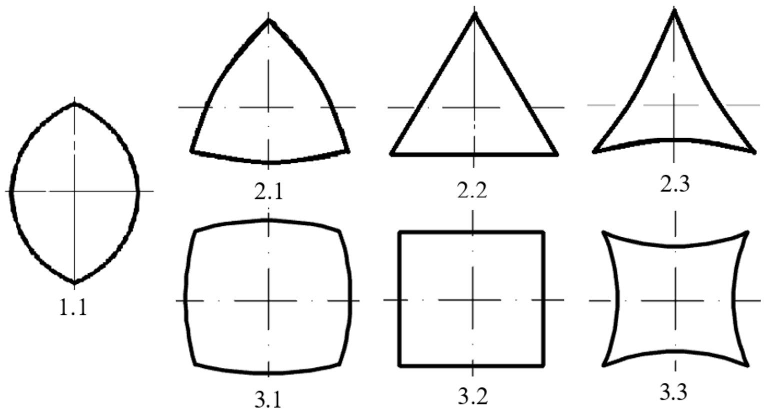

Figure 3. Versions of cross-section shapes of a borehole: 1.1 – with two directions R_{max} and convex sides; 2.1 – with three directions R_{max} and convex sides; 2.2 – with three directions R_{max} and straight sides; 2.3 – with three directions R_{max} and concave sides; 3.1 – with four directions R_{max} and convex sides; 3.2 – with four directions R_{max} and straight sides; 3.3 – with four directions R_{max} and concave sides.

In Tables 1-3, the values of the criteria for shapes in the form of regular figures are considered. The variant of the shape in the form of a circle in Tables 1-3 is presented as the limiting case of the shape when the angle of conjugation of the walls is flat.

Table 1. Criteria for cross-sectional shape with two directions R_{max}

Version of the cross-section shape as per Fig. 3	Maximum radius R_{max}	Criteria		
		Relative range of radii R_o	Angle of walls conjugation ε, degree	Increase in the area of the cavity side surface S, %
circumference	R_{min}	0	180	0
Convex sides (Figures 1, 1.1)	R_{min} to ∞	0 to 1	0 to 180	0 to ∞

Table 2. Criteria for cross-sectional shape with three directions R_{max}

Version of the cross-section shape	Maximum radius R_{max}	Criteria		
		Relative range of radii R_o	Angle of walls conjugation ε, degree	Increase in the area of the cavity side surface S, %
circumference	R_{min}	*0*	*180*	0
Convex sides (Figures 3, 2.1)	R_{min} to $2R_{min}$	0 to 0.5	60 to 180	0 to 28.6
Straight sides (Figures 3, 2.2)	$2R_{min}$	0.5	60	28.6
Concave sides (Figures 3, 2.3)	$2R_{min}$ to ∞	0.5 to 1	0 to 60	28.6 to ∞

Table 3. Criteria for cross-sectional shape with four directions R_{max}

Version of the cross-section shape	Maximum radius R_{max}	Criteria		
		Relative range of radii R_o	Angle of walls conjugation ε, degree	Increase in the area of the cavity side surface S, %
circumference	R_{min}	*0*	*180*	0
Convex sides (Figures 3, 3.1)	R_{min} to 1.41 R_{min}	0 to 0.293	90 to 180	0 to 12.8
Straight sides (Figures 3, 3.2)	1.41 R_{min}	0.293	90	12.8
Concave sides (Figures 3, 3.3)	1.41 R_{min} to ∞	0.293 to 1	0 to 90	12.8 to ∞

4. Conclusion

There is a correlation between the criteria in the cases considered with the correct forms of the cross-section. An increase in the relative range of R_o leads to a decrease in the angle ε of conjugation of the walls of the borehole and to an increase in the area of the side surface of the cavity. The transition, for example, from the square cross-sectional shape to the triangular one with convex sides can provide the same values of the angle ε of conjugation of the walls of the bore-hole or the relative range R_o. The value of the angle ε can be reduced without a significant decrease in the relative range R_o and the area of the side surface of the cavity. In addition, the values of these criteria depend on the number of directions R_{max} of the cross-section of the explosion cavity (see Tables 1-3). The precise determination of the criteria relationships is not considered in this paper, because this relationship depends on many variants of the shapes of the lines making the boundaries of the cavity cross-section provided by the specific design of the drilling tool.

The shape of the non-circular cross-section of the explosion cavity affects the design of the drilling tool that can create the corresponding cavity in the rock, competing with a tool for drilling a conventional circular cross-section of wells or blast-holes. The criteria for the shape of the cross-section allow one to quantify the obtained shape from the point of effectiveness of the explosion action.

The proposed criteria can also be used for a multifactor analysis of the designs of the drilling tool taking into account the shape of the cross section of the explosion cavity created by it for shattering the rock, as well as for consideration of the effect on the mode and power parameters of the drilling process, which are interrelated with oscillating processes taking place both in the rock [9] and in the structure of the drilling tool and machine that in its turn affects the strength of the elements of their structure [10-12].

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