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Assessment of dynamic contact of the bent part of the drill string with the wall of the directed well

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Abstrac **– Taking into account the specifics of the stress-strain state of the bent part of the drill string pressed against the well wall, as well as the geometry of their mutual spatial arrangement, the analytical method of determining the area of their contact forses zone is substantiated.**

Keywords – drill string, well, stress-strain state, contact area, torus, cylinder.

I. Introduction

During the design of the axial load on the bit at the intervals of inclined and horizontal sections of wells, it is necessary to take into account the forces of resistance to the movement of the drill string, since the axial load, which is created by the layout of the drill string, is not completely transmitted to the rock-breaking tool. This feature is one of the reasons for the decrease in the rate of deepening of wells. Of significant interest are the issues of research into the process of further (subcritical) deformation of the drill string, when the latter continues to change its shape under the action of axial load, distributed contact forces and torque as a result of being pressed into the well walls with geometric imperfections. In addition, it is important to know the value of the contact pressure and the area of the visco-elastic interaction zones of the bent sections of the drill string with the walls of the well, at which the established drilling process takes place.

II. Presentation of the Material

In the process of drilling, the configuration of the wellbore does not have a constant rectilinear cylindrical shape. One of the reasons for the formation of formations on the walls of the well is the mechanical action on it of the drill string, which has lost its stability [1, 2].

The force of pressing the drill pipes against the walls of the well is determined by the own weight of the drill string elements, their structural parameters, bending elasticity, pressure drop and the full value of hydrostatic pressure. Its increase helps to improve the adhesion of the drill string to the filter crust [3, 4].

Therefore, information about the actual values of the forces acting in the places of interaction of individual sections of the drill string with the walls of the well, the shape and area of the contact zones will allow to more accurately design the dimensions of the pit layouts, prevent the formation of gutters and determine the most vulnerable sections of the drill string. Many scientific works are devoted to the solution of these questions.

Some of the authors do not take into account the contact area, taking into account only linear contact along the entire length of the pipe string, others take a conditional value equal to a certain fraction of half the diameter when the drill string is pressed against the well wall [3, 4, 5]. Despite this, the contact of various elements of the pipe (lock, pipe body) with the walls of the well covered with a filter crust in the case of possible rubbing of the gutters on the wall of the mine is not taken into account.

Therefore, when considering the problems of the contact interaction of the drill string sections with the walls of the well, an important issue is the determination of the areas of the contacting surfaces. The dimensions of the areas of the contacting surfaces will significantly affect the parameters of the stress-strain state of the drill string and well walls and may cause changes in the dimensions of the design profile [3, 4].

Due to the lack of accurate analytical formulas for determining the area of contact interaction zones between drill string elements and well walls, drilling in practice is currently limited to empirical dependencies [5, 6].

Consider the process of pressing a bent half-wave drill string into the well wall. We will assume that the base of the well wall is a substance with elastic-anisotropic properties, and its surface is covered with a solid filter crust. Upon local contact with the viscous surface of the well wall, the drill string continues to press into it with the subsequent formation of a trough-like surface until the maximum reaction of the wall becomes equal to the maximum force of elastic compression.

When the bent part of the column is finally pressed against the wall, its reaction reaches its maximum value, and the compression speed becomes zero. The results of the analysis of the stress-strain state of the deformed section of the drill string [1, 2] and the process of its compression into the well wall provide the opportunity to generate the necessary data for setting and solving the geometric problem of determining the area of the zone of their mutual contact.

With sufficient accuracy, the outer surface of the section of the drill string bent in a plane parallel to the borehole axis can be identified with the surface of the torus section, and the inner surface of the well wall with the surface of a circular cylinder [7] (Fig. 1). The equation of the torus with the radius of the generating circle *r* and the distance from the center of this circle to the axis (center) of the torus *R* is given in the following form:

$$\left(x^2 + y^2 + z^2 + R^2 - r^2\right)^2 - 4R^2\left(x^2 + y^2\right) = 0\,, \quad (1)$$

and of a circular cylinder with the radius of the generating circle ρ is given as follows:

$$x^2 + y^2 - \rho^2 = 0\,. \quad (2)$$

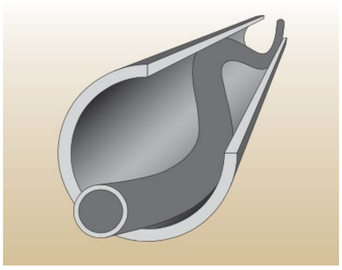

Figure. 1 Contact of the bent part of the drillstring with the cylindrical wall of the well

To determine the pressure of the moving point of the surface of the drill string on the stationary surface of the well wall in the projections on the axis of the rectangular Cartesian coordinate system, the following system of equations of motion must be compiled:

$$\begin{cases} m\ddot{x} = F_x + N_x \dfrac{1}{\Delta f}\dfrac{\partial f}{\partial x} - k\left|N\right|\dfrac{\dot{x}}{\left|\overline{\mathrm{v}}\right|} \\ m\ddot{y} = F_y + N_y \dfrac{1}{\Delta f}\dfrac{\partial f}{\partial y} - k\left|N\right|\dfrac{\dot{y}}{\left|\overline{\mathrm{v}}\right|} \\ m\ddot{z} = F_z + N_z \dfrac{1}{\Delta f}\dfrac{\partial f}{\partial z} - k\left|N\right|\dfrac{\dot{z}}{\left|\overline{\mathrm{v}}\right|} \end{cases} \quad (3)$$

where m – the mass of the bent section of the drill string brought to the point of contact with the well wall; $\ddot{x}, \ddot{y}, \ddot{z}$ – projections of the acceleration of the combined mass movement; F_x, F_y, F_z – projections of external active forces; $f\left(x, y, z\right) = 0$ – the equation of the superimposed bond (walls of the well); N_x, N_y, N_z – projections of the elm reaction on the ortho normal to the surface; $\overline{\mathrm{v}}$ – the average value of the speed of movement of the combined mass; $\dot{x}, \dot{y}, \dot{z}$ – projections of the speed of movement of the combined mass; k – dynamic coefficient of friction;

$$\Delta f = \sqrt{\left(\frac{\partial f}{\partial x}\right)^2 + \left(\frac{\partial f}{\partial y}\right)^2 + \left(\frac{\partial f}{\partial z}\right)^2}\,. \quad (4)$$

A cylinder should be chosen as the elm surface superimposed on the drill string in the directed rectilinear section of the well, and then the partial derivative equations (2) in equations (4) should be determined. After substituting equations (4) into the system of equations (3), it is possible to determine the projection of the reaction of the well wall.

III. Conclusions

Taking into account the geometric dimensions of the cross-sections and forms of deformation of the drill string and well, with the help of equations (1-4) it is possible to analytically determine the contact forces of the bent section of the drill string with the wall of the well.

The implementation of this method will make it possible to more accurately estimate the forces of resistance to the movement of the drill string and its contact pressure on the walls of the directed and horizontal sections of the wells when designing the axial load on the bit. Also, this method will be useful in the study of the process of closed deformation of the drill string during the established drilling process.

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