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MODELING OF WHIRL SIMULATION BITS OF THE DRILL STRING

МОДЕЛЮВАННЯ КОЛИВАНЬ КРУЖЛЯННЯ ДОЛІТ БУРИЛЬНОЇ КОЛОНИ

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At present, hydrocarbon fuel extraction is associated with significant technological difficulties in drilling deep wells. Critical bending bulges of the drill string and its vibrations, which simultaneously include several different oscillatory phenomena, significantly complicate the identification of each of them and do not allow us to evaluate and explain the mechanisms of their influence on the dynamics of the system. In cases where the bit is subject to normal and tangential forces of contact and frictional interaction of the bit with the borehole wall, the geometric center of the bit begins to move around the axial line of the well, ahead of or behind the rotational movement of the string itself. Such movements of the bit are called whirling simulations.

A detailed study of the simulations of the whirlpool based on the mathematical model "mass-spring", in which the bit is replaced by a hard disk, and the elastic column by a spring, began with the work [5]. Analysis of the simulations of the whirlpool using a disk model, in which the dynamic effect is mitigated, was proposed in the works [1, 2]. The disk model of oscillations received the next complication due to the consideration of the elastic compliance of the pipe of the drill string in its lower part [3, 7, 10]. Among the publications in this area, a special place is occupied by the article [6], in which it was first noted that the form of the simulations of the whirlpool largely depends on the geometry of the bit.

As noted in the publication [9], whirling simulations are the most typical dynamic process, accompanying, as practical observations and statistics show, about half of all drilled wells. At the same time, the frequency of whirling simulations can exceed the angular velocity of rotation of the drill string itself from 5 to 30 times, and the forms of movement of the bit form complex irregular figures, leading to fatigue and destructive effects on the structures of the lower part of the drill string. Considering that in the scientific literature these oscillations are studied using very simplified mathematical models, it can be noted that the problem of developing a more accurate mathematical model, compiled taking into account the action of axial force, the real geometric shape of the bit and taking into account its contact interaction with the bottom of the well, is relevant.

The simulations of the whirling drill bit includes bending oscillations of the drill string caused by the action of time-varying normal and tangential forces of contact and frictional interaction between the bit and the borehole wall. In this case, the center of the drill bit begins to move around the borehole axis, leading or lagging behind the rotation of the drill string itself. To study the simulations of the whirling of the initially disturbed system, the methods of nonholonomic mechanics are used [4, 8]. The main differential equations in partial derivatives are derived taking into account the bending compliance of the lower part of the drill string and nonholonomic rolling with rotation of the bit along the bottom of the borehole. To study the buckling of the drill string, a rotational coordinate system is used. Therefore, the Coriolis inertial forces are taken into account. With their use, the oscillations of the whirling of spheroidal, as well as oblong and oblate ellipsoidal bits are analyzed. As established by calculations, under conditions of reduced bending rigidity of the drill string, the oscillation of the bit rotation can be both stable and unstable. Using the simplest kinematic schemes of the ellipsoid body rolling, it was found that flattened bits are more sensitive to initial disturbances and their trajectories can have tortuous lines that resemble a multi-petal flower associated with large values of acceleration and inertial forces.

It is shown that depending on the initial conditions and the shape of the bit, its rolling on the bottom surface can take the most unexpected modes and be accompanied by the movement of the contact point along smooth, tortuous trajectories, curves with looped lines. Some of these trajectories are shown in Fig. 1. Sometimes the bit can stop simulations and change the direction of its circular motion. Such movement is a reverse rotation, since the rotation of the bit and the drill string is carried out in opposite directions. In practice, it is considered the most unfavorable, since it is associated with the greatest dynamic loads on the bit and the drill string.

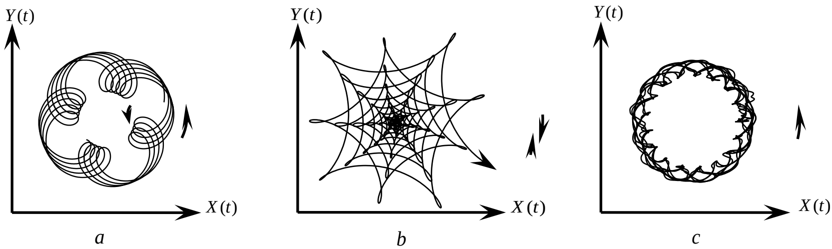

Fig. 1. Modes of the ellipsoid bit center rolling on the bore-hole bottom surface

The developed methods can be used to predict and qualitatively assess the simulations modes of the bit rotation at the stages of well design and drilling.

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