The computer simulation of drill column dragging in inclined bore-holes with geometrical imperfections

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ABSTRACT

The problem about identification of resistance forces acting on a drill column moving in an inclined bore-hole is stated. It is supposed that the well trajectories can have geometrical imperfections in the shape of cylindrical spiral or plane cosinusoidal curves. The system of ordinary differential equations is derived on the basis of the theory of curvilinear flexible elastic rods. It permits one to describe static effects of the drill column bending accompanying the processes of its raising, lowering and rotating inside the bore-hole. Through the use of this system the direct and inverse problems of the drill column deforming are formulated for calculation of internal and external resistance forces acting on the drill column tube. The methods for numerical solution of the constructed equations are elaborated. With their use the phenomena of the drill columns motion and their frictional seizure inside the bore-holes are simulated for different geometrical imperfections and relations between the velocities and directions of their rotation and axial motion.

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1. Introduction

In the last century the time of easy oil and natural gas terminated (Chow et al., 2003; Kerr, 2005). Inasmuch as the reserves of hydrocarbon fuels in easy-to-extract basins approach to depletion the deposits located at the depths of 10 km become to be promising. Now the old bore-hole drilling using vertical wells is being redeveloped by horizontal and inclined wells (McDermott et al., 2005). But the experience gained while drilling vertical wells is not useful for drilling horizontal ones, because mechanical behavior of a drill column (DC) with curvilinear axial line acquires a series of specificities leading to critical situations. So the failure rate at the curvilinear bore-hole driving achieves 1 in 3 holes (Mohiuddin et al., 2007). Taking into consideration that lengths of the modern curvilinear bore-holes are planned to approach 15 km and their costs exceed $60 million, it can be concluded that the problem of computer simulation of the drill column behavior is very urgent. At the same time the efforts to solve it present considerable difficulties determined by a number of factors (Iyoho et al., 2005). Among them the large length of the DC is the main one. As the present day drill columns can be compared by conditions of geometrical similarity with a human hair, usually the computer simulations of internal and external forces acting on them are performed with the use of simplified mathematical models based on the theory of absolutely flexible threads (Bernt and Anderson,

2001; Sheppard et al., 1987). Analysis of these forces is performed only on the basis of investigations of geometrical peculiarities of the bore-hole axis line without considering the contribution of elastic forces generated during raising-lowering operations and the DC rotation. As this takes place, the designs of bore-holes with simple outlines of catenary, brachistochrone, clothoid and the Cornu spiral are performed (Bernt and Anderson, 2001; Sheppard et al., 1987; Choe et al., 2005; Sawaryn and Thorogood, 2005). In papers (Stuart et al., 2003; Prassl et al., 2005; Brett et al., 1989) more general approach is used which is based on the consideration that the well axis outline represents a smooth shape combined from segments of straight lines and circular or catenary curves. It is referred to as a minimum curvature method. With its use explicit analytical equations are derived to model drill column (thread) tension and friction forces for hoisting or lowering operations. In addition, explicit expressions for drag and torque are developed for combined axial motion and rotation of the drill column. Using these equalities, the total drag and torque are derived from the sum of their separate contributions from each section of the hole. Different algorithms and software programs are presented. Several examples demonstrate the use of the analytical models. It is shown that any change of direction in the well path contributes to increased friction.

The formulated conclusion underlines weakness of the used approach which is based on assumption of well trajectory smoothness and possibility to neglect bending stiffness of the drill column tube. In actual practice, the axial trajectories of bore-holes do not represent lines with smooth geometry because geometrical

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