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Nonlinear Dynamics of a Drillstring Immersed in a 3D Curved Well, Simulations and Experiments

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Abstract

During drilling operations, the bit-rock and drillstring-wellbore contacts with stick-slip phenomena, fluid-structure interaction, and mass unbalances distributed along the drillstring yield nonlinear dynamics coupling axial, torsional, and lateral vibrations. Excessive and uncontrolled vibrations may induce drilling equipment damage due to fatigue, cracking, and ruptures. Understanding and predicting the drilling dynamics become necessary to avoid those harmful vibrations.

The drillstring dynamics is modelled in the time domain using the beam finite element method. The contact between the drillsting and borehole is accounted for using radial elastic stops and the fluid effect on the drillstring dynamics is considered by two models. The initial position is obtained from a static equilibrium computation that takes into account the drillstring pre-load. The dynamics is then calculated by applying a time-integration scheme.

The dynamic model is applied to a real case of a quasi-vertical well with field measurements of downhole vibrations along with surface data. Numerical simulations are carried on a drilling assembly of several kilometers' length. The obtained results are compared to the experimental data to analyze the structure vibrations such as forward and backward whirling and stick-slip. Knowing the various uncertainties of some physical quantities like the friction factor and fluid damping, a series of simulations varying the model hypotheses are conducted and the results are compared to clarify the importance of each phenomenon.

The novelty of the proposed dynamics model is its ability to consider a realistic geometry of drilling assembly in 3D curved wells with fluid flows, and to give a complete study of the coupling phenomena between axial, torsional, and lateral vibrations.