IADC/SPE 98965

Advancements in 3D Drillstring mechanics: From the Bit to the Topdrive

S. Menand, SPE, H. Sellami, SPE, M. Tijani and O. Stab, Ecole des Mines de Paris/Armines, D. Dupuis, SPE, Pride-International, C. Simon, DrillScan

Abstract

The well trajectories becoming more and more complex (Extended Reach Drilling, Horizontal or Multilateral Drilling, Ultra-Deep Drilling, 3D wells….), the associated drillstring composition being unconventional and the material being used to its operating limit, the necessity to have a tool that predicts realistically forces, bending moment and contact loads along the wellbore is essential. To simulate the mechanical behavior of the drillstring, the industry generally uses a stiff-string model for the bottom bole assembly (BHA) to predict drilling trajectories, and a soft-string model for the entire drillstring to calculate torque and drag.

The conventional soft-string model gives a good approximation of forces and contact loads in the drillstring for very smooth well trajectories, but is inappropriate when the trajectory becomes tortuous (micro or macro-tortuosity) or complex, as the drillstring no longer contacts the low side of the borehole.

An advanced numerical method has been applied to address the 3D mechanical problem of a complete drillstring moving and freely rotating inside a wellbore : computation of the unknown contacts between the drillstring and the wellbore. As this new model does not use the time consuming finite element analysis, it can be used in real-time drilling operation at the rig to monitor torque and drag. For the first time, it is even possible to perform simultaneously a torque and drag, buckling and directional analysis while drilling.

The power of a 3D visualization of the drillstring deformed inside the wellbore enables to localize easily contact loads on any drillstring component, from the drilling bit (including side force at the bit and tilt) to the top drive or rotary table (hook load and rotary torque at surface), facilitating drilling problems analysis.

This paper will describe the fundamentals of the model developed and shows the differences between the conventional soft-string model and the advanced stiff-string model in terms of tension, torque and contact points between the drillstring and the wellbore, for many actual wells. With the help of the 3D visualization software, this paper will show the cases where the drill pipe contacts the high side of the borehole, or goes up to the right or the left side of the borehole depending on the right or left turn rate of the well trajectory. This new model should improve significantly the torque-drag and buckling calculations and the understanding of the drillstring contributions to overall drilling performance.

Introduction

Drillstring mechanics is essential for many drilling matters : well planning, drillstring design, completion, directional analysis, torque and drag, buckling and drilling bit performance (stability, drillability and steerability). Without an accurate assesment of the forces and stresses all along the drillstring, from the bit to the top-drive, the operator may risk serious well damage. Many mathematical models have been developped in the past to estimate the mechanical behavior of tubulars inside wellbore for many purposes. These models are either static or dynamic, 2D or 3D dimensional, and are sometimes analytical or use numerical methods. Today, the models generally use finite element analysis for BHA modeling to predict the directional behaviour of the drilling assembly, and use analytical models or finite element analysis for the whole drillstring to compute torque and drag. This paper focuses on a model based on a new numerical method to address the 3D static mechanical behavior of a complete drillstring moving and freely rotating inside a wellbore : from the bit to the top-drive.

State of the art

Many approaches have been taken to model the mechanical behavior of downhole tubulars. The simulation of BHAs for directional analysis uses generally finite element analysis to determine the orientation and magnitude of the side force at the bit and the bit tilt angle[1,2,3] . As a result, all types of BHA (steerable mud motor, rotary BHA with variable gage stabilizer, etc …) and wellbore profiles can be modeled, and generally, only 60-100 m of BHA elements are taken into