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State-of-the-Art BHA Program Produces Unprecedented Results

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Abstract

This paper presents the development of a new bottomhole assembly (BHA) program and how it is used to deliver optimal BHA design. The new program allows users to run static and dynamic models in the same application which will save time and minimize errors. For the static model, the program uses the newly developed generic algorithm for solving the Lubinski's BHA equations directly. The strengths of the new algorithm are accuracy and computation efficiency, as compared to the conventional finite-element based BHA programs. In addition, the program is designed to run fast on a personal computer (PC) with an intuitive user interface so that it can be used to optimize BHA design in the office as well as at the rig site.

The program is developed with a goal to provide all the tools needed to design an optimal BHA. It includes static and dynamic models as well as advanced features such as multiple-hole model and models for special drilling tools. The static model is primarily designed for directional drilling applications, such as optimal BHA design for maximum steerability, bending moment calculations to minimize fatigue failure, and BHA sag corrections to improve survey quality. The dynamic model is based on a hybrid of analytical and finite-element methods to calculate the critical rotary speeds of the BHA. Multiple-hole size model is available in the program for drilling and reaming application. A special model has also been developed to model a new low-cost rotary steerable system.

Several case studies are used to describe the significance of using a state-of-the-art BHA program to obtain the unprecedented drilling performance.

Introduction

Bottomhole assembly (BHA) modeling is always an essential component of directional drilling. A state-of-the-art BHA program enables many critical features, such as designing a BHA to optimize directional performance, optimizing stabilizer locations to minimize vibration and increase downhole tool reliability, and improving survey data by

correcting the BHA sag. Since the 1950s, several methods have been developed and applied in the drilling industry to build the BHA models.¹⁻⁷

In general, the challenges encountered in the development of a computationally efficient, flexible, and accurate BHA model can be summarized as follows:

- Nonlinear differential equations
- Unknown upper boundary conditions at the tangential point (location and orientation)
- Unknown boundary conditions at stabilizers
- Collars and wellbore wall contacts
- Large deformation caused by bent housing motor or the bend in rotary steerable tools

The most commonly used method in BHA modeling is probably the finite-element method because it is easy to develop and use. However, to the knowledge of the authors, many commercial finite-elements based BHA programs are still based on the small deformation theory. As a result, they have been shown to lack the accuracy required to model steerable assemblies, such as motor or rotary steerable systems. Finite-element modeling is also cumbersome in handling the collars and wellbore contact. To accurately model steerable systems, the semi-analytical methods are usually required, but semi-analytical methods are inflexible and difficult to program. They are often designed to analyze some specific BHA models and are limited to BHAs with rather simple configurations.

Objectives

In addition to the challenges in finding an accurate and flexible static BHA model, most of the programs are cumbersome to run because of the complicated user interface or the lengthy calculation time. Thus, the objectives of developing a state-of-the-art BHA program include the following: