SPE-217755-MS

To What Extent Can the Notion of an Effective Length Be Reliable to Assess the BHA Lateral Behavior?

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Abstract

Many models in the industry use the notion of an effective length to make predictions about the bottom hole assembly (BHA), whether for its directional behavior or its lateral vibration tendency. A given criteria is chosen to cut the drill string at a certain distance from the bit and use only that part for the computations. In this paper, this cutting distance is referred to as the effective length. Though computationally efficient, and thus providing fast real-time predictions, there is no consensus on what criteria should be chosen, nor a "bulletproof recipe" on how to compute that length. Miscalculating this effective length, especially for vibration mitigation purposes, can lead to suboptimal rotation speed selection, potentially causing failure.

To address this challenge, different choices of effective length computations are compared in terms of BHA yield rate prediction (build/drop and turn rate). Past a given distance from the bit, the computed side force and tilt at the bit are nearly identical, meaning that any element very far from the bit is negligible in the static calculation. However, studying lateral vibrations is more complex especially at low inclinations or in horizontal wells with high weight on bit (WOB) where the drill string can move more freely with snaking and whirling motions. A nonlinear time-domain model is utilized to evaluate the propagation of lateral vibrations up the string. A sensitivity analysis was then conducted on several BHA types and lengths, considering different boundary conditions in vertical and horizontal wells.

Directional models are found to be reasonably unsensitive to the choice of the effective length because they are based on steady-state computations, but the same cannot be stated for dynamics. This study developed a more robust approach to estimate properly the effective length for lateral vibrations, an essential for BHA resonance. The theoretical predictions of critical speeds were compared to time-domain simulations, which take into account the nonlinearities related to contact and friction forces. Spectral analysis of the results helped identify the main sources of vibration, whether it comes from BHA mass imbalance, drill string-wellbore interactions, or other sources. This combination between frequency- and time-based analyses is used to validate our choice of the effective length.

Many models, from steady state to dynamics with both frequency and time domain analysis, are used to approach the effective length problem from various perspectives. This study aims to compensate the lack of in-depth analysis on this important subject. It shows the importance to understand the strengths and limits of frequency-based models compared to the more complex time-domain modeling.

 DOI 10.2118/217755-MS