SPE-208698-MS

Application of a Forced Vibration Modeling Approach to Better Quantify the Role of Downhole Vibrations and Excitation Tools

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Abstract

Drilling operations can induce several external excitations to the drillstring and bottom-hole assembly (BHA) due, namely, to the drillstring-wellbore contacts, bit-rock interactions, fluid flow, and mass imbalances. On the one hand, such undesirable excitations may lead to excessive vibrations and damage to the drill bit, BHA, or drill-pipes. On the other hand, some vibration tools are used to intentionally introduce a source of lateral vibrations in the drillstring to reduce the friction effects and enhance the rate of penetration. Whether these vibrations are undesirable or intentional, efficient models are necessary to predict them accurately to help optimize the drilling parameters and vibration tools placement in the drillstring.

The time-domain analysis can give a detailed portrayal of drillstring vibrations, but usually requires a lengthy computational time, especially for the simulation of long structures. This paper focuses on an alternative analysis using a forced vibration model based on a linearized frequency analysis. It consists of studying the magnitude of the displacement, velocity, acceleration, and internal efforts, when the drillstring is subject to an external harmonic excitation at a given frequency. This numerical model is based on the beam finite element method, where the wellbore-drillstring contact effects are considered using a Jacobian matrix approach.

The forced vibration model is applied to study the lateral vibrations produced either by mud motors or lateral vibration tools. The comparison between the results of frequency and time-domain analyses shows that the forced vibration model can describe the global behavior of drillstring vibrations with a fast computation. When varying the excitation frequency, critical values giving large vibrations could be identified and avoided by the driller thanks to a heat map representation of the vibration magnitude as a function of the position and excitation frequency.

The novelty of this work is in showing the capacities and limitations of the forced vibration analysis compared to time-domain analysis. The fast computation of the frequency analysis can provide efficient and accurate predictions and, therefore, could be employed to optimize the BHA design and drilling parameters, and therefore reduce the harmful vibrations and improve the performance of any drilling systems equipped with downhole excitation tools.

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