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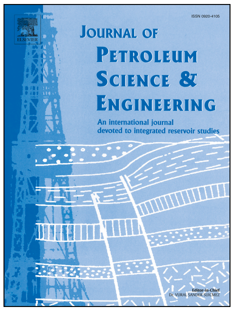


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# Dynamic Model for 3D Motions of a Horizontal Oilwell BHA with Wellbore Stick-slip Whirl Interaction

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## Abstract

Failure of horizontal oilwell drilling equipment, in particular the bottom-hole-assembly, is very costly. Vibration causes tool joint failure, twist-off, and bit-damage, and has motivated extensive research on understanding and predicting the dynamic shock-loading response of the bottom-hole-assembly. This paper presents a model to analyze the dynamics of a horizontal oilwell bottom-hole-assembly. A nonlinear three-dimensional multibody shaft model has been verified and extended to include stick-slip whirl phenomena due to the contact between the rotating bottom-hole-assembly and wellbore. The model has been verified with a dynamic finite element analysis through comparisons of the response of an enclosed shaft under axially compressive load rotating inside the wellbore. Finally, a complete deviated drillstring has been simulated by combining the bottom-hole assembly model with a model of the drill pipe and collars. The pipe and collars are modeled using a lumped-segment approach that predicts axial and torsional motions. The model can predict how axial and torsional bit-rock reactions are propagated to the surface, and the role that lateral vibrations near the bit play in exciting those vibrations and stressing components in the bottom-hole-assembly. The proposed model includes the mutual dependence of these vibrations, which arises due to bit-rock interaction and friction dynamics between the drillstring and wellbore wall. A force excitation source, which simulates an axially-vibrating downhole tool, has been implemented in the horizontal section of the virtual drillstring. Simulations show a better weight transfer to the bit due to the tool, with a low frequency and high amplitude force excitation giving best performance but potentially increasing the severity of lateral shock. The model, implemented using the bond graph formalism, is a useful tool for design and sensitivity analysis due to its physically meaningful parameters and low simulation times on a personal computer.

***Keyword:*** Vibration, bottom-hole-assembly, bond graph, multibody dynamics, whirl, contact, simulation.

## 1. Introduction

Horizontal oilwell drilling is, initially, more expensive and more difficult than conventional vertical techniques, but can lead to greater production from a formation and lower environmental impact at the surface. However, field experience shows that mud motor, drill bit, measurement-while-drilling (MWD), and bottom-hole-assembly (BHA) component failures are very common [1] in horizontal well driling. Downhole data shows that excessive vibration in the drillstring, bottom-hole-assembly and related drilling components present a serious concern to the oil and gas industry. Drilling accounts for 35% of all oil and gas exploration costs [2]. An estimated 2% to 10% of well drilling cost can arise from vibration-related problems, such as lost time while pulling out of hole or fishing, reduced rate of penetration (ROP), poor wellbore quality, and increased service cost because of the need for ruggedized equipment [3]. A schematic of a horizontal oilwell drillstring is shown in Fig. 1. Lateral drillstring vibrations can cause severe problems such as twist-offs due to accelerated fatigue in threaded connections, premature bit failure due to bit whirl, and failure of measurement-while-drilling (MWD) tools due to high shock loads during impacts of the bottom-hole-assembly (BHA) against the borehole wall. Stick-slip can put excessive wear and tear on the BHA and reduce the life of the drill bit. These vibrations are to some degree coupled. Bit whirl can be triggered by high bit speeds during stick-slip motion. Stick-slip can generate lateral vibration of the BHA as the bit accelerates during the slip phase. Large lateral vibration of the BHA into the wellbore can cause bit-bounce due to axial shortening. Induced axial vibrations at the bit can lead to lateral vibrations in the BHA, and axial and torsional vibrations observed at the rig floor may actually be related to severe lateral vibrations downhole near the bit. More information regarding vibrations in oilwell drillstring can be found in [4]. Because of the complexity and huge cost associated with drilling experiment, research is increasing into