Rocking Dynamics of Mud Motor Drilling using a Cosserat Rod Model

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Abstract. "Rocking the pipe" is employed as a technique to reduce static friction while drilling oil wells with a mud motor. In this work, we investigate the dynamics of pipe rocking in the presence of drillpipe-wellbore clearance using Cosserat rod theory. The numerical results for a single frequency rocking input at the surface show that the system behavior is inherently nonlinear: the downhole section undergoes coupled rotational and lateral motion due to frictional contact interaction, and their characteristics are dependent on the frequency and amplitude of the rocking input. These results demonstrate that "rocking the pipe" can result in excitation of lateral vibrations in the downhole tool, which needs to be taken in to account while designing optimal rocking regimes to ensure smooth drilling.

Introduction

Directional drilling for oil wells can be accomplished by slide drilling, wherein a mud motor which converts hydraulic power to mechanical torque is used as the power source. A drawback of slide drilling is its low efficiency, due to drag losses as a result of axial sliding along the wellbore. One possible solution is to "rock the pipe" at the surface, so that a portion of the drillpipe remains in dynamic contact with the wellbore thereby reducing friction. However, this rocking motion must be designed carefully and not transmitted to the bit, as that can lead to loss of directional control. Many researchers have explored optimal rocking regimes in slide drilling, using empirical studies based on measured field data [1], as well as linear models that consider the axial and torsional dynamics of the drillpipe [2]. However, the nonlinearity associated with the drillstring-wellbore contact is seldom considered. While the Kirchoff rod model [3] is the most prominent method to incorporate the nonlinear contact dynamics, we consider the Cosserat rod model in our study, in order to leverage existing computational packages available for simulating the dynamics of Cosserat rods [4]. To model drillstring dynamics, we developed an algorithm to account for cylindrical contact in the software, and the salient results obtained for a sinusoidal rocking input are shown in Fig. 1.

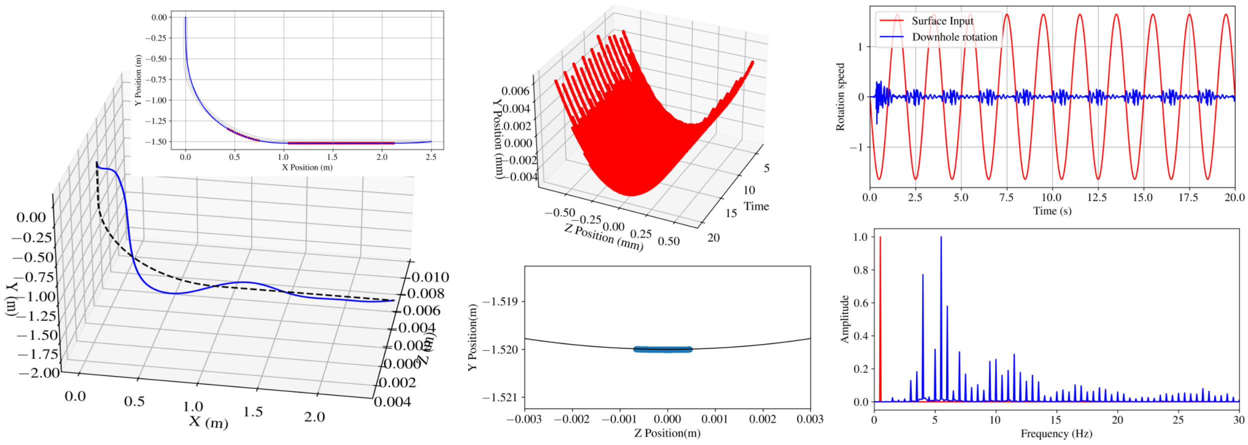

Figure 1: Dynamics of drillpipe in a curved wellbore with clearance, subjected to a rocking input at the surface. The leftmost plot shows the deformation at the end of the simulation, and the inset shows the region of the drillpipe in contact with the wellbore. The middle plots show the time history of motion of the cross-section of the drillstring in the horizontal section. The rightmost plots compare the amplitude and frequency of the rotation speed at the surface and downhole for the rocking input.

Results and Discussion

The leftmost plot in Fig.1 shows that the static deformation of the drillpipe in a curved wellbore with clearance is non-planar, with only a part of the drillpipe being in contact with the wellbore (as highlighted (in red) in the inset figure, which shows the planar projection of the deformed shape). A consequence of this contact interaction is that the lateral and torsional modes of deformation are now coupled, and the drillpipe in the horizontal section rolls on the surface of the wellbore (as shown in the middle plots of Fig. 1). For a single low-frequency rocking input at the surface, the downhole rotation speed is observed to consist of many frequency components, with the dominant component being much higher than the input frequency (rightmost plots of Fig. 1). Further numerical simulations show that the dominant frequency component is dependent on the wellbore configuration, as well as the surface input parameters. These results demonstrate the need to consider the nonlinear dynamics of contact interaction while designing optimal pipe rocking regimes for slide drilling.

References

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