Reduced-Order Models for Drill-String Dynamics

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1. Introduction

A drill sting is a part of the rotary drilling apparatus for constructing a borehole from the earth's surface to an oil/gas reservoir. Reliable models that can be used to predict the motion of a drill string are important to design efficient oil mining operations as well as to mitigate structural failures. The failure of the drill-string system can shutdown the oil production system for time-consuming repairs. With this background, the present effort is aimed at determining reduced-order models for predicting drill-string motions.

2. Reduced-Order Models and Results

From the literature[1,2,3], it is known that drill-string vibrations play a major role in determining the performance of a drill string. These vibrations include the following: i) axial or longitudinal vibrations, which are mostly due to the interaction between the drill bit and the rocks, ii) bending or lateral vibrations, often caused by drill-pipe eccentricity, leading to a rotational motion named as drill-string whirl, iii) torsion vibrations (associated with the stick–slip behavior[1,3,4,5] of the drill-bit) caused by nonlinear interactions[6] between the bit and the rock or the drill string with the borehole wall, and iv) hydraulic vibrations in the circulation system, stemming from pump-pressure pulsations. The dynamics of a drill-string system has features of non- smoothness[4], and this system is capable of exhibiting a wide range of nonlinear behavior including qualitative changes with respect to the rotation speed of the drill string, friction associated with contact between the drill string and the outer shell, and friction associated with contact between the drill string and the well bottom. The coupling amongst torsion, lateral, and axial vibrations has not received full consideration, and it is possible that nonlinear interactions also exist in this system.

To capture of the essence of the dynamics of the drill-string motions while paying attention to the stick-slip interactions, the drill-string system is reduced to a lower order system moving in two-dimensional space. This is carried out by modeling the drill string system as a system made up of two rotating sections, the radial movable inner stator and an outer rotor, with four degrees of freedom. The stick-slip interactions between the drill string and the outer shell are taken into account. As the next generation model, an extra tilting angle of the rotating section is included to extend the four degree-of-freedom model to a five degree-of-freedom model. Simulation results obtained for different values of the friction coefficients, rotation speeds, and rotation torques are presented, discussed, and compared with those in the literature (Figure 1). Experimental results obtained from an arrangement used to study drill-string vibrations will also be presented and discussed (Figure 2).

3. Concluding Remarks

Four and five degree-of-freedom reduced-order models have been used to study drill-string dynamics, and the qualitative features of these numerical results have been confirmed by experiments.

4. References and Bibliography

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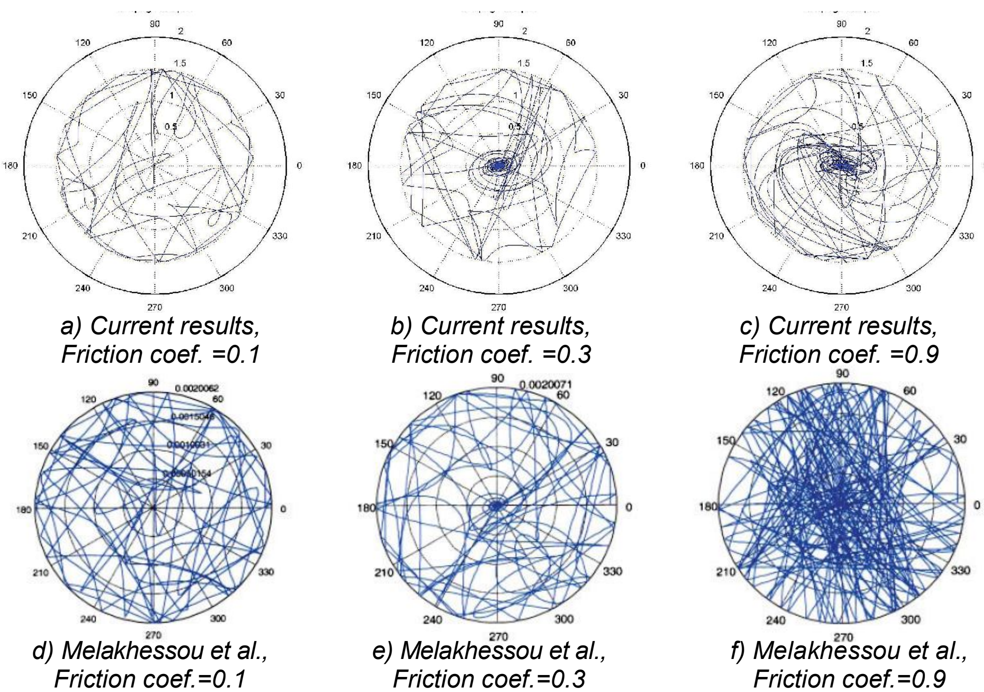
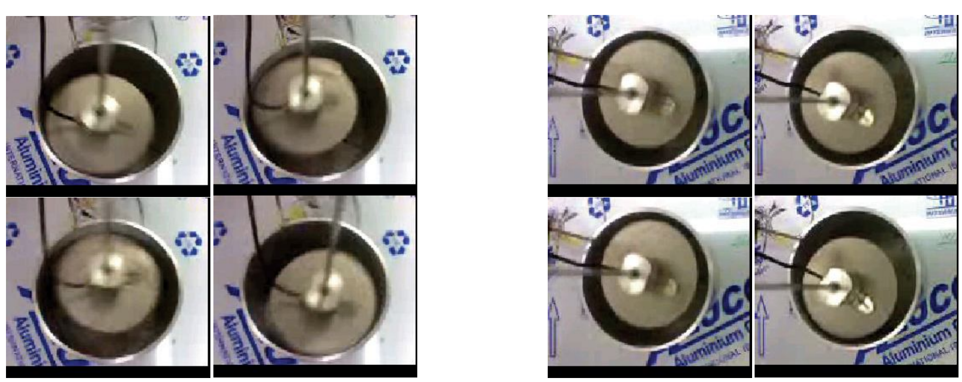


a) Current results, Friction coef. =0.1 *b) Current results, Friction coef. =0.3* *c) Current results, Friction coef. =0.9*

d) Melakhessou et al., Friction coef.=0.1 *e) Melakhessou et al., Friction coef.=0.3* *f) Melakhessou et al., Friction coef.=0.9*

Figure 1. Comparisons of simulation results with Melakhessou *et al.* [2]



a) b)

Figure 2 a) Rotor in rolling mode (order from left to right, up to down); b) Rotor in bumping mode (order from left to right, up to down).