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INFLUENCE OF THE DRILLING FLUID FLOW ON THE DYNAMICS OF A DRILL-STRING

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ABSTRACT

The drill-string dynamics is difficult to predict due to many nonlinear aspects, such as impacts, geometric stiffness, fluid-structure coupling, bit-rock interaction etc. In a drilling operation the drilling fluid is pumped downwards through the drill-string then goes upwards in the annuli between the drill-string and the borehole. In the context of this problem, the present paper investigates the influence of the flow inside and outside a drill-string in the system dynamics. Usually the fluid does not appear in the formulation of the articles concerned with the drill-string dynamics, [1,3,4].

A 3D nonlinear Timoshenko beam model is developed coupled with linearized fluid forces [2], and the system is discretized by means of the Finite Element Method. The computational model is constituted of the usual structural mass, stiffness, and damping matrices, plus the fluid mass, stiffness, and damping matrices, and plus the geometric stiffness matrix that depends on the configuration of the column. It happens that the drilling fluid may have a big influence in the dynamics of a drill-string. In fact, depending on the velocity of the drilling fluid pumped downwards the system may be unstable.

At first, a modal analysis is performed to check the difference in the dynamic characteristics (natural frequencies and normal modes) of the system with and without fluid. This analysis is performed around a prestressed configuration that is calculated using the forces due to the own weight of the column and a reaction force at the drill-bit. In this prestressed configuration the upper part of the column is in tension while the lower part is under compression. It is noted that the flow tends to destabilize the system, and also that the inside pressure tends to destabilize the system while the outside pressure tends tends to stabilize the system. Moreover, there is a term in the fluid stiffness matrix which depends on the pressure that turns the system more stiff in the lower part, because of the great depth and of the consequently great pressure.

Then, in the second part, the dynamic response is calculated with the reduced system. A nonlinear bit-rock interaction is considered as well as shocks between the drill-string and the borehole. The dynamic response of the system is also very influenced by the fluid flow.

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