Attenuation of drill-string torsional oscillations using shape memory alloys

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Abstract. This paper investigates the application of shape memory alloys as pipe coupling on the drill-string dynamics. The goal is to evaluate the influence of the dissipation provided by the hysteresis of the superelastic effect and its help to attenuate severe torsional vibration, commonly known as stick-slip oscillations. A simplified model is used to perform parametric analysis and to find the appropriate structure that leads to a safe region in the drilling operation.

Introduction

Applications of Shape Memory Alloys (SMAs) varies from different industries, spanning from the Aeronautical to the Oil and Gas. In the last decade, one application provided by Schlumberger tries to eliminate the need for welded or threaded joints for metallic piping and tubing by taking advantage of shape memory effect during assembly in offshore systems. This application can avoid problems such as corrosion in welded connection or loosening on threaded tool joints. Furthermore, applying these SMA couplers to a drill-string has an added benefit to its dynamics that was not fully investigated yet.

Initially, a single-degree of freedom pendulum with an SMA element is analyzed to show the general characteristics of its dynamical response, in the same matter as Savi et al. [1]. Then, a multi-degree of freedom of a lumped parameter model is used to model the torsional dynamics of the drill-string, with the imposed angular velocity at the top and a nonlinear bit-rock interaction at the bottom, similar to Ritto et al. [2] modeling. This simplified model is validated by a comparison finite element analysis performed in Abaqus. The thermomechanical behavior of SMA is described using a constitutive model proposed by Lagoudas et al. [3]. Additional modeling of the SMA subloop and an equivalent martensitic distribution in the cross-sectional area follows the work of Enemark et al. [**?**].

Results and discussion

The numerical results show a strong dependence on the system's torsional behavior on the Hysteresis parameters. All analyses are performed considering the drilling conditions such as weight on bit and top angular speed. Knowing that drill-string's harmful vibrations occur in its natural frequency, the evaluation of stiffness and inertia properties magnifies the importance of SMA material parameters, such as the stresses at which the transformation begins and ends during loading and unloading, and the design parameters, such as SMA length, thickness and distribution in the drill-string.

Overall, this work stands that the main variables in drilling operation can be improved by an admissible length of SMA coupler, and it brings new perspectives to smart materials adoption in the drill-string system.

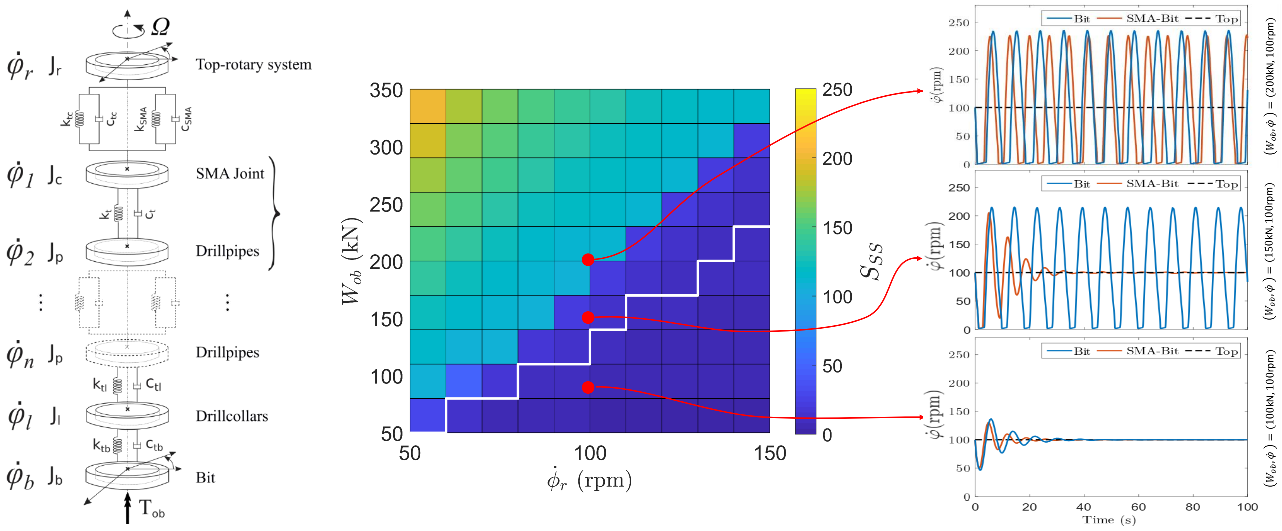

Figure 1: Left: schematics of a lumped parameter model of the drill-string with SMA joint. Center: an operational map of Weight on Bit, W_{ob}, versus Angular Velocity, $\dot{\varphi}_r$, at the top. Right: plots of angular velocity, $\dot{\varphi}$, through time for $W_{ob} = 200$, 150 and 100 kN.

References

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