

Kinematics and Mechanical Properties Analyses on Vibration Converter of Intelligent Damper for Drill Strings

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Abstract. Taking vibration converter of intelligent damper for drill strings as the study object, this paper analyzes the influential factors of motion state of the ball and conducts an explicit dynamics simulation by establishing a mechanics model of vibration converter. The study basis is Newton's laws of motion, d'Alembert's principle and hertz contact theory. And we use world coordinate system, rotating coordinate system and Frenet coordinate system to deduce kinematics equations of vibration converter. The ultimate result demonstrates that the axial velocity and maximum contact stress change with the increment of ball diameter and helix angle. It also proves the validity of our derived kinematics and mechanical models and provides a good consultant value for the design and theoretical arithmetic of vibration converter for intelligent damper of drill strings.

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Key words: Intelligent damper, vibration, converter, kinematics analysis, contact stress.

1 Introduction

As a rotating slender elastic rod, drill strings works under complex conditions. Rock breaking excitation and borehole constraint during its work exerts axial vibration, lateral vibration and torsional vibration on drill strings (Fig. 1), especially in hard formation or soft-hard interlayer. These vibrations can cause serious damages on well-drilling. From variations in weight on bit (WOB) and drilling torque, premature failure of bit, aggravated fatigue of drill strings, thread gluing and fracture, to ground equipment damage, these damages will lead to failure of the valued downhole tools (MWD, LWD and RSS [1]), overall time rises and huge losses. Therefore, vibration mitigation is greatly

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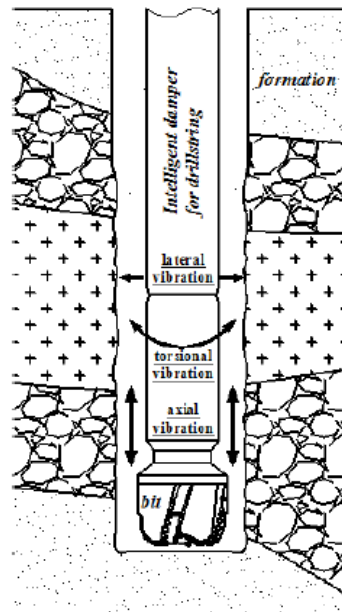


Figure 1: Bottom hole assembly (BHA) and vibration modes.

needed and drill strings damper is a most effective way. In this field, intelligent dampers represent the latest tendency of downhole vibration damping techniques [2], which can monitor real-time drill strings vibration and attenuate it.

The common spring dampers are only able to buffer or eliminate axial vibration. The air damper, with pressurized inert gas injected into the seal cavity, works well in absorbing vibrations by changing its cavity volume. However, the complexity of seal structure is a fatal weakness, and the presetted pressure of inert gas also limits its damping capacity [3]. Overcoming all the drawbacks above is the intelligent damper for drill strings, which can eliminate both axial vibration and torsional vibration simultaneously, as well as providing a wide damping range and long service life.

Vibration converter, as a key part of the intelligent damper for drill strings, take the function of converting torsional vibration into axial vibration. This converted axial vibration, adding up with original axial vibration is mitigated simply by the axial damping elements. To realize that torsional-axial convert, vibration converter usually adopts ball screw. Ball works as an intermediary for transmitting motion and force as well as transforming rolling friction into sliding friction. Therefore, its motion and stress situation has direct effects on the motion characteristics of vibration converter. In the general mechanical industry, the motion characteristics and mechanical properties of ball have been much investigated. D. Mundo and H. S. Yan proposed a method for the kinematics optimization of ball screw transmission mechanisms [4], Yoshida Takafumi et al. presented an analytical method which can be used to determine the motion of the ball and the ball load distribution, and then a parametric study on a ball screw was carried out to esti-