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MODELING OF THE PERCUSSIVE MECHANISM OF A SPECIAL PLANETARY DRILLING SYSTEM

Abstract

Planetary drilling is a vital task in the challenge for space exploration and human colonization. Special percussive planetary drilling devices such as the Ultrasonic/Sonic Driller/Corer (USDC) and Auto-Gopher have been developed by Honeybee Robotics Spacecraft Mechanisms Corporation and NASA Jet Propulsion Laboratory to overcome the limitations of current drilling devices for planetary exploration. The percussive mechanism of the USDC and Auto-Gopher consists of an ultrasonic horn, a free mass, and the drill rod. During drilling operation the ultrasonic horn is vibrated via a piezoelectric actuator. The free mass, located between the ultrasonic horn and the drill rod, is struck by the ultrasonic horn and driven towards the drill rod. The free mass oscillates between the top of the drill rod and the bottom of the ultrasonic horn, thus creating repeated impacts. In this study, the analysis of the local interaction between the free mass-ultrasonic horn and free mass-drill rod and the dynamic response of the overall system is presented. The contact interaction is analyzed using Hertz theory of contact, including the effects of structural vibration and structural damping. An in-house finite element code is utilized, in which a numerical integration scheme with equilibrium iterations is implemented to obtain the displacement of each component of the ultrasonic drill and the contact force developed during each impact. In addition, several support conditions (e.g. fixed, elastic, viscous) of the rod are considered. The effects of the support condition of the drill rod on the contact force and the dynamic response of the ultrasonic drill are presented. It was found that the frequency of oscillation of the free mass is smaller than that of the ultrasonic horn. This is consistent with the purpose of including the free mass to convert the high frequency oscillation of the ultrasonic horn into lower frequency impacts on the drill rod. The support condition of the drill rod affects the overall dynamic response of the ultrasonic percussive mechanism, however, the contact force is affected by the support condition of the drill rod only if the duration of contact between the free mass and the drill rod is larger than the time it takes the wave to travel through the rod and return to the impacted end of the rod. The oscillation frequency of the free mass was observed to be highest for the drill rod with fixed support compared with other support conditions considered in this study.