Covering Shock Waves on Mars induced by InSight's HP^3 -Mole

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ABSTRACT

The question for the formation of our solar system is one major driver of science. Therefore NASAs discovery mission InSight (Interior Seismic Investigations, Geodesy and Heat Transport) [1] aims to gather deeper knowledge about Mars' interior structure. Therefore DLR's HP^3 instrument (Heat Flow and Physical Properties Package) [2] is used to measure the internal martian heat flux in a total depth of 5 m. Thus, its locomotion system, the self-impelling nail nicknamed the "Mole" needs to accomplish the task to hammer itself into the martian soil with less than 5 W of input power.

To allow the HP^3 Mole to fulfill this demanding task, its development has been supported by simulations since the very beginning, as certain environmental aspects cannot be covered in terrestrial test setups. The most precise of these models is a coupled simulation of a multi-body based cross domain model for the hammering device itself and a discrete element model for the soil. Thereby the first covers the dynamics of the mechanism, the electromagnetic behaviour of the motor, the contact dynamics of the internal impacts, as well as the internal gas flow through the mechanism within the multi-body framework using a single solver. The surrounding soil is covered by the particle simulation framework DEMETRIA [3] based on Pasimodo [4]. As the effects of the two main domains happen in different timescales, dedicated solvers and communication strategies need to be applied in order to ensure proper data exchange and numerical stability.

Using this complex coupled model it was possible to yield a prediction of the Mole's penetration performance with an error of less than 16% [3]. The model is used to evaluate the mechanism by analyzing the propagation of hammering induced shock waves through the soil. Adapting gravity and atmospheric conditions, the model is used to predict the behaviour of the Mole in Mars. As the first is not feasible on earth, the high-fidelity simulation is the only way to test the system for its target environment using a virtual prototype. Furthermore the model has been used to analyze a variety of outer shapes to show the influence of different tip geometries.

Concluding, the article will focus on the setup of the coupled model and will also explain the modeling in the single domains. Furthermore an overview of the results based on the model will be given for the in-depth analysis of the Mole, the variation of the outer shape, as well as the operation on Mars.

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