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Soil mechanical simulation of the HP³ penetrator using a discrete element software package.

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Abstract

The NASA InSight is a geophysics mission to investigate the interior of Mars and is due to launch in May 2018. Its major task is to deploy a seismometer and a heat flow probe on the surface of Mars. A mechanical arm will be used to place both main instruments within short distance from the lander main body. The seismometer will listen during the mission duration from one Martian year for internal seismic activity and impacts of larger meteorites. The HP^3 (Heat Flow and Physical Properties Probe) heat flow probe (henceforth called mole in short) will penetrate by an internal hammer mechanism into a depth of 3- 5 m into the top surface regolith to measure the planetary heat flow and the local thermal conductivity. This presentation will deal mostly with the simulation of the mechanical action of the penetration process which will be used to derive soil mechanical properties of the regolith beneath the InSight lander. Additionally we show that an extra manipulation of the regolith top layer with the instrument deployment arm (IDA) can be used to augment and constraint some soil mechanical parameters used for the penetration simulation.

1. Introduction

The HP^3 mole penetration process is dynamically in an interims area between the quasi static and continuous penetration with low speed but constant displacement and high speed impacts of projectiles e.g. anchor harpoons. Somewhere between these extreme cases is the fast but short distance displacement caused by the hammer mechanism of the mole. For quasi static penetration traditionally one dimensional models or specialized finite element software packages have been used whereas for large or even hypervelocity impacts even more specialized software solutions have been used. Unfortunately, neither of these software approaches is particularly useful to model the intermediate energy range of a hammer driven penetrator.

We investigated the usage of a Discrete Element Method (DEM) where the soil is simulated by an accumulation of single spherical particles and the physical interaction between them and the mole body during the hammering process.

For this purpose, a numerical model of the HP3 penetration progress has been implemented in the DEM software package LIGGGHTS to investigate the behavior of a dry granular materials representing Martian regolith during dynamic penetration. This model consists of the mole body penetrating into a calibrated spherical, granular material and a representation of the HP^3 hammering mechanism that generates the downward movement of the probe [1].

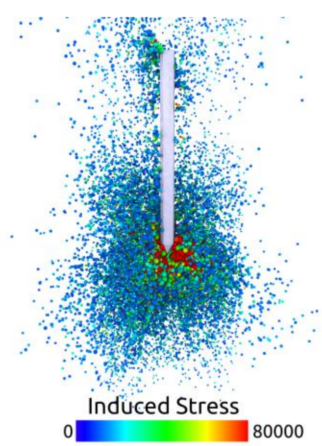

Figure 1: Color coded total stress imparted on particles during one hammer stroke. Particles below a stress threshold of 1 kPa have been blanked out do highlight the affected regions around the mole body.

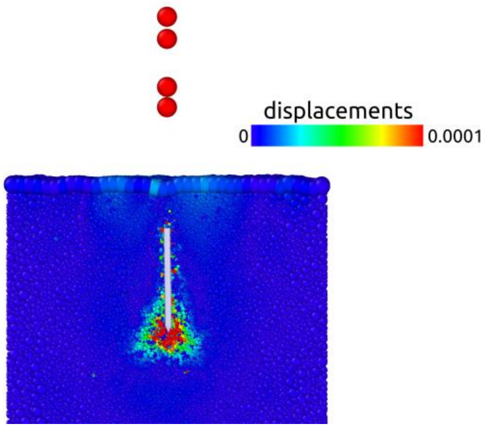

Figure 2: Displacement of particles around the mole tip as result of multiple hammer strokes. The layer of large particles on top simulate the overburden pressure encountered in different depths within the soil but providing more flexibility against horizontal stress and displacement than a rigid simulation boundary of more traditional approaches.

2. Summary and Conclusions

We report on the development of a discrete element model to simulate the hammering actions of the NASA InSight mission HP3 mole in the dry granular regolith of the Martian surface. The implementation in the LIGGGTHS software package showed that the hammer mechanism and the interaction of the mole body can be well matched for the dynamic processes inside the soil and the resulting penetration progress does match experiments performed with the real mole penetrator as it was tested during the development of the flight hardware.

A video of the simulation can be found at

https://youtu.be/y1GkoD0Vp0g

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References

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