PROGRESS DEVELOPING TECHNIQUES FOR DETERMINING MARS SOIL PROPERTIES FROM LABORATORY TESTS, DISCRETE ELEMENT MODELING, AND MARS TRENCHING EXPERIMENTS.

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Introduction: The ability to interpret Mars surface geologic processes and develop engineering analyses for future landed missions depends on understanding the properties of Mars soils, including the mechanical heterogeneities associated with near-surface stratigraphy. Wheel tracks from Mars Exploration Rovers (MER) indicate layering of soils of different composition by digging underlying soil to the surface (**Fig.1)**. Reconstructing the original stratigraphic position and heterogeneity of soil layeris, combined with compositional and physical properties measurements can point to the geological formation process. Interpreting wheel track images and MER wheel current motors to derive soil movement tracks and soil properties will require a combined approach of analytical and numerical laboratory simulation of Mars data.

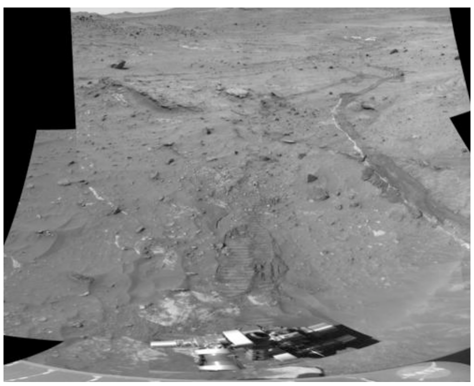

Figure 1. MER Spirit tracks and disturbed soil near Tyrone showing overturned bright soil, clods and push ridges (NASA/JPL-Caltech/Cornel [1]).

Approach and Technique: Laboratory tests of MER wheel trenching experiments and analysis of MER wheel current is used to estimate soil strength (**Fig. 2**). Interpretation of wheel trenching tests proceeds by first analyzing wheel current motors to estimate wheel torque during MER trenching events. Terestrial laboratory tests using an equivalent MER wheel and a simulant of Mars regolith are used to calibrate MER wheel torqure/electric current relationships. In combination with images of soil disturbances from testing, wheel torques were used to estimate soil cohesion and internal friction parameters using the Mohr-Coulomb soil strength model.

Figure 2. MER Wheel laboratory experiment at the Cornell George Winter Laboratory (Sullivan).

Additional laboratory tests using a MER wheel in a test track are used to examine the displacement of soil layers and to develop a semi-empirical model of wheel/soil interaction (**Fig. 3**).

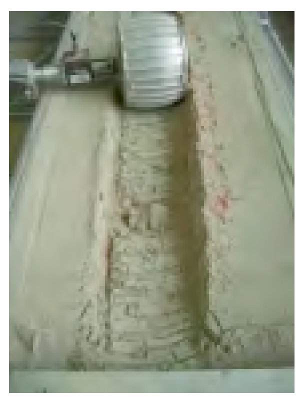

Figure 3. MER wheel test in layered soil at the German Aerospace Center (Richter and Schmit).

A numerical simulation model of MER wheel interaction with soil is being developed using the Discrete Element Method (DEM) (**Fig. 4**). For MER analyses, the important geometric aspects of a specific soil test (e.g., wheel compaction, trenching, or disturbance of layered soil) can be represented by the DEM, along with the soil properties (grain size, and particle contact cohesion and friction) to directly represent the experiment of interest. Once these micro-scale parameters are known the model can be used to examine specific MER equipment behaviors and soil deformation processes.

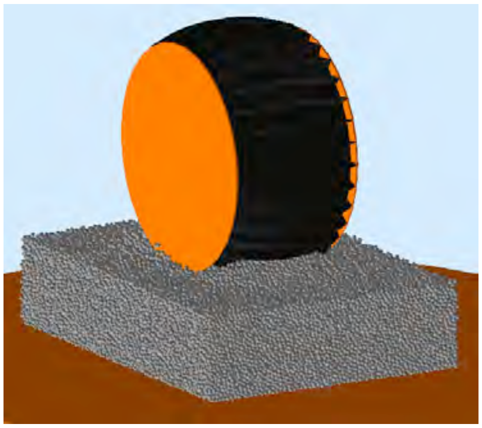

Figure 4. DEM 10 simulation of a MER wheel in soil (Hopkins and Kaempfer).

Progress

A description of the DEM approach and its conceptual application to MER analyses is given in [2]. Since the report in [2], a preliminary DEM simulation has been constructed (**Fig. 4**) that explicitly models the dynamics of MER wheel interaction with soil particles. Both trenching and wheel traversing, with wheel slippage can be included. Analysis of these scenarios requires the ability to simulate the large-scale discontinuous deformations that depend on micro-scale soil particle contact processes, internal breakage of any contact bonds, and compaction of broken fragments. Experience indicates that when DEM simulations accurately replicate test conditions, selected granular material properties are very close to their actual values.

Conclusions: Methods to determine Mars soil strategraphy and physical properties are being developed and applied to help interpret Mars geologic processes and soil engineering properties. A combination of Terrestrial laboratory tests of MER wheel interaction with Mars regolith simulant combined with DEM simulatations are being developed to analyze MER data. A preliminary DEM simulation of the MER wheel/soil system has been developed and is being used conduct a first order examination MER wheel interactions with Mars soil. We will present initial resuts of these DEM simulations.

References:

[1]http://marsrovers.nasa.gov/gallery/press/spirit/20060530a/2NP807ILFARCYL00P1986L000M2-A835R1_br.jpg. [2] Johnson et al. (2006) 37th Lunar and Planetary Scinece conference, Abstr. 1578, http://www.lpi.usra.edu/meetings/lpsc2006/pdf/1528.pdf