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Dynamic loading and release in Johnson Space Center Lunar regolith simulant

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Abstract

The behavior of regolith under dynamic loading is important for the study of planetary evolution, impact cratering, and other topics. Here we present the initial results of explosively driven flier plate experiments and numerical models of compaction and release in samples of the JSC-1A Lunar regolith simulant.

1. Methods

For this work we used the Free Lagrangian (FLAG) hydrocode to explore the potential design space for the experiments, conducted the experiments to obtain compaction and release data on the materials in question, and then attempt to match the experimental results in further hydrocode models in order to assess the performance of the hydrocode.

1.1. Explosively driven flier plate experiment setup

The conical explosive charge (labeled 1 in Fig. 1 (a)) at the top is detonated, and drives a blast wave through the explosives, a 2.5-cm stainless steel plate (2), and another 1.25-cm disk of 9501 explosives (3). These layers condition the blast wave to be approximately planar when it strikes and drives the 1.3-cm thick aluminum flier plate (4) down into the three sample cells held by the aluminum and poly(methyl methylacrylate) (PMMA) baseplate (5, only one sample shown), which are under vacuum. The sample for this experiment was 2.621-mm-thick, with a mass of 5.819 g, and a density of 1.5 g/cm^3, this is approximately tap density for JSC-1A. It was held in a sample cell that consisted of a 2.072 mm copper buffer at the top, an aluminum cartridge, and a 21.467-mm-thick PMMA window at the bottom. The velocity of the flier plate, the timing and velocity of blast wave breakout from the sample holder and the front and back of the sample cartridge are measured using photon doppler velocimetry (PDV)[5].

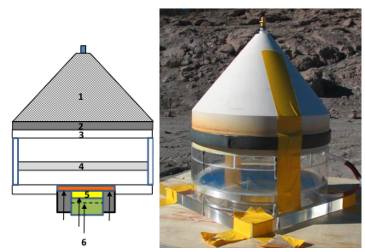

Figure 1: The experiment setup (left), and the apparatus just before firing (right).

1.2. JSC-1A regolith simulant

We chose to study the JSC-1A simulant because it is more similar to regoliths found on the moon and many asteroids than material models in current use for numerical modeling of impact processes (e.g., [8], [3], and [7]) , while still being easy to obtain. These equations of state have been sufficient while other sources of uncertainty dominated the total uncertainties on the numerical models, but increased computing power and better understanding of the objects in question make new models useful to the numerical modelers.

The JSC-1A lunar mare regolith simulant is a processed basaltic volcanic ash from the San Francisco volcano field near Flagstaff, Arizona, produced by the Orbitech corporation for use in geotechnical research. The strength properties of JSC-1A were measured by Alshibli et al. (2009)[1], and a geochemical analysis was conducted by Hill et al. (2007) [4].

1.3 The FLAG hydrocode

For this work we used the staggered grid Lagrangian hydrocode FLAG [2] and the SESAME [6] equation of state libraries. Equation of state data, compaction and release curves, for the materials of interest were of unavailable at the beginning of this work. We used data for Nevada alluvium, dry sand, and basalt as proxies for the materials of interest in our calculations.

2. Results

2.1 Explosively driven flier plate results

The experimental setup described above was fired on February 22, 2011. The flier plate velocity was 1.682 km/s. We measured the velocity of various locations on the top and bottom faces of the sample container. The velocity at the bottom center of the cell, Fig. 2, shows the velocity jump as the blast wave breaks out of the bottom of the sample at $t = 71$ μsec, a pulse of approximately constant velocity, and then the release of the material back down to lower pressures and densities. The velocities observed in Fig. 2 correspond to a peak pressure of approximately 31 kbar.

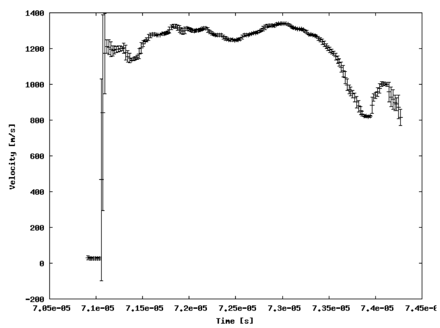

Figure 2: v vs. t from the center of the sample cartridge. The plot shows breakout of the wave at the bottom of the sample and release from compaction.

2.2 FLAG hydrocode model results

We conducted preliminary models to explore the experiment design space. The preliminary model closest to the experiment has a 2-mm-thick Nevada alluvium sample at a density of 1.8 g/cm^3, and a flier plate velocity of 1.7 km/s. In this model, the peak velocity observed at the bottom face of the sample is 0.9 km/s, which corresponds to a peak pressure of 46 kbar. After the experiment was conducted, we used the precise as-built specifications of the model to conduct a second set of hydrocode calculations in an attempt to match the initial conditions and outcomes of the experiment as closely as possible. Post-experiment model results, further experiment results, and analysis of their implications for the numerical modeling of lunar regolith simulant and its use as a proxy for lunar regolith in high strain-rate problems will be presented at the meeting.

Acknowledgements

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