INSTRUMENTED IMPACTORS AND PROBING BED DEPTH WITH IMPACT PENETROMETRY.

K. J. Walsh[1], A. H. Parker[1], A. Whizin[1] and D. Durda[1]. [1]Southwest Research Institute, Boulder, CO, USA (kwalsh@boulder.swri.edu)

Introduction: The physics of penetration into granular media has been explored in numerous environments and experimental setups with significant effort having been focused on characterizing the forces imparted on the impactor in a "universal" force law [1]. Typical experimental design requires target beds that exceed the impactor diameter by five in depth and width to eliminate boundary effects to alter experimental outcomes [2]. Here, we describe a series of experiments to track the divergence from the expected universal force laws as the target bed depth is decreased. The goal is provide a framework to interpret acceleration profiles of impactors hitting granular materials at low speeds with minimal prior knowledge of the local material properties.

Instrumented Impactors: Our experimental technique relies on instrumenting impactors with accelerometers as a flexible way to track the forces imparted during their impact. The requirements on the experimental setup are all directly related to the size and capabilities of the accelerometer embedded in the impactor. The design of the impactor has iterated three times to be compatible with experiments in our institute laboratory and also on reduced gravity flights. Here, we describe properties of our 2nd-generation impactor, which was used for many of the results described. We also look ahead to the 3rd generation impactor, which is smaller than a ping-pong ball and will be utilized on the next campaign of reduced gravity flights (Figure 1).

The 2nd generation impactor is a 80mm-diameter sphere that has two cutouts to hold YOST 3-space IMU sensors. These sensors can record 3-direction accelerations at over 200Hz with a range of maximum *g*-level and accuracy.

The 3rd generation impactor is a 35mm diameter sphere that houses TinyShield stack of accelerometer, battery and SDcard logger. This smaller setup will be capable of a many factor increase in data logging rate that will allow for a wider range of impact and material combinations that can be effectively explored.

Setup: A series of experiments to explore the imparted force on impactors as a function of bed depth were initiated in a 80cm-diameter aluminum chamber. Airsoft pellets were selected for the test medium. Due to their large size (6mm) these pellets allow for numerical modeling to match the exact number of particles in each simulation, and the range of masses (0.12g – 0.25g) will permit explorations of inertial dependences.

The experiment described here relied on a series of drops from similar heights into beds of varying depth. Changes in drop height, and thus impact speeds, were also varied between series of experiments.

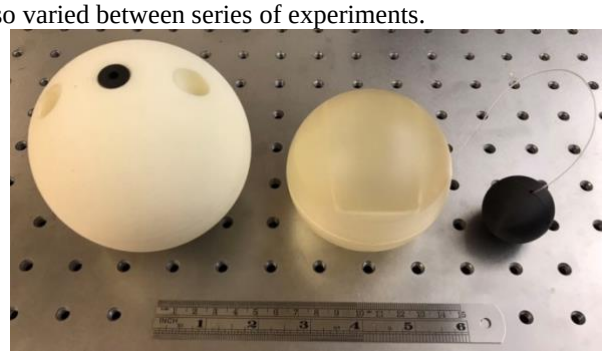

Figure 1: Instrumented impactors generation 1-3 (from left to right).

Results: The relative size of the AirSoft pellets to the impactor create relatively 'noisy' impacts (i.e., significant drop-to-drop variation in results). To mitigate this each drop height was done numerous times with an average profile extracted for each suite after a series of drops (Figure 2). The average curves from each suite of drops provides the force profile for each point on the height vs bed depth experiment. Each profile is reduced to collapse the data for direct comparison with the expected profiles from Universal force laws.

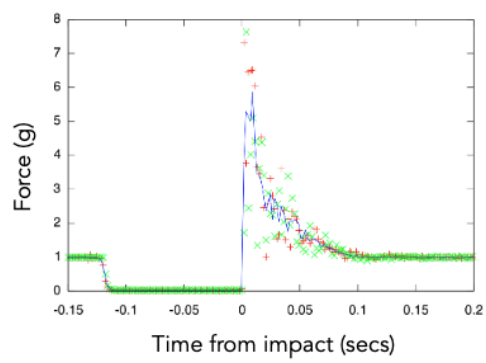

Figure 2:A example suite of 10 separate drops are shown in terms of the acceleration as a function time during impact (with two individual drops in green and red points) with an average result illustrated in the blue line.

References

[1] Katsuragi H., and Durian D. J., Nature Physics, Volume 3, Issue 6, pp. 420-423

[2] Seguin A., Bertho Y., and Gondret P., ys. Rev. E 78, 010301(R)