PDC2015
Frascati, Roma, Italy

X Mitigation Techniques & Missions

IAA-PDC-15-P-51

Momentum transfer via direct impact: Experimental measurements

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Keywords: *Deflection, kinetic-impact, momentum-transfer, ejecta, experiments*

ABSTRACT

Kinetic impact is an effective, relatively simple method for altering the orbits of potentially hazardous objects smaller than several hundred meters diameter. The method relies on the impulse delivered directly by the impacting spacecraft and that due to the excavated asteroid material that permanently escapes. Given that the volume of a hypervelocity impact crater can be orders of magnitude larger than the impactor volume, and that much of the ejecta escape the weak gravity field of a small asteroid, the impulse contribution from the ejecta can be significantly larger than the direct contribution from the impactor. Physical and numerical experiments measure that factor.

The efficiency of this process is characterized by a parameter, β, defined as the total momentum change of the body divided by the momentum of the impacting spacecraft. In the limiting case of a perfectly inelastic collision (no ejecta), β =1. When a considerable mass of ejecta escapes at high velocity, β can be significantly greater than 1.

We use experiments, scaling analysis and shock wave codes (hydrocodes) to study the momentum transfer for a deflection mission. Here we summarize our recent experiments. The experimental methods have been described elsewhere (2).

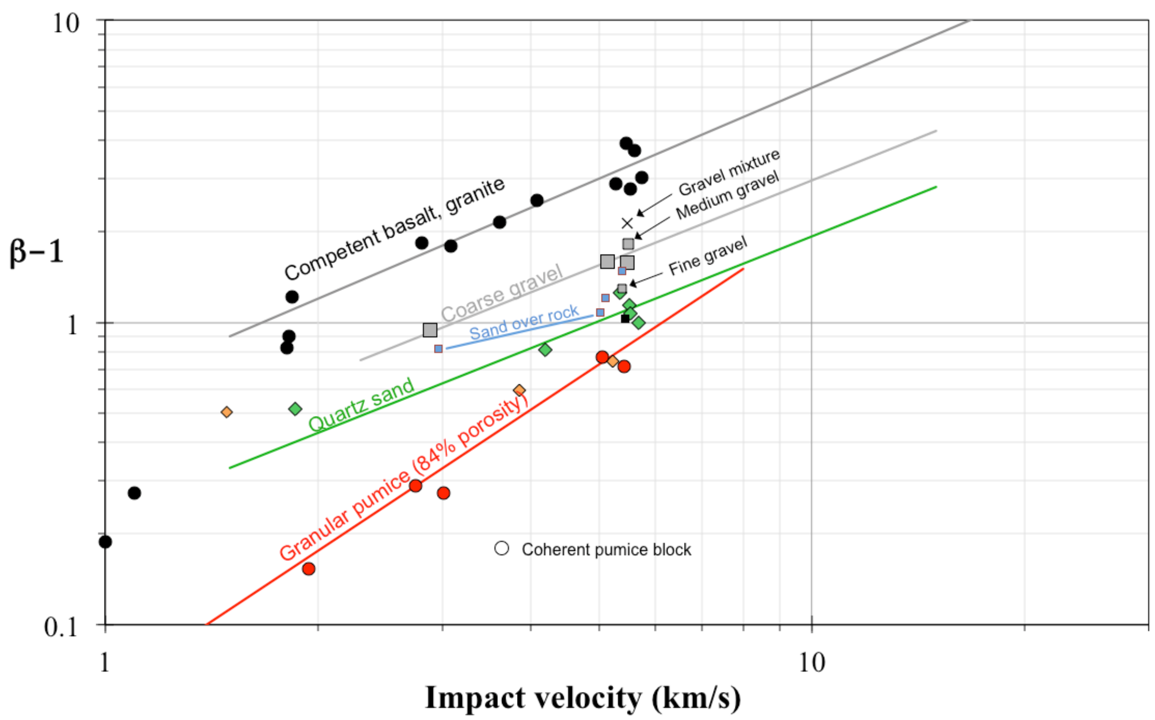
Asteroids and comets exhibit a rich diversity of shapes, bulk densities, reflection spectra and surface features. This undoubtedly reflects a corresponding diversity in the mechancial properties of the surface materials, which affect the amount and speed of material ejected during a kinetic impact deflection mission. Our approach is to measure β for a wide variety of target material types and configurations to reveal the expected range of β that could be expected during impact on a potentially hazardous body.

The point-source theory of hypervelocity impact indicates that β -1, i.e. the contribution from the ejecta, should increase as a power of the impact speed (1). The figure below shows our current set of experimental results as a log-log plot of β-

1 vs impact speed *U*, in which case the power-law dependence becomes a straight line. The experiments confirm the scaling theory.

We find that competent, nonporous rock exhibits the highest value of β, due to the high ejecta velocities observed for these materials. β might be as large as 10 at speeds of 15 to 20 km/s. At the other extreme, highly porous materials such as pumice rock tend to show much lower β, often close to the inelastic limit of β =1. This is due to the rapid decay of the shock in porous materials, and correspondingly low ejection velocities (3). Granular materials, such as sand or gravel, lie between these two cases. Dry sand targets (green data points) have small β at the low impact speeds, but could reach 4 to 5 at speeds of 15 to 20 km/s.

Additionally, we have performed impact experiments in gravel targets of various grades of coarseness (rubble piles), as well as rock targets overlain with a layer of sand, meant to simulate a regolith layer on a rocky asteroid. The results of these experiments will be summarized in the presentation. These results define the efficiency of deflections by direct impacts.



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