EFFECTS OF TARGET PROPERTIES ON IMPACT EJECTA DISTRIBUTIONS: TIME RESOLVED EXPERIMENTS AND COMPUTATIONAL BENCHMARKING

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Introduction: Long regarded as "second order" differences, the effects of impact angle and more physically realistic target and impactor properties on ejection processes are highly relevant for interpretation ejecta, particularly due to the flood of recent high resolution data of the terrestrial bodies and impact missions such as Deep Impact and LCROSS missions. Recent advances in the high-speed measurement of this ejecta have been able to characterize the time-resolved ejecta velocity distribution for oblique impacts into sand targets (e.g., [1]). While these data represent a first step toward realistic ejecta distributions on planetary bodies, they were necessarily limited in scope to sand targets for a restricted set of impact angles and projectile qualities. Although the effects of target compressibility, cohesion, and comminution are well known to affect the crater, virtually all ejecta velocity studies have been conducted with ``strengthless'' sand or spherical particles. While asymmetries are measured in the high-speed ejecta for impacts into sand targets, the ejecta distributions emplaced near the crater (lower speeds) appear considerably more symmetrical than those on planetary bodies or impacts into regolith-analog materials [2].

In this study, we present novel data on the ejecta velocity distribution for vertical and oblique impacts into more realistic target materials with comparisons to CTH simulations as part of an ongoing PGG investigation.

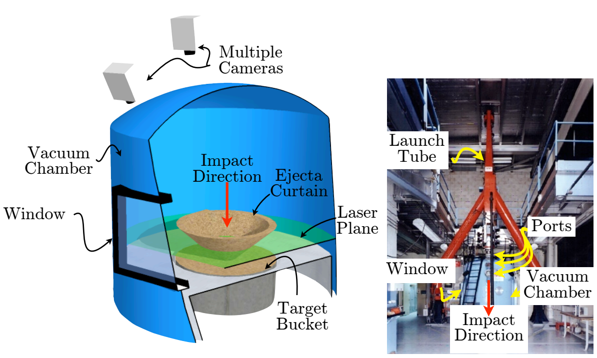

Figure 1 Experimental setup and schematic for studies at the AVGR (side view). A pulsed laser is optically spread into a horizontal light sheet (i.e., parallel to surface), and is projected a few centimeters above the target, serving as the sole light source for the experiments. As ejecta reach the laser plane, light pulses stroboscopically illuminate the discrete particles in cross-section; these slices are recorded in stereo by multiple high-speed cameras.

Preliminary Experiments and Discussion:

A suite of impact experiments designed to study the high speed component of impact ejecta was performed at the NASA Ames Vertical Gun Range (AVGR) in Moffett Field, CA (Figure 1). In this study, aluminum projectiles were launched orthogonally into granular targets. Particle Tracking Velocimetry (PTV) techniques were developed and employed to non-intrusively measure the velocity, position, and number of particles in the profile of the ejecta curtain to high spatial and temporal resolution. High-speed cameras (>15,000 frames per second or fps) allow measurements of particle velocity over a significant dynamic range from ~700 m/s for the fastest material to a few meters per second. See [1 for a full description of the development and application of the technique.

Several target materials were employed, including a) regolith-like simulant materials (such as air-fall pumice dust), b) highly compressible targets (e.g., perlite) and c) mixtures of materials such as Ottowa sand with a smaller grain size or resin mixed in to adjust cohesion and friction. The airfall pumice dust (grain sizes ranging from ~ 10μm to ~ 100μm with a bimodal distribution centered at 25μm and 85μm; bulk δt = 1.28 to 1.5g/cm^3, depending on compaction) is a realistic analog for planetary regolith since it is moderately compressible and composed of coarse, heterogeneous, agglutinitic particles that exhibit a high degree of cohesiveness under static conditions that loose bulk strength under extension behind the shock [3]. The size of the pumice dust particles presents a resolution challenge to the cameras; however, neutral density tracers are seeded into the target (as previously used during LCROSS studies).

Preliminary results from our study are presented in Figure 2. The ejecta velocity and launch angle distribution were measured for 1) the canonical sand target, 2) airfall pumice dust and 3) sand grains mixed with resin beads and baked in a kiln to form a block of cemented sand. This target exhibits significant strength, and is intended to be analogous to an ice-welded regolith type material. While the first two target materials form craters arrested by gravity (e.g., the final size of the crater is determined by the minimum ballistic speed to launch material over the crater wall), the welded target forms a "strength-controlled" crater arrested by the internal strength of the material. All experiments were performed under vacuum conditions (< 0.5 Torr of atmosphere).

While the velocity of the ejecta exhibits a dependence on target material, the most profound effect appears in the constraint on ejection angles (Fig. 2). The sand target is ejected close to the nominally expected 45°; however, the pumice target exhibits uniformly lower ejection angles consistent with a shallower depth of coupling (equivalent to depth of burst in explosions). The consolidated target, on the other hand, exhibits considerably higher ejection angles (>60°) throughout the measurement period. When the shock pressure decays to below the yield strength of the resin, large spall plates are produced at similar ejection angles before the termination of crater growth.

While this work represents a first look at these effects on the high-speed component of the ejecta distribution for vertical impacts, the extension to oblique incidence during this study is essential for a more complete and accurate understanding of the ejecta on planetary bodies.

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References:

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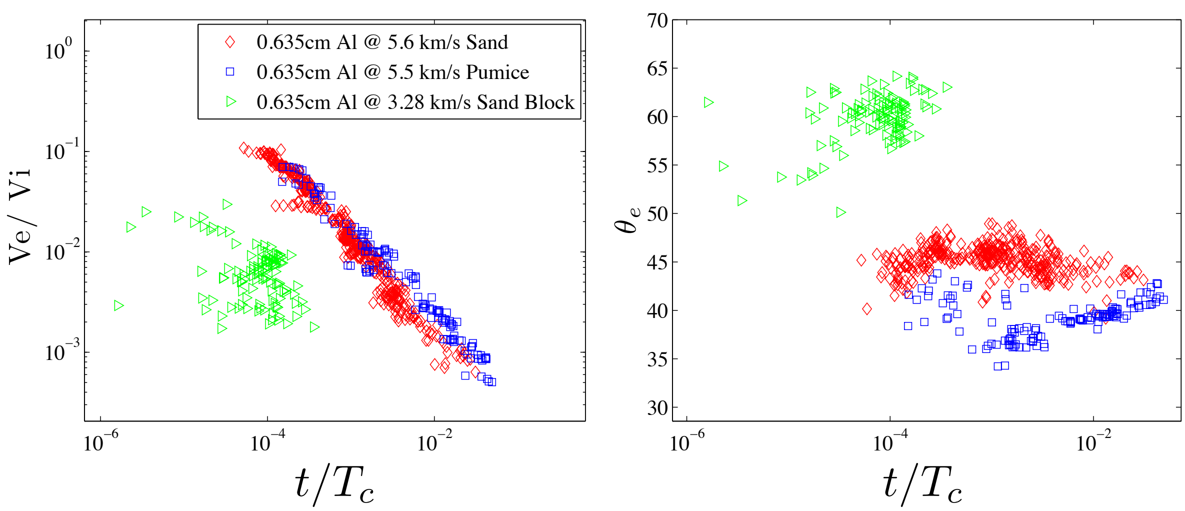

Figure 2. Velocity (left) and ejection angle (right) of ejecta from vertical impact experiments into sand, regolith-simulant (air fall pumice dust) and a cohesive sand block. Ejecta velocity Ve is scaled to the impact velocity V i; time after impact t is scaled to the total time of crater formation Tc. Adapted from Hermalyn and Schultz, 2011.