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Scaling analysis of cavity morphology and disruption threshold for highly porous targets

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The morphology of the cavity formed by an impact can be dependent on parameters such as porosity, bulk density and strength of target bodies and size, bulk density, strength and impact velocity of impactors. Laboratory impact experiments have been conducted and cavity diameter and depth have been studied in previous studies in which highly porous targets up to 60% in porosity were used (e.g. gypsum, sintered glass and snow). Based on recent spacecraft missions and ground-based observation, it is shown that small bodies have even higher bulk porosities up to 86% (Consolmagno et al., 2008). Experiments using further highly porous targets are necessary for understanding collisional evolution of such bodies in the formation period. We study cavity morphology of highly porous targets and compile the result with previous studies. We also study disruption threshold of targets and compile the results.

We prepared porous targets with three different porosities, which have porosity of 94%, 87% and 80% (Okamoto et al.,2013). Various projectiles with different density and strength were used; titanium, aluminum, stainless steel and nylon spheres of 1 and 3.2 mm in diameter, and basalt cylinder of 3.2 mm in diameter and 2.0 mm in height. The impact velocity was ranged from 1.7 to 7.2 km/s.

The track was long and thin, in carrot-shape, when the projectile was intact, while it was short and thick, in bulb-shape, when the projectile was fragmented. We report the results of bulb-shape cavity in this presentation.

We apply crater scaling law in strength regime for maximum diameter and entrance hole diameter of the cavity. We compile data of previous studies and ours to obtain empirical relationships. A correlation is shown between the distance from entrance hole to maximum diameter and characteristic depth where initial kinetic energy of projectile becomes 1/e. Characteristic length is a function of drag coefficient. Since the drag coefficient depends on the fragmentation degree of projectile, it is shown that disruption of projectile affects the distance from the entrance hole to the maximum diameter.

Volume, maximum diameter and depth of cavity during its growth were measured on flash X-ray images. Normalized cavity volume and time (Schmidt and Housen., 1987) are applied for the analyses of the results. They have a power law relationship. The power law index for shots with larger density ratio (target density / projectile density) is slightly larger than those with smaller density ratio. Similarly power law relationships between normalized depth of cavity, maximum diameter and normalized time were obtained, respectively. The power indices are consistent of the power index determined for the normalized volume and time. Thus the growth of cavity volume can be explained by growth of maximum diameter and depth.

The threshold energy density for disruption $Q*$is defined by energy density leading to a largest remnant having half the mass of the target. $Q*$increases slightly with porosity of the targets. $Q*$for the targets with equal diameter-height ratio is slightly larger than those with longer shape (diameter /height=0.5). In this presentation, we will discuss scaling of $Q*$with various previous study.

Keywords: impact experiment, small body, crater, catastrophic disruption