

Catastrophic disruption of layered targets simulating parent bodies of C-type asteroids : Development of Measurement Method of Velocity Distribution for Impact Fragments by Digital Image Correlation Method

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Planetesimals are believed to have evolved into planets via collisional disruption and re-accumulation processes of fragments. In order to understand the collisional disruption phenomena in an early evolutionary process, impact strength Q^* , defined as a critical specific energy of which when one-half of the original target mass remains as a largest fragment, has been used. This Q^* is represented as Q_d^* in the gravity-dominated which gravity controls the re-accumulation of fragments rather than the material strength for objects larger than 100m in size. The Q_d^* has been estimated through numerical simulations, but it needs to be verified by laboratory experiments because the Q_d^* shown in previous studies fluctuates from one another.

In order to verify Q_d^* by laboratory experiments, it is necessary to determine the mass-velocity distribution for all the fragments generated by impact fracture. The fragment tracking method using a high-speed camera can only measure the fragments ejected from the target surface, so it has been difficult to verify Q_d^* by laboratory experiments. In this study, we will conduct an impact experiment on a hemisphere, and analyze the cross-section of the hemisphere by Digital Image Correlation (DIC) analysis to obtain the internal particle velocity distribution. We also aim to establish a method to determine the mass-velocity distribution for all impact fragments generated from the target.

Impact experiments were conducted by a two-stage light-gas gun set at Kobe University. We used a polycarbonate projectile (the diameter of 4.7 mm) while impact velocity was varied from 2.6 to 4.0 km s⁻¹. Since planetesimals are expected to have various porosities and internal structures depending on the thermal evolution process, we used layered target samples with aqueous alteration cores and porous mantles and porous homogeneous target samples. Layered target samples were prepared using 2:1 mixture of sand and gypsum for mantle and 3:1 mixture of bentonite and silicone oil (10⁵ cP at 25°C) for core. The diameter for each layered target sample is 60mm with a core diameter of 30mm and the porosity of mantle part is 38%. Homogeneous target sample was also prepared using 2:1 mixture of sand and gypsum and had the diameter of 60mm. For the DIC analysis, the cross section of the hemispherical target was sprayed with speckle patterns. The impact disruption was observed by a high-speed camera at 10⁵-2×10⁵ fps.

Experimental results on the layered target showed that both of the core and mantle are finely fractured and the largest fragments at catastrophic disruption were from the mantle part. The fracture of the core was confirmed to be ductile fracture with plastic deformation and that of the mantle was tensile fracture as in the homogeneous target. The impact strength Q_s^* of the layered target was 226 J kg⁻¹. This Q_s^* is one order of magnitude smaller than that of the homogeneous target similar to the mantle component. From the DIC analysis, using the imaging data up to 1ms after the impact, the internal velocity distribution obtained for each target was found to be slowest near the antipodal point, ejecting in the same direction as the projectile's impact direction. The region near the impact point ejected in the opposite direction as the projectile with high velocity and the core near the impact point of the layered target also ejected with high velocity. The internal velocity distribution in the homogeneous target showed that the shock or the

stress wave propagates concentrically from the impact point. The internal velocity distribution in the layered target showed a gap in the displacement and the stress reflection at the core-mantle boundary near the impact point. The results of internal velocity distribution obtained by the DIC analysis are consistent with that obtained by the visual tracking of specific points, so that the DIC analysis can be used to determine the internal velocity distribution.

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