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Measurements of fragment velocities in catastrophic disruptions of core-mantle bodies.

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The fragment velocity in collisional breakup of small bodies is one of the most crucial parameters to elucidate the planetary accretion processes. Hypervelocity impact experiments using homogenous materials such as basalts and porous gypsum have been conducted to study the velocity of disrupted fragments of small bodies with homogenous structure. Meanwhile, the layered structures may be very common in small bodies because a layered body with core-mantle structure could be formed as a result of internal thermal evolution. Thus, the impact disruption of thermally evolved planetesimals with sintered core-porous mantle structure is important to clarify the origin of small bodies such as asteroids. Okamoto and Arakawa (2008) clarified that energy fraction of core and mantle controls the collisional outcomes of core-mantle targets. However, it is not clear how fragment velocities of core-mantle targets depend on the energy fraction of core and mantle. So, we conducted impact experiments of spherical targets with glass cores covered with porous gypsum mantle in order to study the fragment velocities of thermally evolved planetesimals.

Impact experiments using a two-stage light gas gun were carried out at Nagoya University. The specific energy (Q), defined as projectile kinetic energy imparted per unit target mass, was between 1 x 10^3 and 4 x 10^4 J/kg. We prepared core-mantle targets with various core/target mass ratios (R) to simulate the various degrees of the internal evolution. Soda-lime glass (or quartz) and porous gypsum were used as analogs of the sintered core and porous mantle, respectively. In the case of R of 0 and 1, the targets are homogenous gypsum and glass (or quartz) targets with spherical shape, respectively. The collisional disruption was observed by using high-speed photography. Then we measured the velocities of impact fragments of core-mantle targets as a result of the collision.

The fragment velocity at the antipode of the impact site was derived from high-speed photography as a representative fragment velocity of the disrupted target. The previous data of gypsum showed us that the antipodal velocity could be several times smaller than that of basalt (Nakamura et al., 1992). This is due to rapid attenuation of shock wave in porous media. We can recognize the material dependence of fragment velocity. The antipodal velocity of core-mantle target spread between glass data and gypsum data at the same specific energy. The antipodal velocity depends on the internal structure: the velocity increases with the increase of R and corresponds to the data of homogenous glass sphere at high R whereas the velocity is similar to the data of homogenous gypsum sphere at low R. This means the fragment velocity of core-mantle target is controlled by the energy partitioned into core and mantle parts. The energy fraction, f, consumed by the disruption of the glass core is defined by the ratio of the kinetic energy applied to the core to the initial kinetic energy of the projectile. The f was estimated from the effective specific energy achieved in the core, which is different among the targets with various R at the same specific energy (Q). We estimated the antipodal velocities among various R by using the energy fraction, and semi-theoretically investigated the relationship between R and antipodal velocity. The estimation showed a good agreement with our experimental results. Hence, we can recognize the energy fraction is a good parameter for describing the fragment velocity of core-mantle body.