Experimental study on impact disruption for low strength target and implication for effect of tensile strength on impact strength

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Asteroids could be composed of various materials based on the study of meteorite parent bodies. S-type and C-type asteroids are predicted to be composed of mm-sized chondrules and μm-sized matrix which are the constituents of chondrites. Some of C-type and S-type asteroids have been observed to have a large porosity inside. The impact strength is one of the most important physical properties of asteroids because it could determine the evolution of the size-frequency distribution of asteroid. The impact strength strongly depends on the asteroid size and it is dominated by the material strength of the bodies at the size smaller than 100m. In laboratory experiments, a lot of studies have been conducted for rock, ice, and their porous materials to investigate the effects of material strength on the impact strength. However, the impact experiments using the target with simulating asteroids with the strength continuously changed and with low tensile strength simulating asteroids have been hardly conducted so far.

In this study, we conducted impact experiments using the targets simulating asteroids composed of chondrules, matrix and pore and changed the internal structure of the target such as matrix contents and porosity; the tensile strength was changed about two orders of magnitude, then we studied the relationship between the internal structure and the impact strength(Q*).

Impact experiments were conducted by using two-stage light gas gun at Kobe University, and we used a polycarbonate projectile with the size of 4.7mm and a nylon projectile with the size of 2mm. They were lunched at the impact velocity from 0.9km/s to 5.7km/s, and impacted at a head-on collision. Spherical targets with the size of 40mm, 60mm and 80mm were prepared by using quartz sands with the size of 100μm and porous gypsum, and they were mixed with various mass ratio of quartz to gypsum at 2:1, 4:1, 8:1 and 20:1. The tensile strength of these materials (Y_t) was measured by using Brazilian test. The impact disruption was observed by a high-speed camera at 10^5 FPS.

Brazilian tests showed that tensile strength of the targets decreased from 800kPa to 10kPa with decreasing gypsum mass contents. The impact experiments gave the relationship between the specific energy (Q: kinetic energy of projectile / original target mass) and the normalized largest fragment mass (m_l/M_t), and this relationship is described by the equation: m_l/M_t=AQ^-b. The constant A changed from 10^3.6 to 10^1.2 and the constant b changed from 1.3 to 0.6 with the decrease of the gypsum mass contents. Therefore, the Q* was found to change from 1900J/kg to 100J/kg with the decrease of the gypsum mass contents. This means that the Q* is directly proportional to the tensile strength. On the other hand, the ejection velocity at the antipodal point of the target (V_a), which was measured by using high-speed images, had a power-law relationship (V_a=10^-2.0Q^0.7) with the specific energy, Q, and the V_a was found to be independent of tensile strength.

Finally,in order to discuss the scaling law for the catastrophic disruption of a targets mixed with quartz and gypsum, we investigated the relationship between A non-dimensional impact strength(P_I) and m_l/M_t. P_I is defined as the ratio of the target tensile strength to the antipodal pressure, and is expected to scale the difference of tensile strength. As a result, the relationship between P_I and the m_l/M_t was shown by P_I=C(m_l/M_t)^-d. However, we found two different relationships in this empirical equation. When the mass ratios of quartz to gypsum are 2:1 and 4:1, the constants C and d are derived to be $10^{0.3}$ and 1.2, respectively, and when the mass ratios of quartz to gypsum are 8:1 and 20:1, the constants C and d are derived to be $10^{1.0}$ and 1.5, respectively.

Keywords: impact disruption, low strength target, impact strength