Experimental study on collision destruction simulating the primitive meteorite parent body

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We studied the impact strength of weak brittle materials changing the strength continuously from 40kPa to 800kPa, and found that the impact strength could be well scaled by using the non-dimensional impact strength.

Asteroids are believed to be constructed from various materials based on the long-term study related to meteorites. The components of S-type and C-type asteroids could be composed of chondrules and matrix; the chondrules are sub-mm size glass spherules and the matrix could be micron-size fine grained materials such as phyllosilicates and lithic fragments etc. Moreover, these components could have a wide range of porosity inside because they might be residual pore during the compaction process of planetesimals or relics of water ice or volatiles escaping from these bodies. Impact strength is one of the most important physical properties of asteroids because it could control the evolution of the size-frequency distribution of asteroids at the asteroid belt. The impact strength strongly depends on the asteroid size and it is dominated by the material strength at the size smaller than 100m, so that the impact strength should be determined by the laboratory experiments. Therefore, a lot of research have been conducted for rock, ice, and porous materials to investigate the material dependence, however the impact experiments using the target with the strength continuously changed have been hardly conducted so far. Then, we prepared the targets simulating asteroids composed of chondrules, matrix and pore and changed the internal structure of the target such as matrix ratio and porosity; the tensile strength was changed more than one order of magnitude, then we studied the relationship between the internal structure and the impact strength.

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 and they were lunched at the velocity from 0.9km/s to 5.7km/s. The impact was conducted at a head-on collision. A spherical target with the size of 60mm were prepared by using quartz sands with the size of 100 μm and porous gypsum, and they are mixed with various mass ratio of quarts to gypsum from 2:1 to 8:1. The tensile strength of these materials (Y_t) was measured by using Brazilian test and it was found that the tensile strength changed from 40kPa to 800kPa with the increase of the gypsum mass ratio. The impact disruption was observed by a high-speed camera at 10^5fps.

The impact strength (Q^*) was determined by using a largest fragment mass for each shot, and Q^* was found to change from 400J/kg to 1900J/kg with the increase of the gypsum mass ratio. This means that the Q^* is directly proportional to the tensile strength. However, the ejection velocity at an antipodal point (v_a), which was measured by using high-speed images, showed the almost similar results, irrespective of the tensile strength. A non-dimensional impact strength (P_I) is defined as the ratio of the target tensile strength to the antipodal pressure such as $P_I=Y_t/P_a$, where P_a is calculated by $\rho C_b v_a/2$. This P_I was proposed to scale the target with the different tensile strength. Then, the relationship between the largest fragment mass and P_I was examined to discuss the P_I scaling law for the catastrophic disruption. We found that P_I is able to scale the largest fragment data very well, and this might mean that P_I could be applicable to asteroid components composed of weak brittle materials.

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