Impact cratering experiments on glass beads with bead size frequency distribution: Implications for cratering process on asteroid Ryugu

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Some impact craters with a diameter of a few hundred meters are found on asteroid Ryugu while there are few small craters of < several meters on the asteroid. Many boulders are found on Ryugu and they have the size frequency distribution similar to that of impact fragments obtained by the impact experiments of rocky materials [1]. When an impactor collided with a larger boulder compared with the impactor size, the boulder could be disrupted but the crater might not form. Some researchers conducted impact experiments on granular targets with a particle size larger than the projectile size and they found that the crater radius became smaller as the size ratio of the target particle to the projectile was larger [e.g., 2]. In this study, we conducted impact cratering experiments on granular targets having the size frequency distribution similar to that of boulders on Ryugu to examine the relationship between the particle size frequency distribution and the crater size.

We conducted cratering experiments by using a one-stage light gas gun at Kobe University and a two-stage light gas gun at ISAS. We used glass beads having the diameters of 0.1, 1, 3, and 10 mm as a target and prepared four types of target; two targets consist of one size of glass bead (0.1 or 3 mm glass beads) and the others consist of mixing three (1-10 mm) or four (0.1-10 mm) different-sized glass beads with the same mass ratio. We used only four glass bead mixing target at ISAS. At Kobe University, the stainless-steel spheres with a diameter of 2 and 3 mm were used as a projectile and the impact velocity was changed from 53 to 181 m/s. At ISAS, the aluminum projectile with a diameter of 1 mm was used and the impact velocity was changed from 1.2 to 4.4 km/s. The collisional phenomena were recorded by high speed camera to observe the rebound of the projectile and the ejection of glass beads.

We observed the ejection of glass beads from the target surface. In the case of 0.1-mm bead target, the beads were ejected radially and the corn-shaped ejecta curtain was observed. In the case of 3-mm bead target, some intact beads were ejected at lower speed. In the case of four bead mixing target, some 0.1-mm beads were ejected like a smoke passing through other beads. Furthermore, the projectile rebounded from the target surface in most cases of 3-mm bead target and two mixing bead targets. When the projectile collided with a 10-mm bead, the amount of the ejected beads decreased drastically.

We applied our results to the crater scaling law showing as $\pi_R = a \cdot \pi_2^{-b}$, where π_R is the non-dimensional parameter related to the crater radius, π_2 is the non-dimensional parameter related to the gravity, the projectile size, and the impact velocity, and *a* and *b* are constants. As a result, the π_R of the 0.1-mm bead target was largest. The π_R of the 3-mm bead target and two mixing bead targets matched each other and a little smaller than that of the 0.1-mm bead target when the projectile did not collide with a 10 mm glass bead. Furthermore, the π_R of mixing bead targets was much smaller when the projectile collided with a 10-mm bead.

Finally, we revised the crater scaling law of mixing bead targets by using the scaling law of the 0.1-mm bead target (a=0.58 and b=0.21). In this study, we assumed that the projectile collided with a 3-mm or 10-mm bead and the momentum of the projectile was transferred to the impacted bead, then the bead penetrated into the target slowly and the cavity was formed. On this assumption, we constructed the revised crater scaling law by using the coefficient of the restitution of projectile, *e*, and the momentum conservation law. As a result, we could obtain e=0.5-1 to match our experimental results with the revised crater scaling law.

[1] Satakani et al. (2018), 2nd Aqua Planetology Symposium, Kobe University. [2] Tatsumi & Sugita (2018),

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