

Crater formation and impact-induced seismic shaking in two-layered granular layered targets

*Yuya Yamamoto¹, Masahiko Arakawa², Minami Yasui², Sunao Hasegawa¹, Yusaku Yokota², Reia Kakinoki², Haruna Toyoshima²

1. Japan Aerospace Exploration Agency, 2. Graduate School of Science, Kobe University

It is known that rubble-pile asteroids are common among small asteroids, for example, Itokawa, Ryugu, and Didymos, and their surface are covered by low strength boulders with size distribution. The importance of understanding the geological activity associated with impact events in these bodies is increasing. The surface of Itokawa has a regional distribution of regolith and boulders, with some smooth areas with extremely few boulders. This is thought to be due to the fluidization of regolith on the surface caused by impact-induced seismic shaking. On Ryugu, the SCI crater has a small pit close to the impact point on the crater floor, suggesting that Ryugu subsurface has a layered structure which consists of a relatively hard layer of several hundred Pa covered by a softer cohesionless regolith (Arakawa et al. 2020). On the other hand, unlike Itokawa, Ryugu is covered with boulders globally and no topographic features that could have derived from the vibrations have been identified. There was also little boulder movement due to impact-excited oscillations during the formation of the SCI crater. The difference in the degree of topographic relaxation due to impact-induced seismic shaking between Itokawa and Ryugu might be due to the differences in the physical properties of the constituent particles of the asteroid surface and in their internal structures. In this study, to investigate the effects of the strength and size of the target grains and the layer structure on the crater shape and impact excitation vibrations, we conducted impact experiments on layered targets made of weathered tuff grains of two different sizes.

Cratering experiments were conducted by using vertical gas gun sets at ISAS. A spherical acetate projectile with the size of 1 mm and a spherical Nylon projectile with the size of 4.7 mm was launched at the impact velocity at 4 and 6 km/s. These projectiles were impacted on the target surface at the normal direction. Granular targets were prepared by using weathered tuff granules with the size of 1 to 4 mm (small grains) and the size of 1 to 4 cm (large grains). We set these grains in a tarry with the small grains in the lower layer and the large grains in the upper layer. The thickness of the layers was varied to ensure that upper layer : lower layer = 80:80, 60:100, 50:110, and 30:130 mm. The crush strength of these tuff grains was measured to be about 60 kPa and 13 kPa, respectively. To measure the impact-induced seismic waves at each layer, one accelerometer was embedded in the upper layer and two in the lower layer, at different distances from the impact point.

As a result of an acetate projectile at the impact velocity of 4 km/s, the projectile impacted a large grain target with a diameter of 2 mm, and only one grain was disrupted by penetration. When Nylon projectile was impacted at 4 km/s, the crater size varied with the size and position of the first-impacted target grain, with the crater size decreasing as the projectile impacted the larger grain. In the range of impact velocities in this study, the crater size did not vary with layer thickness. The crater depth-diameter ratio was varied in the range of 0.2-0.4. At the same impact velocity, the shallower the upper layer, the smaller the depth-diameter ratio. At the same upper layer thickness, the depth-diameter ratio decreased with increasing impact velocity. These results suggested that in this study, crater excavation flow is less likely to propagate into the lower layer in a layered target. The magnitude and propagation velocity of the impact-induced seismic waves at each distance from the impact point will also reported in the presentation.

Keywords: crater, regolith, impact-induced seismic shaking, impact experiment, layered target