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Laboratory Experiment on Impact Process of Granular Target under Microgravity: Drag Equation of Projectile Penetration

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Regolith and boulders are observed on the surface of asteroids. These objects could be formed by impact and reaccumulation. For example, images taken by Hayabusa showed that the surface of asteroid Itokawa was divided into rough terrain, mostly consisting of numerous boulders, and smooth terrain composed of fragmental debris with grain sizes (Fujiwara et al. 2006). Itokawa is 300-m sized small asteroid, which has the escape velocity of 10 to 20 cm s^{-1} from the surface and microgravity of 0.1mm s^{-2}. Reaccumulation process would have occurred below the escape velocities, i.e., asteroids of similar size to Itokawa would have reaccumulated at a velocity as low as cm s^{-1} to m s^{-1}. Crater formation process and ejection mechanism under such condition are not fully understood. In this study, to understand reaccumulation process on the surface of asteroids, we conducted low velocity impact experiments of granular target, that is simulated asteroid surface, under microgravity. In this presentation, we focus on drag equations of projectile to understand penetration of boulders into regolith surface of small asteroids.

Glass beads (sphere) and sand (irregular shape) were used as targets. The grain sizes ranged 90-106 micro meters and 355-500 micro meters for glass beads, and 100-180 micro meters and 300-600 micro meters for sand. Aluminum cylinder with diameter of 5 mm and length of 15 mm with a hemispherical tip was used as a projectile. Impact experiment was conducted by a drop tower in Braunschweig University of Technology, Germany. By dropping a projectile and a container filled with the target material with a time interval, low velocity impact under microgravity was achieved (Beitz et al., 2011). Two high-speed cameras are also dropped with the target. Impact velocities were ˜5cm s^{-1}, 23cm s^{-1}, ˜50cm s^{-1} and ambient pressures in the chamber were ˜20 Pa and ˜500 Pa.

Ejecta cone was not clearly observed for sand target whereas it was observed clearly for glass bead target. We measured the distance between the rear edge of projectile and the surface of target on high speed camera images and analyzed the deceleration process of projectile. The result showed that projectile was decelerated more effectively in sand target than in glass bead target. As a first analysis, we applied three equations of motion; drag force is proportional to square of projectile velocity; drag force is proportional to velocity; drag force is proportional to a constant and independent of velocity. The deceleration curve of the drag force proportional to velocity fitted the experimental data better than the other curves. Drag force proportional to velocity was also shown in an impact experiment and numerical simulation of plastic sphere into glass bead target at initial velocity of 70 m s^{-1} (Nakamura et al. 2013). We discuss how the deceleration process depends on target material, grain size of target and impact velocities.