Impact experiments on low strength coarse-grained regolith simulating surface materials on asteroid Ryugu

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Impact cratering is one of the most important physical processes, then we study crater scaling laws and impact induced seismic waves in order to elucidate various flow processes on asteroids caused by impacts. The conventional crater scaling laws are categorized into two regions according to the controlling physics for the crater growth: they are gravity and material strength. A crater formed on regolith layer is surely controlled by the gravity, however when the regolith layer was filled with coarse particles with low mechanical strength, then the several coarse grains might be disrupted to consume the Ek. Thus, the crater size could be affected by the disruptions of the coarse grains. We speculate that not only the gravity but also the grain strength could affect the final crater size. Then, we made cratering experiments by using the target made of weak particles, and studied the effects of the particle strength on the crater scaling law and the impact induced seismic wave.

Experiments: Cratering experiments were conducted by using a gas gun set at Kobe University and ISAS. Granular targets were prepared by using weathered tuff granules with the size of 1 to 4mm (small particle) and the size of 1 to 4cm (large particle). The crush strength of these tuff particles was measured to be about 60 kPa. A spherical projectile with the size of 3mm which is made of iron, zirconia, alumina, glass, and nylon) was lunched at the impact velocity from 40 to 200m/s, and a spherical Al projectile with the size of 2mm was impacted at the impact velocity from 1.2 to 4.5km/s, then these two types of the projectile were impacted on the target surface at the normal direction. Impact cratering process and ejecta curtain growth were observed by a high-speed camera at 10^3-10^5 fps, and the video images were used to analyze ejecta particles to reconstruct the trajectories. After the shot, the crater morphology was recorded and the diameter and the depth were measured. Impact induced seismic waves were measured by using 3 accelerometers (specific frequency is 30kHz) set at different positions from the impact point, and a data logger was used to record the seismic data through charge amplifiers (data acquisition rate is 100kHz) connecting to the accelerometer.

Results: The crater size was found to increase with the projectile kinetic energy (Ek) at lower than 0.14J and at higher than 0.63J, so that the crater size was almost constant among them, and more the crater size obtained at very high Ek was almost on the extrapolated line from the relationship given by the low Ek data. The pi-scaling law was used to construct the relationship between normalized radius (πR) and normalized gravity ($\pi 2$), and πR at small $\pi 2$ was found to be rather smaller than that obtained for sand and glass beads targets, and more πR at large $\pi 2$ was found to be consistent with that for sand and glass beads. More detail analysis tells us that all the data separated into two trends with large offset according to the impact velocity and the projectile material. This offset might be caused by the disruption of several tuff particles. The ejection velocities of each tuff particle were so scattered, then the distinctive relationship between initial position of particle and the ejection velocity was not derived in the low velocity range. The propagation velocity of the impact induced seismic wave was about 30 m/s, and it is 1/3 of that for glass beads. Furthermore, we found that the relationship between the maximum acceleration and the distance from the impact point was about 1/10 of that obtained for glass beads: the seismic wave in the tuff granules attenuated so quickly compared to the glass beads. But, when the distance is normalized by the crater radius, these relationships almost consistent each other, so that the normalized distance could be a good parameter for the scaling of the acceleration of seismic wave.

Keywords: impact cratering experiment, low strength, impact-induced seismic shaking, crater scaling law