Experimental study on propagation process of impact-induced seismic wave in quartz sand simulating asteroid regolith layer

*Kazuma Matsue[1], Masahiko Arakawa[1], Minami Yasui[1], Shota Takano[1], Sunao Hasegawa[2]

1.Graduate School of Science, Kobe University, 2.Institutes of Space and Astronautical Science, JAXA

Planetary explorations in the solar system have revealed that the asteroid surfaces were covered with the regolith layer made of boulders and granular materials. The surface morphologies of asteroids formed on the regolith layer were recently proposed to be modified due to the impact-induced seismic activity. Then, it is important for us to understand the physical mechanism of the impact-induced seismic vibration. Therefore, we carried out impact cratering experiments on quartz sand using a polycarbonate projectile to observe the seismic wave propagating through the sand (Matsue, (JPGU 2015)). Recently, we established a sabot-stopper method to launch various kinds of projectiles at a vertical type two stage light gas gun, then we performed the high-velocity impact experiments using a projectile made of different materials with the diameter of 2mm, and measured the impact-induced seismic wave. Based on the result of this study, we examined the attenuation rate of seismic wave in the quartz sand and the energy partition rate between the projectile kinetic energy and the kinetic energy of the seismic wave.
Impact cratering experiments were conducted by using a single stage vertical gun set at Kobe University and a two-stage vertical gun set at Japan Aerospace Exploration Agency (JAXA). The impact velocity was 0.2-6.9km/s using a polycarbonate projectile and 2,4,5km/s using a projectile made of different materials with a diameter 2mm: glass, aluminum, titanium, zirconia, stainless steel, copper and tungsten carbide. We used a quartz sand target with the particle diameter of 500μm and the bulk density of 1.48g/cm^3. The accelerometers were set on the target surface at different distances from the impact point. After each experiment, we measured the crater profile by using a laser profiler in order to acquire the crater shape quantitatively.
The crater shape formed by the polycarbonate projectile at different impact velocities showed the similarity, irrespective of the velocity, however the similarity was not followed by the results obtained by the projectile with different densities. Then, we found that the ratio of the crater depth to the diameter (d/D) was not constant and depended on the projectile density. On the other hand, the crater size is expressed by the π-scaling law. The impact induced seismic wave was classified into two categories according to the distance from the impact point: at the region far from the impact point, the seismic wave looks like a damped vibration wave, and at the region near the impact point, the seismic wave looks like a single pulse wave. It is noticeable that the peak value of the acceleration changes with the propagation distance: the maximum acceleration, g_{max}, has a power law relationship to the normalized distance x/R, where x is propagation distance and R is crater radius as follows, $g_{max}=10^{2.2\pm0.04}(x/R)^{-3.11\pm0.11}$. We calculated the impact-induced seismic efficiency factor, k; that is, the ratio of the impact-induced seismic energy to the kinetic energy of the projectile. The impact-induced seismic energy was assumed to be the kinetic energy of the quartz sand vibrating at the thin shell region with a width corresponding to one cycle of the seismic wave. As a result, the average of k was obtained to be $(8.1 \pm5.0)\times10^{-5}$ for the polycarbonate projectile impacts.

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