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Experimental study on propagation process of impact-induced seismic wave in quartz sand

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Introduction:

Recent spacecraft surveys clarify that the asteroid surface is covered with regolith made of boulders and pebbles such as that found on asteroid Itokawa by the Hayabusa spacecraft. The surface morphologies of asteroids formed on a regolith layer were found to be modified. For example, high-resolution images of asteroid Eros surface revealed the evidence of downslope movement of a regolith layer, then it could cause the degradation and the erasure of small impact crater. One possible process to explain these observation is the regolith layer collapse caused by seismic reverberation after projectile impacts (Richardson et al.2004, 2005). The impact-induced seismic activity might be the important physical process which affected the morphology change of asteroid regolith surface. Therefore, it is important for us to know the relationship between the impact energy of the projectile body and the impact-induced seismic energy. McGarr et al(1969) conducted the high-speed impact experiments on the loose sand target simulating the lunar surface in order to confirm the detectability of asteroid impacts on the lunar surface by seismographs set on the moon by the Apollo mission. Yasui et al. (in prep) conducted impact experiments at 100m/s on the glass beads target with the mean diameter of 200μm by using various projectiles and studied the decay process of impact-induced seismic wave to clarified the energy transfer efficiency from the impacting projectile to the seismic wave. It is important to study the dependence of the energy transfer efficiency on the different target materials and the impact velocity. So in this study, we carried out impact cratering experiments to observe the seismic wave propagating through the target far from the impact crater crater in different conditions that the quartz sand target was used and the impact velocity was extended up to 7km/s.

Experimental method

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 200m/s for a single-stage gas gun, 1.5-6.9km/s in a two-stage gas gun. We used a quartz sand with the particle diameter of 500μm, density of 1.48g/cm^3. The spherical polycarbonate projectile with the diameter of 4.75mm and the density of 1.2g/cm^3 was used. The target was set in a large vacuum chamber below 10 Pa. The three accelerometers with the charge sensibility of 5.47pC/ms^{-2} and the frequency response of 0.5Hz-10kHz was set on the target surface at different distances from the impact point. The acquired acceleration data of the acceleration were recorded by a data logger with A/D conversion rate of 100 kHz.

Result:

The waveform of impact-induced acceleration recorded by the accelerometers has a single peak and attenuates with time. It is noticeable that the peak value of the acceleration varies with the propagation distance, and the impact-induced seismic wave is found to attenuate with the propagation distance. The maximum acceleration, g_{max}, has a good relationship to the normalized distance x/R, where x is propagation distance and R is crater radius: $g_{max} = 160(x/R)^{?2.98}$, irrespective of the impact velocities for the quartz sand. Furthermore, we examined the propagation velocity of the seismic wave by using the traveling time from the impact point. The seismic wave velocity was obtained to be 75±15m/s for the quartz sand.

Application to asteroid:

According to Richardson et al.2004, the critical physical condition to cause the surface morphology changes can be described by the acceleration of the regolith particles exerted by the seismic wave, and the condition is that the acceleration is greater than the surface gravity acceleration. By determining the distance x where g_{max} is the same as the surface gravity, it is possible to estimate the region where the surface morphology could change when the projectile body is impacted.

Keywords: impact, cratering, impact-induced seismic wave, regolith layer