Experimental study on effect of cohesive force on dynamical evolution of regolith layer due to vibration

*大村 知美[1]、中村 昭子[1]
*Tomomi Omura[1], Akiko Nakamura[1]

1. 神戸大学大学院理学研究科
1. Graduate School of Science,Kobe University

Evolutional history of an asteroid is recorded on regolith layer as geological features. These geological features are changed by thermal environment, impact and impact-induced vibration. The vibration triggers fluidization, convection, and compaction of the regolith layer and alters these geological features. One of examples of the geological features which is explained by these mechanisms is the low number of small craters on Eros and Itokawa. This is thought to be due to erasure of small craters by the impact-induced shaking (Richardson et al., 2004). The evolution of the regolith layer due to vibration includes compaction of the layer structure. On the moon, it is known that the regolith layer is densified by soil pressure and impact-induced vibration (Mitchell et al., 1974). The behavior of granular material due to vibration is characterized by the dimensionless parameter called Γ, which is the maximum vibrational acceleration normalized by gravitational acceleration. For instance, granular convection is triggered at Γ≈1 when Γ is increased (e.g. Garcimartin et al., 2002) and this value has been used to estimate weather the geological feature is changed on asteroids due to vibration. It was also revealed that the filling factor of granular layer compacted by tapping increases till an equilibrium value with Γ under the condition of Γ 1.2 (Phillipe and Bideau, 2002) and it seems possible to characterize the behavior of filling factor of regolith layer caused by vibration using this kind of value. However, the experiments conducted on the earth used millimeter sized particles. In this condition, the effect of interparticle force is enough small to be ignored when compared with the gravitational force. On the other hand, gravitational acceleration is extremely small on asteroids and the particle diameter on asteroids was estimated to be within a range from ~10 μm to centimeter (Gundlach and Blum, 2013). Under this condition, the effect of interparticle force should become significantly large.

In this study, we investigate the effect of cohesive force on the compaction behavior of granular material due to vibration. We used particles smaller than 100 μm as sample powder to mimic the magnitude of effect of interparticle force acting on the particles on asteroids. Sample powder was sieved into a sample die. Samples were tapped by the free fall of the sample die. The vibrational acceleration applied to the sample was controlled by falling height of the die and recorded by an accelerometer which is attached to the die. The maximum acceleration of the pulsed wave ranged from ~150 to 500 m/s^2 (Γ=~15-50). Samples were tapped 10, 30, 50, and 100 times and the filling factor of the sample before and after tapping was calculated from the volume and mass of the samples.

We use spherical glass beads with diameter of 18 μm as one of powder sample. The filling factor of the sample before tapping was ~0.43. The filling factor of sample after 100 times tapping increased with Γ. The filling factor increased with the number of tapping at all cases with different Γ and didn't achieve the equilibrium even when the sample was tapped 100 times. On the other hand, in previous study (Phillipe and Bideau 2002), 100 times tapping is enough to achieve the equilibrium filling factor when the applied tapping acceleration was larger than Γ~3 (Phillipe and Bideau, 2002). It means that the acceleration larger than Γ=50 is needed to achieve the equilibrium filling factor by 100 times tapping for the powder bed consisting of cohesive particles. It is suggested that under the microgravity environment, where the interparticle force is dominant, the value of Γ that characterizes the phenomena due to vibration may change in orders of magnitude.

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