Experimental study on the effects of the interparticle force on the compaction of regolith layer due to vibration

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Many, if not most, surface of asteroids are covered with regolith, which is unconsolidated debris. Observations have shown that the regolith has a filling factor of ~0.4-0.6 *(e.g. Busch et al., 2007; Ostro et al., 2004)* and that this value is different for each asteroid. The filling factor of the regolith affects the results of impacts and the thermal evolution of asteroids. It can be changed by the thermal environment, impacts and the impact-induced vibration. Asteroids experience a lot of impacts during their lifetime, and impact-induced vibration may change the filling factor of the regolith after asteroid formation. The compaction behavior of granular material due to vibration is characterized by the dimensionless parameter Γ *(e.g. Phillipe and Bideau, 2002)*, which is the maximum vibrational acceleration normalized by the gravitational acceleration. The vibrational acceleration required to attain a certain Γ is very small on asteroids because of their extremely low gravity, and small impacts are thought to be sufficient to change the filling factor of the regolith. However, the Γ dependence of vibrational phenomena is obtained by experiments conducted under Earth gravity using relatively coarse (~mm) particles. The interparticle force acting on the particles is negligible compared to the gravitational force under this condition. However, under the low gravity of an asteroid, the effect of gravitational force acting on regolith particle is very small and the effect of the interparticle force becomes significant.

In this study, we investigated the effects of interparticle force on the compaction of regoliths under microgravity. We used particles smaller than 100 μm as a sample powder to mimic the regolith layer under microgravity because their particle mass is very small and the interparticle force is effective. The sample powder was sieved into the sample die and tapped by the free fall of the sample die. The vibrational acceleration applied to the sample was controlled by the falling height of the die and recorded by an accelerometer that was attached to the die. The maximum accelerations of the pulsed waves were 270 and 680 m/s^2 (Γ=28 and 69, respectively). Samples were tapped 10, 30, 50, 100, 500 and 1000 times and the filling factor of the sample before and after tapping was calculated based on the volume and mass of the samples.

We used spherical glass beads with a diameter of 50 μm as one of the sample powders. For this sample, the interparticle force acting on the particles was ~10^3 times larger than the gravitational force under Earth gravity. This is similar in strength to a 5 mm particle under the gravitational acceleration of 10^{-3} m/s^2. The filling factor of the sample before tapping was ~0.57 and it increased with the number of taps. The filling factor reached steady state after a certain number of tapping. In the case of Γ=69, the filling factor reached a steady state of ~0.63 after ~500 times tapping. We compared these filling factors and their evolutionary timescale with the results of a previous study that used millimeter sized particles. In the previous study, this steady state filling factor was obtained at a Γ smaller than ~1.3, and this timescale was obtained in the case of $1.8 \lesssim \Gamma \lesssim 2.3$ *(Phillipe and Bideau, 2003)*. This suggests that under a microgravity environment, where the interparticle force is effective, it is not suitable to use the same value of Γ obtained under Earth gravity to estimate the evolution of the filling factor on asteroids, and the interparticle force should be considered as a parameter.