Laboratory and numerical study of rock particle behavior to understand the surface evolution of small bodies

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Small celestial bodies are of increasing interest to the scientific community because of their importance in understanding the formation and evolution of the Solar System. The asteroids that have been visited by spacecraft are covered by a loose granular material, which is often referred to as regolith. Segregation of the regolith is particularly evident on the asteroid Itokawa, suggesting that the surface materials may have migrated and segregated possibly due to seismic motion caused by celestial impacts. To critically test this hypothesis, it is necessary to gain a better understanding of the behavior of granular particles repeatedly exposed to external energy sources. The segregation of granular materials under vibration has been studied extensively, while only a few studies have used irregularly shaped particles, which is often the case with naturally occurring particles such as the regolith of small bodies. Also, most studies use a narrow range of particle sizes confined in a small container, where the effect of the interaction with the wall surface becomes the primary issue. However, such a condition is usually not achieved for naturally occurring particles. Therefore, in this study, we perform laboratory and numerical experiments to determine the behavior of a regolith-like granular system composed of particles with complex shapes and a wide size-frequency distribution in response to external energy, such as vibration. We develop an experimental system, where the interaction between the wall and the particles does not affect the behavior of the entire granular material. We then numerically study the effects of friction and particle shape on the behavior of the particles. We find that particles with certain frictional properties exhibit convection regardless of their shape. The convection pattern is as follows: the particles rise at the center of the granular material, are exposed to the surface, and then move radially parallel to the surface, before descending in a circumferential descending region. In addition, three particle parameters have important effects on particle stability in the observed convection phenomena: particle-particle friction, three-axial length ratio, and angularity. We conclude that the velocity of particle motion in convection is sensitive to these parameters. This seems to reveal another complexity of granular physics.

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