Scaling and Structure of The Convective Velocity in A Vertically Vibrated Granular Bed

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Miyamoto et al. reported that migrations and sorting on surface of the asteroid Itokawa could result from gravel fluidization induced by vibration caused by an impact [1]. It has not been considered that such phenomena occur under microgravity. In order to understand the mechanism of such phenomena, fundamental physics of vibrated granular matter must be revealed. When granular materials such as regolith are shaken, we can see various phenomena, e.g. convection, segregation, pattern formation, and so on. In this study, we study the granular convection by the experiment. Although many literatures have reported on both experimental and numerical studies of granular convection [2-5], most of them have used spherical grains as constituents. In general, geophysically relevant sand grains are not spherical. Thus, we use rough shaped sand as well as spherical glass beads, to examine the influence of grains shape to the granular convection. In the experiment, we investigate the global structure of granular convection and measure the convective velocity, and estimate the relation between the convective velocity and gravity with dimensional analysis.

The experimental setup consists of a cylinder made by plexiglass of 75 mm inner diameter and 150 mm height, which is mounted on an electromechanical vibration exciter (EMIC 513-B/A). The vibrator frequency f is varied from 10 to 300 Hz and the dimensionless vibrational acceleration is varied from 2 to 6. The grains used are glass beads (0.8 mm in diameter) and JIS (Japan Industry Standard) standard sand (from 0.71 mm and 1.4 mm in diameter). The height of granular layer is fixed to 50 mm. We use a high-speed camera (Photoron SA-5) with a macro lens to record the motion of grains at 1000 fps. PIV (Particle imaging velocimetry) method is used to compute the convective velocities on the side wall of the container.

We find that the global structure of convection shows a transition from single cycle roll to doughnut like roll as f increases. In the former, grains rise up on the one side wall and fall down on the other side wall. In the latter, grains rise up at the center of container and fall down on all over the wall. We also find that the convective velocity field of sand grain seems to have spatial and temporal inhomogeneities.

By the systematic dimension analysis, we find that the maximum convective velocity can be scaled by the characteristic velocities of gravity and vibration. The obtained scaling implies that the convective velocity decrease as the gravitational acceleration is reduced.

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