Understanding characteristics of granular convection by visualizing rotation of individual particles in tapped granular bed

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Granular material is defined by a collection of athermal particles, and it sometimes behaves like fluid despite solid property of each particle [1]. One of the fluid-like behaviors is convection of granular bed induced by vertical vibration, and it can be observed in laboratory experiments with various types of particles and vibrations. Recent studies propose that granular convection relates to resurfacing process of small asteroids covered with regolith (e.g., [2]). Thus the mechanism of the granular convection is not only physical but also geophysical problem.

One of the ways to understand the mechanism of granular convection is to monitor all degrees of freedom (DOF) of individual particles as well as to monitor the collective motion such as convection. The considered DOF of individual particles are (1) translational and (2) rotational velocities of each particle and (3) contact forces applied between particles besides body forces. However, in most of laboratory experiments, only translational velocities have been monitored (e.g., [3]). Recent study has visualized contact forces by using photoelastic discs [4,5]. However, they have not monitored rotational motion of particles. Particularly, although the particle rotation has not been measured well so far, it could significantly relate to the mechanism of granular convection.

In this study, we are going to monitor all these DOF in granular convection by using photoelastic discs. We use bidisperse photoelastic discs to make two-dimensional granular layer. Then, vertical intermittent tapping is applied to the granular layer by using an electromagnetic vibrator. We conducted experiments with several tapping conditions (duration and the maximum acceleration of tapping impulse). The photoelastic discs are painted with a fluorescent paint along the diameter to visualize the rotation by using ultraviolet-light illumination [6].

All DOF of individual particles in each tapping can be obtained as follows. Figure shows three types of pictures taken in this experiment. They are taken by using (a) white light source, (b) ultraviolet-light illumination, and (c) white light source under cross-polarized mode, respectively. Translational velocity and associated vorticity of granular convection are obtained by analyzing (a). The rotational velocities of individual particles are obtained by analyzing (b). In addition, the contact forces can be computed by (c). As the first step, we will focus on the analysis of (a) and (b) in this study, and understand the relation between granular convection and rotational velocities of individual particles.

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Figure. Samples of photos taken by using (a) white light source, (b) ultraviolet-light illumination, and (c) white light source under cross-polarized mode, respectively.

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