Scaling of convective velocity in intermittently vibrated granular packing

*NAOKI IIKAWA[1], Mahesh M Bandi[2], Hiroaki Katsuragi[1]

1. Nagoya University , 2. OIST

When a granular packing is mechanically vibrated in a container, convective motion of constituent particles is often induced. This peculiar phenomenon is called ‘granular convection’. Recent studies have suggested that granular convection could occur on the surface of small asteroids such as Itokawa [1,2]. To quantitatively examine the feasibility of asteroidal granular convection, a scaling relation for granular convective velocity has been experimentally developed [3]. However, this scaling relation has been obtained under the steady vibration condition although the actual asteroidal vibration events should be induced by very intermittent meteorite impacts. The scaling relation for convective velocity in an intermittently vibrated granular packing has not been quantitatively obtained so far. Thus, it is necessary to study the granular convective velocity in an intermittently vibrated granular packing. Therefore, in this study, we experimentally measured the granular convective velocity in a two-dimensional granular packing under the successive intermittent vibrations, (tappings). And the obtained velocity scaling is compared with the scaling obtained with a steady vibration.

In the experiment, a two-dimensional chamber filled with bi-disperse disks (diameter: = 10 or 15 mm) is vertically mounted on an electromagnetic vibrator. Then the chamber is subject to 1,000 successive tappings (each tapping event consists of a single period of sinusoidal oscillation). The interval between these tappings is fixed at 2 s. We define the tapping strength Γ as $\Gamma = A(2\pi f)^2/g$, where A is vibration amplitude, f is its frequency, and g is gravitational acceleration (*i. e.* Γ means the ratio of maximum tapping acceleration and gravitational acceleration). Γ is systematically varied as $\Gamma = 2.5, 5, 10, 20$, and f is also varied in the range of $f = 50, 100, 200$ Hz.

In the analysis, we calculated particle velocities using by the particle tracking velocimetry method. In addition, we calculated vorticity field from each particle velocity so that we quantitatively evaluated the occurrence of convective motion in the intermittently tapped granular packing. When the particles form convective motion, we first normalize the mean particle’s velocity v as $v^* = v/(gd)^{1/2}$, where $(gd)^{1/2}$ is the characteristic velocity created by gravity and particle size. We then constructed the scaling relationship between v^* and the dimensionless parameter $S = (2\pi Af)^2/gd$ (Here, S denotes the balance between the squared tapping-velocity and the squared characteristic velocity created by gravity).

As a result, we found a scaling relationship between v^* and S for the intermittently tapped granular packing: $v^* \sim S^{0.56}$ (Fig.1). This result indicates that v is roughly scaled by $S^{1/2}$ which is almost identical to the scaling obtained with a steady vibration. Therefore, we conclude the intermittency of oscillation doesn’t affect the velocity of granular convection.

[1] H. Miyamoto *et al.* , Science **316**, 1011 (2007).
[2] T. M. Yamada *et al.* , Icarus **272**, 165 (2016).
[3] T. M. Yamada and H. Katsuragi, Planet. Space Sci. **100**, 79 (2014).

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