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Effect of liquid viscosity on the shaking condition required for the granular medium fluidization

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A liquid-immersed two-layered size-graded granular medium, where the upper layer forms a permeability barrier against the upward percolating liquid, is shaken vertically. A gravitational instability occurs above a critical acceleration (Γ_c) and its amplitude grows. We have previously reported the results of experiments for the water-immersed case (Yasuda & Sumita, 2014). Here we proceed to study the viscosity dependence by conducting experiments for the case in which the liquid is more viscous such that the Stokes velocity is smaller by a factor of 17, and shake it for a corresponding longer time span. We vary the acceleration and frequency of the shaking by 2 and 3 orders of magnitude, respectively, and find that fluidization occurs most efficiently at a frequency band centered around 100 Hz. Importantly, the high viscosity (HV) case has a smaller Γ_c. In addition the instability of the HV case has a shorter wavelength, and when scaled using the Stokes velocity, the growth rate is faster. The critical acceleration becoming minimum at 100 Hz can be interpreted as follows. For a flame structure to form, a sufficient amount of liquid should accumulate at the 2-layer boundary. A combined condition of energy and jerk of shaking exceeding their critical values, can explain this frequency dependence. A smaller critical acceleration for the HV case can be interpreted as a result of viscous lubrication. To confirm this, we conducted shear stress controlled fluidization experiments of the jammed particles using a rheometer. We indeed find that the fluidization occurs under a smaller shear stress for the HV case. Our experimental situation in which the gravitational instability occurs can be approximated as a thin low density, low viscosity layer underlying a thick high density, high viscosity (with a viscosity which is $\times\ \epsilon$ that of the low viscosity layer) layer. For this situation, linear stability analysis for viscous fluids indicate that the wavelength (λ) scales as $\lambda \propto \epsilon^{1/3}$. Our experimental results suggest that ϵ becomes smaller for HV case such that λ becomes shorter. A smaller ϵ value for HV case is consistent with our result indicating that fluidization occurs under a smaller acceleration.

Our experiments indicate that if shaken for a sufficiently long time, fluidization of the HV case occurs under a smaller acceleration because of viscous lubrication. This implies that fluidization of magma is more susceptible to fluidization than the water-saturated case. This may be relevant to liquefaction of magma and earthquake triggering of volcanic eruption.

Reference

Yasuda, N., Sumita, I. 2014, Shaking conditions required for flame structure formation in a water-immersed granular medium, Progress in Earth and Planetary Science, 1:13.

Keywords: earthquakes, liquefaction, fluidization, magma, triggered eruption, shaking experiments