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Intruders size-segregating under oscillating shear flows

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Granular geophysical flows are composed by particles of different sizes that segregate under the action of gravity and shear-induced dilatancy. Size segregation is the physical process by which small particle percolate through gaps left by the relative movement of grains (kinetic sieving) and posterior ascent of large particles, squeezed upwards by surrounding small particles (squeeze expulsion). The development of simple continuum models for particle-size segregation has provided a better understanding, nevertheless determining the functional dependance of the segregation rates remains as a challenge. The present work investigates particle-size segregation through simple shear experiments of bidisperse granular materials.

The experimental setup consists of two parallel plates that rotate over pivot points to generate an oscillatory shear flow within the granular media. Simple shear flows have been used extensively to study granular segregation. For the present work, two different shear cells have been used: a 2D and a 3D cell. The 2D cell width ranges from 55 to 280 mm, in 15 mm steps. This cell is filled with Polyoxymethylene (POM) disks of fixed diameter and a single intruder of different size, all of them have the same thickness as the cell gap ($\sim$ 5 mm). The 3D shear cell consists of two parallel plates that pivot around an upper point located at 80 mm from the movable bottom of the load cell. The separation between the plates is set to 45 mm while the plate thickness is 68 mm. For the 3D shear cell, we used the refractive index match (RIM) technique for visualizing the intruder. Poly(methyl methacrylate) (PMMA) spheres, transparent for the substrate and opaque for the intruders, are used in the experiments along with Triton X-100 to achieve the refractive index matched mixture. We ran experiments using isolated intruders immersed in a differently sized medium in both shear cells. Trajectories, local velocities and the shear rate tensor invariants are calculated. An estimation of the segregation rate as a function of the size ratio is also obtained for both cells.

Results indicate higher values for the dilatancy and shear rate in the upper half of the intruder circumference, independently of the intruder size. As the intruder size is increased, an increment in the values of the stress tensor invariants is observed, specially in the upper half of the circumference. These differences in the values of the invariants suggests a local rheology that determines the segregation rate, depending on the size ratio of the intruder and the media.

Size segregation in the 2D shear cell is observed only for large intruders immersed in smaller media because of the constraints imposed by the planar configuration. In contrast, in the 3D shear cell small particle percolation occurs and it may stop at middle positions in specific cases, while large intruders immersed in smaller media do not segregate under certain conditions. These observations raise the question: what is initiating and restraining segregation? Based on the presented results, we suggest the interstitial fluid and size ratio may prevent and restrain segregation.