Segregation of binary mixtures: competing effects of gravity and shear rate gradients

Kimberly M. Hill and Yi Fan*

St. Anthony Falls Laboratory, Department of Civil Engineering,

University of Minnesota, Minneapolis, MN 55414†

It is well-known that a mixture of different sized particles will segregate in a gravitational field. However, it has only recently been shown that a gradient of shear rate alone can drive segregation in dense sheared systems [1]. In contrast with sparse energetic granular materials, in dense sheared systems, large particles segregate to the regions with higher shear rates. We develop a model for shear-induced segregation in dense mixtures of different sized particles. The model is comprised of two primary parts. The first involves the tendency of a gradient in kinetic stress – stress associated with velocity fluctuation correlations – to drive all particles toward regions of low shear rate. The second is essentially a kinetic sieving effect in which small particles are more likely to find voids into which they can travel than large particles. The two features together segregate small particles to regions of low shear rate and squeeze large particles in the opposite direction. We validate this model via 3D Discrete Element Method (DEM) simulations in a vertical chute. We then combine this theory for segregation via kinetic stress gradients [2] with a theory for gravity-driven segregation of granular materials (first proposed by Gray and Thornton, [3]) to study how these competing segregation mechanisms can give rise to a variety of trends that have been observed in dense sheared granular flows.

References

[1] Fan, Y., and K. M. Hill, Phase Transitions in Shear-Induced Segregation of Granular Materials, Physical Review Letters, **106**, 218301/1-4 (2011).

[2] Fan, Y., and K. M. Hill, Theory for shear-induced segregation of dense granular mixtures, New Journal of Physics, **13**, 095009/1-29 (2011).

[3] Gray, J. M. N. T., and A. R. Thornton, A theory for particle size segregation in shallow granular free-surface flows, Proceedings Of The Royal Society A-Mathematical Physical And Engineering Sciences, **461**, 1447 (2005).

*Now at Department of Mechanical Engineering, Northwestern University, Evanston, IL 60201, USA.

†Electronic address: kmhill@umn.edu