Shear-induced diffusion in cohesive granular flows

Matthew Macaulay*†[1] and Pierre Rognon[2]

[1]Particles and Grains Laboratory, School of Civil Engineering, The University of Sydney – Australia
[2]Particles and Grains Laboratory, School of Civil Engineering, The University of Sydney – Australia

Abstract

This presentation discusses the effects of intergranular cohesive forces on the self-diffusion of grains in granular flows.
Shear-induced diffusion underpins the mixing of grains in a variety of geophysical and industrial granular flows. At a continuum scale, the definition of a coefficient of self-diffusivity serves to predict grain diffusion. Dimensionally, diffusivity involves a length scale and a time scale, which are often considered to be the grains size and the shear strain rate. This proved, however, insufficient to capture a number of shear-induce diffusion behaviour.

Without cohesion, diffusivity arises from the grain random-walk trajectories, which itself may be interpreted in terms of grain velocity fluctuations (Hsiau & al., 2008). Recently, this random walk was evidenced to result from the spontaneous development of rigid and short-lived grain clusters, which size and lifetime depend not only of the grain size and shear rate, but also on the inertial number (Kharel & Rognon, 2017). The diffusivity was then expressed in terms of these two mesoscopic scales. This micro-mechanism underpinning diffusivity further helped rationalising observations such as finite system size effect and duration of super-diffusive behaviour.

Our recent numerical work (Macaulay & Rognon, 2018) explored the process of shear-induced diffusion in cohesive granular flow. Confirming previous studies, we found that inter-granular cohesive forces lead to clustering during shear (Roy & al., 2017). We found significant qualitative and quantitative differences between cohesionless and cohesive clusters. In particular, cohesive clusters are long-lived. In this presentation, we will discuss how this strongly enhances macroscopic diffusivity, and how it challenges the scaling between granular temperature and diffusivity that is valid without cohesion.

Hsiau, S.-S., Lu, L.-S., Chou, C.-Y., & Yang, W.-L. (2008). Mixing of cohesive particles in a shear cell. *International Journal of Multiphase Flow, 34.*

Kharel, P., & Rognon, P. (2017). Vortices enhance diffusion in dense granular flows. *Phys. Rev. Lett., 119.*

Macaulay, M., & Rognon, P. (2018). Shear-induced diffusion in cohesive granular flows: effect of enduring clusters. *JFM Rapids, 858.*
Roy, S., Luding, S., & Weinhart, T. (2017). A general(ized) local rheology for wet granular materials. *New Journal of Physics, 19.*

*Speaker
†Corresponding author: matthew.macaulay@sydney.edu.au

Keywords: Granular Media, Granular Diffusion, Cohesion