A non-local model for stress, velocity, and packing fraction in a rotating drum: Theoretical, numerical and experimental approach for grains from convex to highly concave

Weiyi Wang[1], Jonathan Barés*[2], Emilien Azéma[3,4], and Mathieu Renouf[5]

[1]Laboratoire de Mécanique et Génie Civil – Laboratoire de Mécanique et Génie Civil (LMGC), Université de Montpellier, CNRS, 34090 Montpellier, France – France

[2]Laboratoire de Mécanique et Génie Civil – Laboratoire de Mécanique et Génie Civil (LMGC), Université de Montpellier, CNRS, 34090 Montpellier, France – France

[3]Laboratoire de Mécanique et Génie Civil – Laboratoire de Mécanique et Génie Civil (LMGC), Université de Montpellier, CNRS, 34090 Montpellier, France – France

[4]Institut Universitaire de France – Ministère de lÉducation nationale, de l'Enseignement supérieur et de la Recherche, Ministère de l´ducation nationale, de l'Enseignement supérieur et de la Recherche, Ministère de lÉducation nationale, de l'Enseignement supérieur et de la Recherche, Ministère de lÉducation nationale, de l'Enseignement supérieur et de la Recherche, Ministère de lÉducation nationale, de l'Enseignement supérieur et de la Recherche, Ministère de l'Education nationale, de l'Enseignement supérieur et de la Recherche – Maison des Universités 103 Boulevard Saint-Michel 75005 Paris, France

[5]Laboratoire de Mécanique et Génie Civil – Laboratoire de Mécanique et Génie Civil (LMGC), Université de Montpellier, CNRS, 34090 Montpellier, France – France

Abstract

In this presentation, we examine the influence of particle shape, ranging from spherical to highly concave, on steady granular flows within a rotating drum. This system provides a unique environment to study the transition from jamming at deeper layers to unjamming near the surface. We propose an analytical model to describe the granular behavior in the drum:

(i) First, we decompose the shear stress and resolve discrepancies between simulation data and theoretical predictions by establishing a link to the angle of repose.

(ii) Second, we extend the generalized Bagnold scaling, incorporating a non-local fluidity relation based on packing fraction. This allows us to model the correlation between shear stress, shear rate, and packing fraction. Additionally, we introduce a characteristic length scale that quantifies the effects of particle shape and drum speed.

The proposed model provides explicit functional forms for the profiles of key physical quantities, which are validated experimentally in a thin rotating drum and numerically in a two-dimensional drum. Our results show that the model accurately captures the velocity variation from the drum's base to the free surface. Furthermore, for different particle shapes and drum speeds, the characteristic length effectively describes the interplay between shear stress, shear rate, and packing fraction variation.

*Speaker