FLOW OF DENSE COLLOIDAL SUSPENSIONS IN MICROFLUIDIC HOURGLASSES

LABORATORY : Institut Lumière Matière

LEVEL : M2
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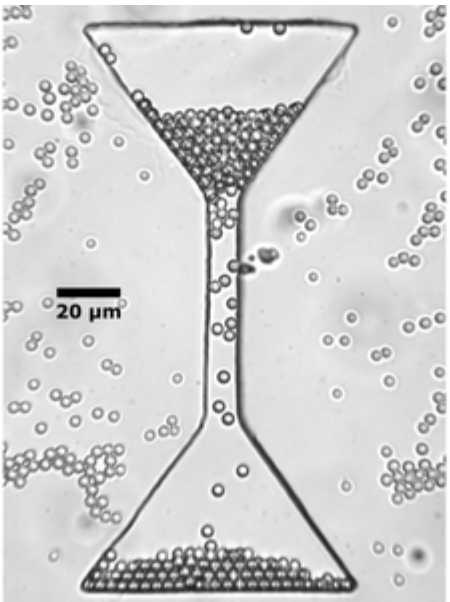
KEYWORD(S) : Colloids / Granular / Microscopy

SCIENTIFIC CONTEXT :

Flows of granular media in confined geometries, in particular in narrow channels, are relevant in numerous industrial situations (silo discharges, concrete pouring, powders and pastes in agronomy or pharmaceutical supply chains, etc.). They have been widely studied at the macroscopic scale. In those situations, three different regimes can be observed: particles can flow continuously, intermittently, or a clog can occur and completely stop the flow, which can have important consequences [1].



Microfluidic Hourglass (200 μm) filled with silica colloids (3,97 μm)

In this experimental project, we will study the flowing properties of a dense colloidal suspension: a system made of particles dense enough to sediment under their own weight, and form a well-defined pile, but small enough to be submitted to Brownian motion. Those suspensions are very similar to "classical" granular suspensions, except that they show peculiar properties due to the effect of thermal agitation. For example, contrary to what is observed in macroscopic systems, they do not stop flowing at a finite repose angle, and even small inclinations are enough to start an avalanche [2]. Therefore, their behavior in more complex geometries is worth studying, to be compared with the know behaviors of athermal granular media, both dry or immersed in fluids.

MISSIONS :

During the internship, we will study the flow of a dense colloidal suspension in a microfluidic "hourglass", where particles have to go through a narrow channel (see figure, and movie: https://www.youtube.com/watch?v=nhgEVsT2EsO). The experimental set-up will be made of a microfluidic cell (made in the clean-room facility available at the laboratory), on a custom-built horizontal microscope (whose observation plane is vertical). Using video image analysis, the student will measure how the flowrate depends on various external parameters: the hourglass geometry, the particle size (changing the relative influence of the thermal agitation to their weight), the friction between the particles. In particular, they will test whether or not macroscopic laws, such as the Beverloo law [3] that predicts the flowrate as a function of geometrical parameters, still hold in the microscopic regime. They will also study the potential formation of clogging events in the hourglass neck, responsible for intermittent flows. The results will be compared with macroscopic systems, in particular when the grains are submitted to mechanical vibrations that enhance the flowability of the media [4].

OUTLOOKS :

The intership can be followed by a PhD thesis (fully funded by ANR project).

BIBLIOGRAPHY :

[1] Zuriguel et al. “Clogging transition of many-particle systems flowing through bottlenecks”, Sci. Rep. 4, 7324, 2014.

[2] Bérut et al. “Brownian Granular Flows Down Heaps” Phys. Rev. Lett. 123, 248005, 2019.

[3] Beverloo et al., “The flow of granular solids through orifices” Chem. Eng. Sci., 15, 260-269, 1961.

[4] Janda et al. “Unjamming a granular hopper by vibration”, 2009 EPL 87 24002.