Post-Doc 2 years, starting mid-2024

Rheology of a Multimodal Suspension

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Context :

Many industrial sectors, such as pharmaceuticals or civil and military aeronautics, require the use of raw materials made from mixtures of constituents that are as homogeneous as possible. The most common industrial mixers are intrusive, i.e. they use solid moving parts (grid, rotating blades…) to induce an homogenising flow, and they require relatively long process times. To reduce mixing times, a new, non-intrusive technology using acoustic resonance (RAM) has been developed. The container with the raw materials is set into strong vertical vibrations, which induces both macroscopic convective movements and micro-vortices. This post-doc is part of the SINRAM ANR project, which gathers an industrial partner (ROXEL) and two academic partners (I2M for numerics and LMFA for experiments), in view of fully characterise and model this new mixing method in the specific case of very dense polydisperse suspensions.

When mixing a dispersed solid phase in a fluid matrix, a key parameter is the suspension effective viscosity, on which depends crucial quantities such as the acoustic resonance, or the gas-removal time. First modelling attempts have considered a model suspension of spherical grains with a single size, for which several models exist to predict the effective viscosity : Krieger, Maron-Pierce, Eilers,…[1]
In dense mono-disperse suspensions, this effective viscosity is known to be entirely controlled by the distance to the maximal volume fraction phi_max, over which the medium jams and stops to flow [1].

However, in real applications, the composition can vary sensibly from the ideal case. In particular, the first sensible deviation occurs when there is not a single grain size in the problem anymore. It is known indeed that suspensions with a bi-modal, tri-modal, or even a continuous flat grain size distribution, have a lower viscosity at the same volume fraction, than the mono-disperse grains [2]. This is directly related to the possibility of reaching a higher solid volume fraction when the grains are composed of different sizes, due to the possibility for the small grains to fill the gaps between the larger grains. Recent simulations [2] proposed also that a suspension with a broad grain size distribution should behave like a bimodal suspension with equivalent statistic moments (mean, standard deviation and skewness).

Another sensible deviation from the ideal case occurs when the suspending fluid is non-Newtonian. If the modelling of the rheology of such mixture has been done already, less can be said of the transient process of particle migration, for which very few works exist so far. It has been reported [3] that in some configurations, particles may be attracted towards regions of high shear rate, a process opposite to the classical particle migration in Newtonian suspensions. It has been proposed that this could be due to the variation of viscosity associated with high shear, that induce a separate flux of particles, however this is based on ad-hoc models [4], and needs to be clarified. A rigorous modelling as well as systematic controlled experiments are still missing.
We propose in this project on one hand to measure experimentally the viscosity of a multimodal, non-buoyant suspension, and compare it with recent models, and on the other hand to evidence and quantify the particle migration in non-Newtonian fluids.

Objectives:

The goal of this 2-years post-doc is to model effectively the viscosity of the suspensions used in real-case situations. To reach this objective, the work will be divided in three parts:

- First, a methodical bibliography study should give an overview of the different models available in the literature. Part of the work will be to combine models describing the viscosity of a mono-disperse suspension, with models predicting the maximum packing fraction for a given assembly of bi, tri or multi-modal grain size distribution.
- Second, the candidate will measure experimentally the viscosity of suspensions with a rheometer in the vane cup geometry. Focus will be made on varying independently the grain size distribution and the total grain volume fraction, in order to compare the viscosity measured as well as the maximum packing fraction with the literature.
- The candidate will also initiate with the research team a new project in order to measure particle migration in a dedicated shear flow setup of suspension in a a yield-stress suspending fluid.

Experimental results and rheological models will be typically discussed in bi-annual meetings with the project partners, in view of publication in scientific journals.

As the obtained models are destined to be implemented by the I2M partners in the NOTUS simulation software, special care will be given to their transmission.

Candidate profiles:

The post-doctoral student we are looking for should have strong skills in physics, specially with modelling and experimenting in granular matter and/or suspensions. A strong background in experimental rheometry will be appreciated.

Références :

[1] Guazzelli, É., & Pouliquen, O. (2018). Rheology of dense granular suspensions. Journal of Fluid Mechanics, 852, P1.

[2] Pednekar, S., Chun, J., & Morris, J. F. (2018). Bidisperse and polydisperse suspension rheology at large solid fraction. Journal of Rheology, 62(2), 513-526.

[3] Chambon, G., Ghemmour, A., & Naaim, M. (2013, April). Particle migration within free-surface flow of a viscoplastic fluid. In EGU General Assembly Conference Abstracts (pp. EGU2013-7904).

[4] Phillips, R. J., Armstrong, R. C., Brown, R. A., Graham, A. L., & Abbott, J. R. (1992). A constitutive equation for concentrated suspensions that accounts for shear-induced particle migration. *Physics of Fluids A: Fluid Dynamics*, *4*(1), 30-40.