PhD Position
Complex modeling and simulation of near-wall particle dynamics in turbulent flows

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Keywords

Two-phase flow, modelling, simulation, particle resuspension, stochastic approaches

Job environments

The PhD position is offered within team Calisto at Inria SAM. The team research is focussed on complex SDEs and stochastic particle modeling applied to simple phase and multiphase flows. This research is carried out in collaborations with researchers that share interest in environmental applications (including physicists specialized in turbulence and two-phase flows modeling) and in numerical methodologies (with a strong focus on numerical SDEs and probabilistic/statistical numerical methods).

Scientific context

Particles are omnipresent in both environmental and industrial applications. Particle-laden flows indeed impact a large range of industrial processes, from energy production facilities (fouling of heat exchangers by iron oxides), to automotive (soot deposition in combustion engines) through oil transportation (use of polymers to modify the fluid rheology). Particles are also suspended in a number of environmental flows, including atmospheric flows (such as volcanic cloud and ash fallout, droplet growth in clouds or fog formation) and marine systems (e.g. silt deposition in delta rivers, plastic pollution in oceans and rivers, plankton sedimentation in oceans).

As transpires from these examples, the particles encountered are complex and driven by intricate mechanisms: particles are polydisperse, not exactly spherical but of any shape and deform (as bubbles and droplets); they can collide together in the fluid and form larger agglomerates; they have complex interactions with surfaces, on which they can deposit and later be resuspended again. Particle-laden flows is thus a highly multi-disciplinary topic, involving issues related to: fluid mechanics, interface chemistry, surface and material science. Besides, it spans a wide range of temporal and spatial scales (from the nanometer scale up to geological scales). The challenge is thus to develop numerical models that capture all this rich and intricate phenomena to help in the design of optimal industrial processes or environmental solutions.

To address such challenges, researchers and engineers are increasingly relying on the use of macroscopic numerical models. This framework is broadly referred to as "Computational Fluid Dynamics" (CFD). Team Calisto is developing stochastic Lagrangian models for the simulation of particle-laden flows. The team is also relying on microscopic simulations to improve such macroscopic models.

State of art on particle resuspension in turbulent flows

This Ph.D. project is focused on the specific topic of particle resuspension. Resuspension refers to the physical process by which a bed of solid microscopic particles adhering to a surface is re-entrained into a gas due to the action of the flow. Despite a century of research, the underlying physical mechanisms behind particle resuspension in turbulent gas flows as well as the numerical models are still incomplete [2, 3].

In fact, there exists on the one hand a large body of literature on individual resuspension from monolayer deposits, in which the interparticle distance (L) is usually much greater than the particle diameter (d), that is $L/d \gg 1$. On the other hand, inter-particle collisions and deposit morphology were thoroughly investigated in a number of studies on multilayer deposits, where the interparticle distance is close to zero $L/d \to 0$. Yet, there is neither an overall physical description nor macroscopic models that are able to reproduce the wide range of phenomena occurring from monolayer resuspension to multilayer resuspension.

Objectives

The aim of this doctoral research project is to bridge the gap between monolayer and multilayer models. For that purpose, the student will study specifically the case where the distance L and the diameter d have the same magnitude order. Recent experimental investigations [4] indeed show a combined role of two mechanisms: individual resuspension events (due to the action of the turbulent flow) and collision-induced resuspension events (as in avalanche effects).

To reach these objectives, the doctoral project involves several steps. First, new physical models will be developed drawing on the novel effects identified in the recent experiments and implemented in fine-scale simulations (relying on Direct Numerical Simulation). Second, sensitivity analysis techniques will be used directly on the results obtained from such microscopic simulations as well as on their meta-modeling. This analysis will help design probabilistic reduced model (e.g. a law for the resuspension rate). Third, this model will be calibrated with modern uncertainty quantification techniques. This overall methodology will result in the development of higher-order macroscopic models that can be used in practical applications. Such macroscopic model will be coupled with existing CFD software for two-phase flows, especially the stochastic Lagrangian approach available within the team. This choice is motivated by the fact that stochastic Lagrangian approaches inherently include statistical description of the physical phenomena.

Profile and skills

Candidates must have a **Master 2 (Master degree)** with a major in one or more of the following topics:

- Scientific computing;
- Fluid mechanics;
- Statistical physics;
- Meta-modelling.

Candidates with the following knowledge/competences will be **highly appreciated**:

- Code development;
- Stochastic modeling and numerics.
- Knowledge of programming languages (python/ C / C++);
- Fluent in English.

The following **optional skills** will be preferred:

- Rigorous, autonomous and creative thinking;
- Interest in environmental applications;
- HPC skills.

To apply

Applicants are required to send a cover letter, a CV, a transcript of their Master grades and at least one recommendation letter.

Please send an email to:

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References

[1] Balachandar, S., & Eaton, J. K. (2010). Turbulent dispersed multiphase flow. *Annual review of fluid mechanics*, 42, 111-133.

[2] Henry, C., & Minier, J. P. (2014). Progress in particle resuspension from rough surfaces by turbulent flows. *Progress in Energy and Combustion Science*, 45, 1-53.

[3] Henry, C., & Minier, J. P. (2018). Colloidal particle resuspension: On the need for refined characterisation of surface roughness. *Journal of Aerosol Science*, 118, 1-13.

[4] Banari, A., Henry, C. et al. (2021). Evidence of collision-induced resuspension of microscopic particles from a monolayer deposit. *submitted to Physical Review Fluids*.