Postdoctoral position
Laboratoire de Mécanique des Fluides et d'Acoustique

Sedimentation of spherical particles in a homogeneous isotropic turbulent flow

Scientific background:

The project is devoted to the problem of particles settling in a homogeneous isotropic turbulent flow [1–3]. Several mechanisms have been considered to describe how turbulence affects the settling velocity U_{sett}, some leading to an increase of U_{sett} (“preferential sweeping”, according to which particles sample preferentially the regions where the fluid moves downward), some leading to a decrease of U_{sett} (“loitering”, according to which particles spend more time in regions where fluid moves upwards, or trapping in vortices of horizontal axis). It has been proposed in particular that the loitering mechanism cannot be captured by pointwise particles models, unless the drag force is nonlinear [1,2]. The role of such a force on the settling velocity U_{sett}, however, remains controversial [3]. The numerical work done so far has not provided conclusive evidence.

Numerical simulations have also shown that an additional effect of settling is to diminish preferential concentration (the tendency of particles to accumulate at certain locations in a turbulent flow), by reducing the interaction time between the particles and the vortices in the fluid [2]. Most earlier studies have been carried out for particles of density much larger than that of the fluid (density ratios $R_\rho \sim 10^3$), as one of the main motivations for studying these problems comes from cloud physics (water droplets in air). In this regime, the particles are subject only to drag and buoyancy forces.

Project description:

We will consider here lighter particles ($R_\rho \sim 10$), which makes it necessary to include other forces, such as those due to fluid acceleration, added mass, or history (Basset force). The influence of the drag force (linear or nonlinear) as well as the statistical convergence of the data will be carefully studied. It can be noted that a weaker ratio between the density of the particles and that of the fluid implies a shorter response time. As a consequence, the effects of the particle inertia (Stokes number) and settling (gravity parameter) are expected to be weaker than in the case of very heavy particles.
One of our objectives will be to generalize the results of [4] to other important physical phenomena, such as preferential concentration. Connections will be established with the results already obtained in the case of very heavy particles.

The project will consist first in implementing the history effects as well as the effects of added mass and of the fluid acceleration, using a code already available and capable of integrating the Navier-Stokes equations by direct integration (direct numerical simulation, DNS) and to follow the motion of heavy particles.

Context:

This position is part of a larger project, “Particles drifting and propelling in turbulent flows”, that is financed by the IDEXLYON and involves several postdocs and PhD students.
This project makes possible collaborations and exchanges with the other partners involved: Laboratoire de Physique (École Normale Supérieure de Lyon), Institut Camille Jordan, Centre de Recherche Astrophysique de Lyon, Laboratoire de Géologie de Lyon, and Institut Lumière Matière, bringing together experimental, computational, theoretical, and multidisciplinary approaches.

Duration:

2 years.

Job requirements:

A solid knowledge in theoretical fluid mechanics and in numerical methods for PDEs is a requisite. Experience/training in turbulence and/or particle transport are an advantage.

Location:

The postdoc will be based at the Laboratoire de Mécanique des Fluides et d'Acoustique (LMFA), École Centrale de Lyon. The project may include interactions with the experimental group at École Normale Supérieure de Lyon, or elsewhere in Lyon, depending on the progress of the work.

Contacts:

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References:

[1] Good, G. H., Ireland, P. J., Bewley, G. P., Bodenschatz, E., Collins, L. R., and Warhaft, Z. (2014). Settling regimes of inertial particles in isotropic turbulence. J. Fluid Mech., 759:R3.

[2] Ireland, P. J., Bragg, A. D., and Collins, L. R. (2016). The effect of Reynolds number on inertial particle dynamics in isotropic turbulence. Part 2. Simulations with gravitational effects. J. Fluid Mech., 796:659–711.

[3] Rosa, B., Parishani, H., Ayala, O., and Wang, L.-P. (2016). Settling velocity of small inertial particles in homogeneous isotropic turbulence from high-resolution DNS. International Journal of Multiphase Flow, 83:217 – 231.

[4] van Hinsberg, M. A. T., Clercx, H. J. H., and Toschi, F. (2017). Enhanced settling of nonheavy inertial particles in homogeneous isotropic turbulence: The role of the pressure gradient and the Basset history force. Phys. Rev. E, 95:023106.