PhD Position

Inertial Particle Dynamics in the Turbulent/Non-Turbulent Interface

Project summary

In spite of its apparent simplicity, the physics of finite size spheres advected by a fluid hides a whole hierarchy of rich imbricated phenomena, some of which are still shrouded in mystery. This is for instance the case when a particle is in a turbulent environment and/or when hydrodynamic couplings emerge between many particles, resulting in subtle collective behaviours. Unveiling the fundamental mechanisms of such phenomena remains crucial to improve our capacity to accurately model and predict particle laden flows. These flows are present in many different processes such as coalescence (rain formation), agglomeration (particles in the atmosphere), settling velocity (sedimentation), chemical transformations (risers), among many others.

All such flow configurations present many open fundamental questions and are subject of great interest in current research. Indeed, because of their higher density compared to the carrier fluid, inertial particles interacting with the underlying turbulence tend to form high (clusters) and low (voids) concentration regions (as exemplified in Fig.1). These regions span almost the whole range of turbulence scales, i.e. from the Kolmogorov length scale up to the integral length scale or even larger for superclusters, and the widest regions exhibit self-similarity. Such non-trivial spatial organization of particles, a phenomenon referred to as **preferential concentration**, has strong consequences on the flow dynamics by way of momentum exchanges between phases, of velocity fluctuations generation or of collective dynamics, as well as on particle transport and dispersion. Ultimately, these features control the efficiency of all the applications mentioned above.

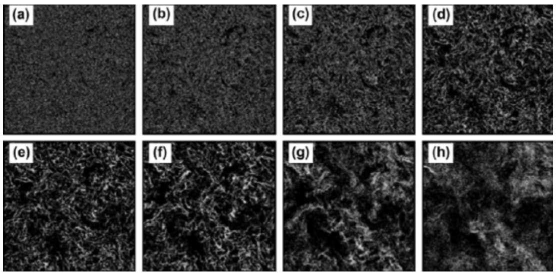

Figure 1: Illustration of the formation of clusters and voids from the simulations of Yoshimoto and Goto 2007

This experimental project will study the dynamics of inertial droplets in a turbulent/non-turbulent interface, with and without the presence of shear, and with different orientations with respect to gravity. To conduct this research, we will employ unique facilities and measurement techniques, namely, two wind tunnels equipped with turbulence-producing systems that can be activated differentially to generate a turbulent/non-turbulent interface. With the two experimental setups (see figure 2 for an example), this collaboration will be able to cover a wide range of turbulent intensity gradients, shear rates and Reynolds numbers for the study of inertial particle dynamics in turbulent/non-turbulent conditions. The joint study will produce data on different droplet sizes that span the range of Stokes numbers, which characterize the inertia of the particles compared to the turbulence microscale, that are of interest in application areas such as fuel injection in energy conversion systems, industrial spray coating, warm rain formation in clouds and sea spray from breaking waves in the surf zone.

Different advances are expected:

- On a first stage, measuring campaigns in LMFL-École Centrale de Lille (Lille, France) and in the University of Washington (Seattle, USA) facilities are envisioned. Measuring techniques such as Phase Doppler interferometry, Particle Image Velocimetry, Phase detection optical probes are already mastered as well as post-processing routines to access drop size, velocity, concentration and combined statistics as done in former contributions from both groups. All the required equipment is available. **The PhD student will spend the first 18 months in Lille while the rest of the time they will be in Seattle**.

- The PhD student will explore how to generate a turbulent/non-turbulent interface in both wind tunnels. This can be achieved by means of an active grid in LMFL or by changing the injection system in University of Washington. The student will continue a previous work, where an interface was achieved in Seattle's wind tunnel (see Ferran et al. 2024).

- Finally, a systematic study of clustering of inertial particles on the turbulent/non-turbulent interface will be performed: the shape and orientation of clusters on such flow, the role of gravity and entrainment, etc…

The expected outputs are the following: (i) to produce insights into the behavior of particle-laden flows in the presence of a Turbulent/non-turbulent interface, (ii) quantify the properties of clustering on the parameter space (that includes the turbulence parameters, the Stokes number, the orientation of gravity) and (iii) produce some simple models to quantify such phenomenon.

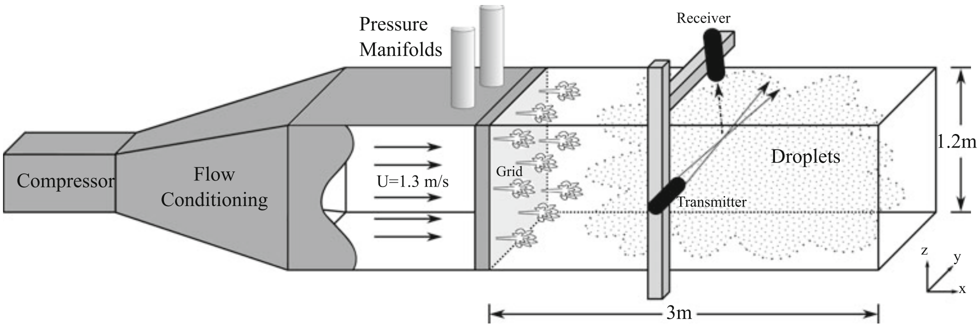

Figure 2: University of Washington Wind Tunnel. Air Jets Generated Turbulence.

References

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- Ferran, A., Machicoane, N., Aliseda, A. and Obligado, M. An experimental study on the settling velocity of inertial particles in different homogeneous isotropic turbulent flows. Journal of Fluid Mechanics, 970, p.A23 (2023).
- Aliseda A., Cartellier A., Hainaux F. and Lasheras J., Effect of preferential concentration on the settling velocity of heavy particles in homogeneous isotropic turbulence. J. Fluid Mech., 468, pp.77-105 (2002).
- Sumbekova S., Cartellier A., Aliseda A. and Bourgoin M., Preferential Concentration of Inertial Sub-Kolmogorov Particles. The roles of mass loading of particles, Stokes and Reynolds numbers. Phys. Rev. Fluids 2, 024302 (2017).
- Balachandar, S., Eaton, John K., Turbulent Dispersed Multiphase Flow, *Annual Review of Fluid Mechanics*, 42, pp. 111-133 (2010).
- Gerashchenko, S., Warhaft, Z, Conditional entrainment statistics of inertial particles across shearless turbulent interfaces. *Experiments in Fluids* 54:1631 (2013).
- Good, G., Gerashchenko, S., Warhaft, Z., Intermittency and inertial particle entrainment at a turbulent interface: The effect of the large-scale eddies. *Journal of Fluid Mechanics, 694*, 371-398 (2012).

Location and practical aspects

3 years PhD fellowship offer, starting in 2024.

The successful applicant will be hosted by the laboratory **LMFL** (located at Lille, https://lmfl.cnrs.fr) in the EDT team and the Engineering Department at the University of Washington (from Seattle, USA). They will work under the supervision of Prof. Martin Obligado from laboratory LMFL and Prof. Alberto Aliseda from Washington University (www.me.washington.edu/facultyfinder/alberto-aliseda).

Qualifications of the applicant

Engineering or physics background with strong formation in fluid mechanics. Interest in experimentation measuring techniques and modelling. Experience using Matlab and/or Python is recommended.

Applications

Interested candidates should send their CV and cover letter to Martin Obligado (martin.obligado@centralelille.fr) and/or Alberto Aliseda (aaliseda@uw.edu).

Deadline for the application: 10/05/2024