OSCILLATING GRID HIGH REYNOLDS EXPERIMENTS IN SUPERFLUID

Ndeye Fatimata SY [1], Mickaël Bourgoin [2], Pantxo Diribarne [1], Mathieu Gibert [3] & Bernard Rousset [1]
[1] *Université Grenoble Alpes, Service des Basses Températures, UMR-E 9004 CEA/UJF-Grenoble 1 CEA/INAC/SBT 17, rue des Martyrs 38054 Grenoble Cedex 9 France*
[2] *Université Grenoble Alpes, Dep. Laboratoire des Ecoulements Géophysiques et Industriels, CNRS/UJF/G-INP, UMR5519, Université de Grenoble, BP53, 38041, Grenoble Cedex 09, France*
[3] *Université Grenoble Alpes, Institut NÉEL, F-38042 Grenoble, France, CNRS*

Abstract The study of particle preferential concentration in oscillating grid turbulence is described. Clustering in normal helium and superfluid helium is presented.

In inertial particle-laden turbulent flows a phenomenon which is called preferential concentration or "clustering" occurs. This may lead to strong inhomogeneities and is well described in [1] for several type of flows like free shear flows and homogeneous flows.
In this work, we focus on clustering in normal and superfluid helium. Liquid helium exists in two different phases : He I and He II. At temperatures above 2.17K, He I has classical Navier-Stokes properties. Below 2.17K, He II can be viewed as a mixture of a normal (viscous) and a quantum (inviscid) components with a relative ratio depending upon the temperature. In He II, the inviscid nature of the superfluid component complemented with the Laplace equation imposes the constraint that the vorticity must be concentrated into atomic sized quantized vortices. How is the preferential concentration of particles related to turbulent scales in He I and He II? Are there any effects of quantized vortices on clustering? These are the questions driving our experiments.

The innovation of our experiment is the study of clustering in a low temperature oscillating grid turbulence experiment using He I and He II. Oscillating grid turbulence is an Homogeneous Isotropic Turbulence with no mean velocity so there is a large observation time. Moreover, for same particles, Reynolds **Re** and Stokes **St** numbers can be modified independently. Indeed **Re** only depends on the fluid viscosity which is a function of temperature and the grid characteristics (stroke, frequency and mesh size) while **St** is a function of particle characteristics (diameter and density) and distance downstream the grid. That is the reason why oscillating grid was chosen for our study. Besides, many oscillating grid experiments were performed then this type of flow is well calibrated [2]; the turbulence characteristics are well known.
In our apparatus (see figure 1), there is a grid oscillating vertically at frequencies up to 5Hz in a limited space into a helium tank which is surrounded by a 77K-nitrogen tank : liquid nitrogen minimises the liquid helium radiation losses. The grid solidity is 34.5% and the mesh size M is 15mm and the stroke S can reach the mesh size $\frac{S}{M} \leq 1$. Tanks are cylindrical and are made of glass. Measurements are mainly based on visualisation with high-speed camera equipped with microscope lenses. To seed the flow, hollow glass spheres are used. In this small setup, Reynolds number based on Taylor scale $\mathbf{Re}_\lambda$ can reach up to 300 due to the helium low kinematic viscosity (e.g. ν_{helium}(T=3K, P=1bar) = $2.54.10^8$ m^2/s).
Measurements are taken in He I and He II. In He I, operating temperatures range from 2.4K to 4K. He I is boiling at 4.2K under 1bar and is not a quite good thermal conductor. Therefore, there are bubbles in the helium bath when the temperatures follow the saturation line. To avoid this, after cooling down to 2.4K by pumping, helium gas is reintroduced above the liquid interface enabling pressurization and stratification. In He II, however, due to its high conductivity, there is no bubble and no need to pressurize the helium bath.

First tests have proved that this setup was operational and no mechanical problem was found at low temperatures. Voronoï diagram is used to study clustering [3]. Our preliminary results presented on figure 2 show no difference between He I and He II when studying the PDFs of the Voronoï cells areas. To analyse the existence of clustering, those PDFs areas are compared to the PDF area of a Random Poisson Process RPP. The PDFs areas indicate that the distribution of the particles is quite random and there are few clusters either in He I or in He II. We are also interested in particle dynamics to study their correlation with clustering in He I and He II.

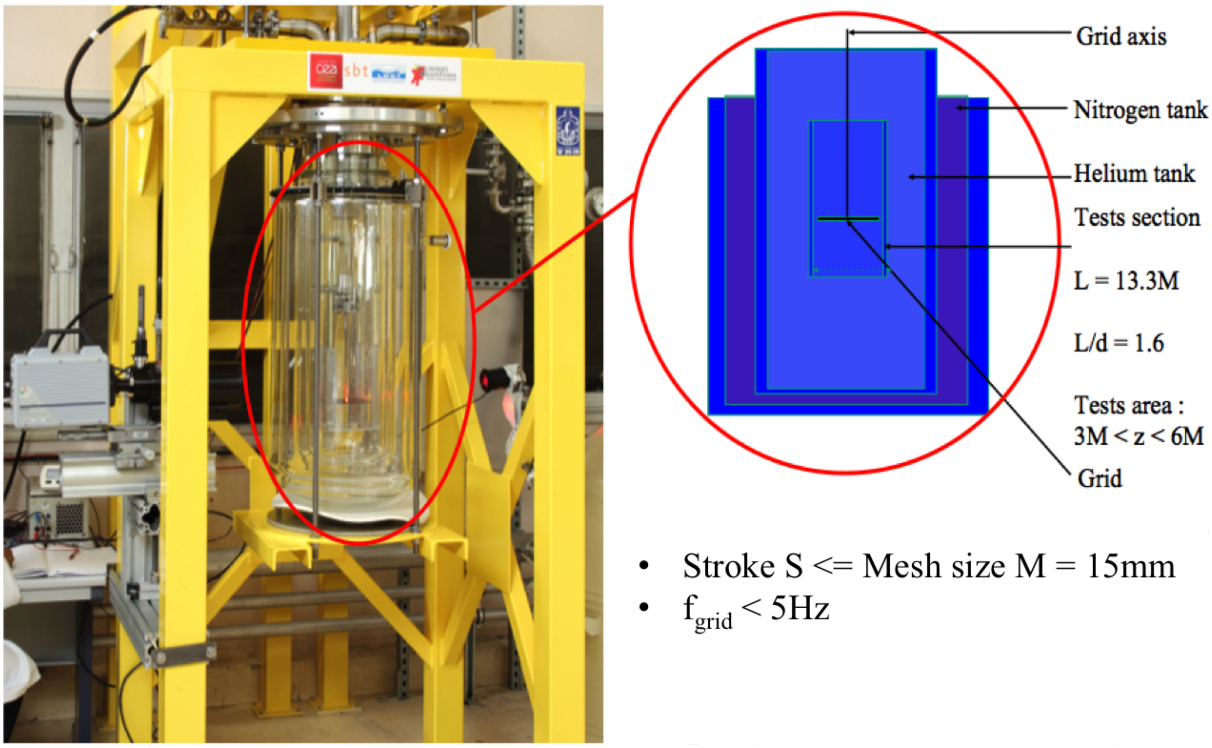
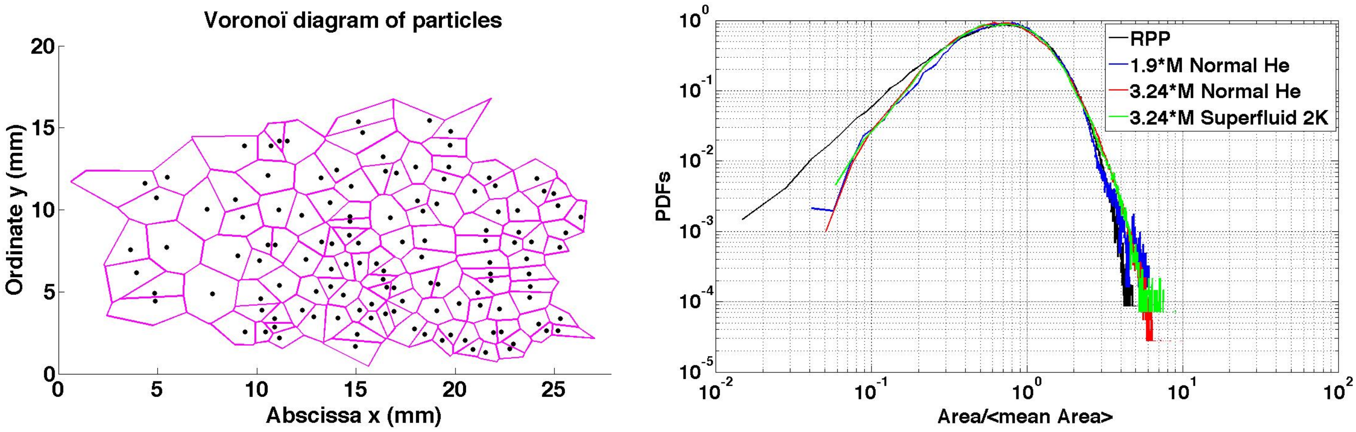


Figure 1. Experimental setup



(a) (b)

Figure 2. (a) example of Voronoï tesselation. (b) Probability distribution of normalized Voronoï area. RPP refers to Random Poisson Process. These measurements were taken at 5Hz. $\frac{S}{M}$ = .83 with S the stroke of the grid and M the mesh size. Their mean density $\rho_{particles}$ is 180kg/m^3 and ρ_{Helium} = f(T) = (135 $\pm$ 10)kg/m^3.

References

[1] J. K. Eaton and J. R. Fessler. Preferential concentration of particles by turbulence. *Int. J. Multiphase Flow*, 20:169–209, February 1994.

[2] D. De Silva I. P and H. J. S. Fernando. Oscillating grids as a source of nearly isotropic turbulence. *Physics of Fluids*, 6(7):2455, July 1994.

[3] R. Monchaux, M. Bourgoin, and A. Cartellier. Preferential concentration of heavy particles : A voronoï analysis. *Physics of Fluids*, 22, 2010.