DISENTANGLED EFFECTS OF THE REYNOLDS AND STOKES NUMBERS ON THE CLUSTERING OF HEAVY PARTICLES IN TURBULENCE

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Abstract Further to intriguing results recently obtained (Fiabane *et al.*, *Phys. Rev. E* **86**, 2012), we study the clustering of heavy particles in homogeneous and isotropic turbulence. We use glass particles of diameter ranging from 150 μm to 500 μm in flows with the Kolmogorov length scale ranging from 159 μm to 41 μm. We investigate the particle concentration using a Voronoï tessellation analysis for all the diameters, in flows with different level of turbulence. This makes possible the study of the disentangled effects of the Stokes and Reynolds numbers, comparing particles of the same diameter in different turbulent flows on the one hand, and particles of different diameters in flows with the same level of turbulence.

CONTEXT OF THE STUDY

Turbulent flows laden with particles are widely studied, due to their omnipresence in industry and environment. One feature of these flows is the trend for particles to concentrate in preferentially sampled regions of the carrier flow (known as *preferential concentration* or *clustering*). The usual key parameter of the studies involving particles interacting with turbulence is the Stokes number: it is a dimensionless number quantifying the ratio between the particle viscous relaxation time and a typical time scale of the flow. This is motivated by the simplicity of Stokesian models, where the dominant force acting on the particle is taken as the drag due to the difference between the particle velocity and the fluid velocity. Stokesian models suggest that particles with non-vanishing Stokes number tend to exhibit preferential concentration.

In a recent work [1], we experimentally investigated the spatial structuring of particles of diameter significantly larger than the dissipation scale of the carrier flow (*finite size particles*) in a homogeneously and isotropically turbulent flow generated by the Lagrangian Exploration Module (figure 1). The spatial structuring of these inclusions was characterized through a Voronoï tessellation analysis as initially proposed in Ref. [2], from images of particle concentration field taken in a laser sheet at the center of the flow. The main results of our study dealt with neutrally buoyant particles, which did not exhibit clustering despite large Stokes numbers (of the order of 1). Those results were compared to the observed clustering of heavy particles made of glass ($\rho_{\rm glass}/\rho_{\rm water} \approx 2.5$), yielding similar results as in other studies (see *e.g.* Ref. [3]).

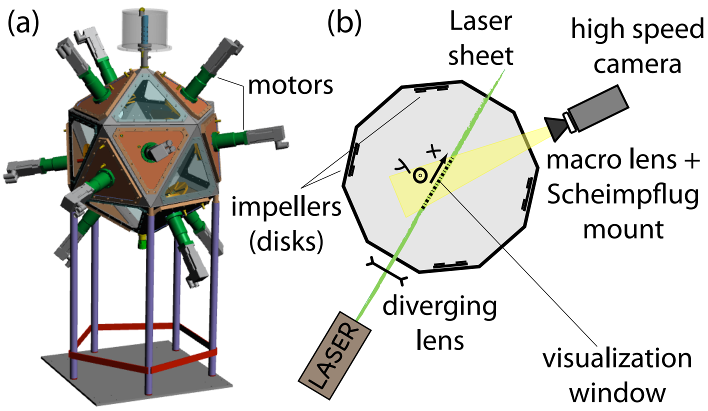

Figure 1. (a) CAD drawing of the LEM. (b) Schematic upper view of the setup.

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In addition, we studied the evolution of the clustering with the Stokes number in the particular case of the heavy particles (figure 2). Namely, we established a diagnosis of the clustering using the standard deviation of the normalized Voronoï areas, and varied the Stokes number of the particles by tuning the flow dissipation time scale (thus tuning the Reynolds number as well). The glass particles diameter was kept constant of value 250 μm throughout the whole experimental campaign. The corresponding Stokes number spanned a range from 0.5 to 6.2.

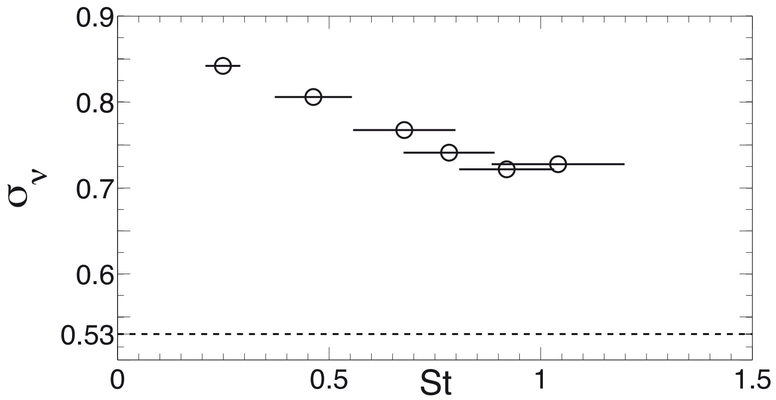

Figure 2. Preliminary result: evolution of the clustering diagnosis (namely the standard deviation $\sigma_\mathcal{V}$ of the normalized Voronoï areas) with entangled Stokes and Reynolds numbers. The dashed line is the standard deviation of a Random Poisson Process (*i.e.* a seeding with no spatial structuring), of value $\sigma_{\text{RPP}} \approx 0.53$.

We find the clustering level to globally decrease as the Stokes number (and thus the Reynolds number) increase, with no hint of maximum clustering for $St \approx 1$, contrary to common observations [3]. If a maximum of clustering exists in our case (which is reasonable assuming that tracer behavior is to be recovered for $St \to 0$), the peak would be at $St < 0.25$. In order to verify this assumption, we carry out another set of experiments with glass particles of different diameters, in flows of different levels of turbulence.

We use the same setup as in [1], with glass particles of diameter ranging from 150 μm to 500 μm. The Kolmogorov length scale ranges from 159 μm to 41 μm. We monitor the particles settling, especially for the larger particles in low turbulent flows, so that the mean number of detected particles in the plan is of the order of 150 in all the configurations. This allow us to study the disentangled effects of the Stokes and Reynolds numbers, comparing particles of the same diameter in different turbulent flows on the one hand, and particles of different diameters in flows with the same level of turbulence.

References

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