Lagrangian acceleration measurement of bubbles in water using Laser Doppler Velocimetry

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Turbulent flows play a major role in mixing, chemical process in reactors, and transport of pollutants in the atmosphere. In this context, even if the lagrangian point of view which describes the fluid flow properties along the trajectories is the most natural, lagrangian measurements are rare due to the precision needed for the measurement at large Reynolds numbers. One needs to track small particles ($10 - 100$ μm large) in turbulent flows with Reynolds numbers $R_\lambda > 100$ with a temporal resolution of the order of the Kolmogorov frequency $f_K = \sqrt{\epsilon/\nu} \sim 1 - 10$ kHz, ϵ beeing the injected power per mass unit, and ν the fluid viscosity. This was achieved in the recent past in von Kármán flows using ultrasound techniques in Lyon [1], or by PTV using several synchronized fast cameras at Cornell university [2], two techniques which have in common to be difficult to handle, and difficult to export to other flow geometries.

We have developped a new optical technique to measure the particle velocity along their trajectories. This technique is based on the Laser Doppler Velocimetry (figure (a)) : two large laser beams are used to make interference fringes in a volume $v \sim 1$ cm^3 at the center of a von Kármán flow of water. When a particle crosses the fringes, the light intensity scattered, which can

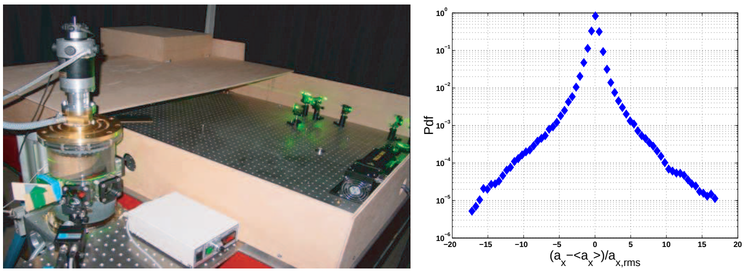

Figure 1: (a) Schematic of the LDV setup. (b) Probability density function of the lagrangian acceleration 10 μm particles at $R_\lambda \sim 200$ measured with the Laser Doppler Technique.

be recorded with a photomultiplier, is modulated at a frequency proportionnal to its velocity. As the beams are large (unlike the classical LDV), one can follow the particles for a long time as compared to the Kolmogorov time scale $\tau_\eta = \sqrt{\nu/\epsilon} \sim 0.1$ ms. With the same fast demodulation algorythm used by Mordant *et al* for the accoustics [1], we can reconstruct the evolution of the velocity along the trajectories, and thus the lagrangian acceleration. Recording many trajectories, we can compute the one point lagrangian acceleration statistics of the particles (figure (b)), quantity which plays a major role in numerical models of turbulent transport.

We report here the first measurements of the lagrangian acceleration statistics of bubbles used as passive tracers in water, at Reynolds numbers up to $R_\lambda \sim 300$, and show the comparison with small rigid particles whose size is comparable with the Kolmogorov length scale, with a densitity close to the one of water.

References

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