

Lagrangian velocity and acceleration measurements, PTVA, in quasi-two-dimensional electromagnetically controlled multi-scale flows

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A self-adaptive iterative method (Particle Tracking Velocimetry and Accelerometry, PTVA), amenable to accurately extract the Lagrangian velocity and acceleration of a multi-scale flow, has been developed and applied to an electromagnetically controlled, quasi-two-dimensional multi-scale turbulent-like flow.

PTVA can be considered as an evolution from previous acceleration measurement methods like PTV, as its parameters only relies on the determination of the smallest flow structures to be measured. Particle positions are obtained from standard PTV and then used to extract trajectories using a moving polynomial approximation with an adaptive number of tracked positions, depending only on the local flow properties. The only adjustable parameter used is the diameter D of the smallest vortex to measure. Velocities and accelerations components along each trajectory are obtained subsequently as the first and second derivative in time of the trajectories.

PTVA is here applied to a quasi-two-dimensional multi-scale flow experiment, designed and developed to study and control some aspects of turbulence, stirring and mixing. This flow has a multi-scale (8 in 8) distribution of stagnation points (zero velocity point in Eulerian reference frame) according to the scale of the flow structures which they are connected to. We fully control the topology and the forcing of this flow.

PTVA, performed on that multi-scale turbulent-like experiment, provides good measurements of the velocity and acceleration field. The velocity field is precise enough to allow a second order spatial derivative on it and so to give the measurement Eulerian field of the viscous term of the Navier-Stokes equation. So PTVA allow us to experimentally measure each of the Navier-Stokes components, as well as the power input, output and transformation in the whole investigation field, fundamental for minimization of power input needed for efficient mixing purpose. It is to notice that the measurements shown in this paper were filmed at only 10 Hz, so the use of higher frequency cameras could allow the application of the PTVA on faster turbulent flows. It is also meaningful that we use the diameter of the smallest structure to be measured as the only adjustable parameter of our method, without artificial smoothing that can change the measured values according to the filter applied.

Among the results presented in the paper, the pdf of Lagrangian acceleration components highlights some of the turbulent-like characteristics of this flow. From the comparison between the Eulerian fields of velocity and acceleration, it is found that the number of zero acceleration points is larger than the one of zero velocity points (stagnation points), as it happens in turbulent flows.

Moreover, we are able to measure the Eulerian field of Navier-Stokes equation's viscous term over the whole investigation field: this permits to see that the viscous term is weak compared to the acceleration one and concentrated at the small scales (like in turbulent flows) and to obtain an indirect measurement of the pressure gradient over all the area of interest. Finally, the possibility of measuring the power input, output and transformation in the flow according to its topology may be useful to better understand how it is related to mixing.

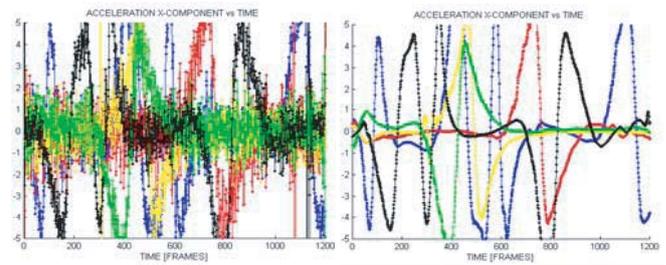


Fig. 1 Comparison of the acceleration x component (in pixel/s², 1 pixel is 0.411 mm) versus time (in frames) measured with a polynomial approximation of order 4 and a fixed number of positions (21), illustrated on the left, and with PTVA ($D = 8$ px), on the right.

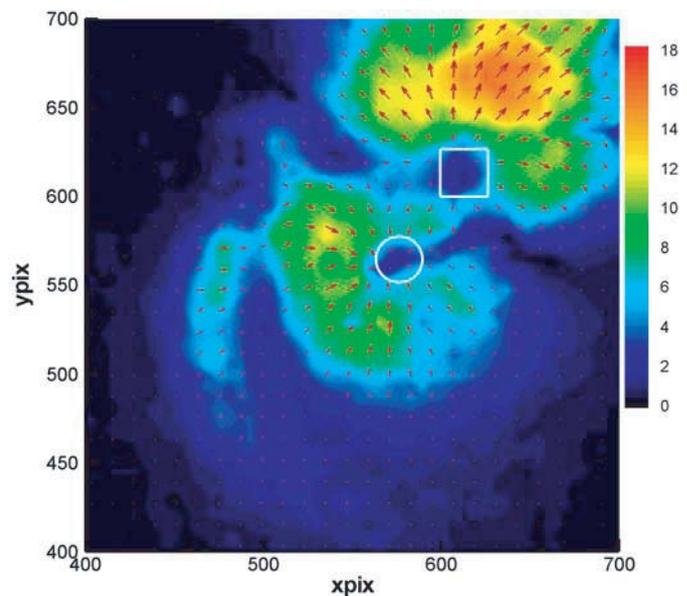


Fig. 2 A zoom on the intensity of the acceleration field, $\|a\|$ in pix/s².