Comparison of Tomographic PIV algorithms on resolving coherent structures in locally isotropic turbulence

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Keywords: Experiment, Tomographic PIV, Isotropic homogeneous turbulence, comparisons

Two independently developed tomographic PIV algorithms, one developed by the fluids group at the University of Cambridge and the other by LaVision GmbH, have been used to compare various turbulence quantities computed from a common experimental dataset of locally isotropic turbulence at reasonably high Reynolds number.

The ensemble averaged results and the statistics of the mean velocities, \textit{rms} of the fluctuating velocities, divergence fields, velocity correlation functions and fluctuating velocity gradients are calculated and compared in details, followed by the comparisons of turbulence energy over the measurement volume. Comparisons of the statistical flow topology are also made, with the conditional averaging on divergence magnitudes. High enstrophy structures in an instantaneous flow field are also presented and compared at the end of this paper, showing some hints of vortex stretching dominant features on the high enstrophy structures.

The comparisons of the results from the two tomographic algorithms basically showed very good agreements in the ensemble averaged mean velocities, while some differences of magnitudes, variances and distributions are observed in velocity gradient related quantities, such as divergence. In particular:

1. Both algorithms reproduced similar fields of velocity magnitude and \textit{rms} as well as similar statistical values.
2. Important differences between the algorithms occurred when computing velocity gradients. Differences in both the divergence fields and statistics were observed. The LaVision algorithm produced lower divergence values. The PDFs of all nine components of the velocity gradient tensor from both algorithms basically agree with DNS studies, with LaVision dataset showing better behavior on the diagonal components.
3. The ability of both algorithms to capture higher order gradient statistics was tested by calculating the invariants of the velocity gradient tensor. Joint PDFs of Q and R from algorithms were unable to produce the characteristic asymmetric teardrop shape due to the effect of noise and insufficient resolution. Casting resolution issues aside this shows that 3D measurements of fine-scale motions are strongly affected by noise, which is mostly produced during the reconstruction process.
4. It was shown that both algorithms suitably capture the same coherent high-enstrophy structures showing that the tomographic PIV technique is perfectly suited to investigating the structure and dynamics of turbulence.

References