An advection model to increase the time-resolution of PIV time-series

Fulvio Scarano¹, Peter Moore¹

1:Aerospace Engineering Department, Delft University of Technology, The Netherlands, F.Scarano@tudelft.nl

Keywords: time-resolved PIV, Lagrangian time scales, advection, frozen turbulence

A simple post-processing technique based on the advection equation is investigated for the enhancement of the temporal resolution of PIV data sets obtained at a sufficient or barely sufficient recording rate with respect to the flow time-scales. The method is based on the application of the advection equation, invoking Taylor’s hypothesis of frozen turbulence. When such an approach can be applied, the requirement on flow sampling rate is based on the Lagrangian time scales, which are significantly longer than the Eulerian ones. The working principle is based on a Lagrangian evaluation of the flow velocity at intermediate time instants with respect to the measured samples. The applicability is verified by means of planar and 3D tomographic experiments conducted at temporal resolution higher than that dictated by Nyquist criterion. The flow past the trailing edge of a NACA0012 airfoil closely approximates frozen turbulence and the largest ratio between Lagrangian and Eulerian temporal scales is found. As a result, an order of magnitude reduction of the needed acquisition frequency is possible. In the separated flow around a bluff body a separated shear layer produces unstable waves shed at approximately 270 Hz. The time super-sampling technique applied also in the shear layer region shows a smaller (due to a smaller ratio between Lagrangian and Eulerian flow time-scales), yet substantial increase in effective measurement frequency.

Three-dimensional time-resolved tomographic PIV measurements of a transitional jet are considered. In this case, the Lagrangian approach can be implemented following three-dimensional trajectories. The qualitative inspection of the flow field and vortex topology indicates possible reduction of the needed frequency from 1,000 Hz to approximately 100 Hz. All experiments reveal that the current requirements for time-resolved PIV experiments can be revised when spatial information can be poured into temporal, i.e. the instantaneous convective velocity is used to perform temporal super-sampling. A yet important side effect of this approach is that the frequency spectra become significantly less affected by aliasing.

The paper contains first a short discussion on Taylor’s hypothesis and its relation to the flow time scales and required measurement frequency. Then a section is devoted to the description of the mathematical approach followed for the time super-sampling of the PIV sequence. The investigation of the applicability of the method in real experiments is structured in three parts with planar and three-dimensional cases.

---

3.1.2.