Time Resolved High Dynamic Range PIV Using Local Uncertainty Estimation Methods

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The dynamic velocity range of particle image velocimetry (PIV) is determined by the ratio of maximum to minimum resolvable particle displacement. Various techniques have been developed to extend the dynamic range by increasing the maximum or reducing the minimum measurable displacement [1, 2]. Nevertheless, implementations with a wide velocity range still challenge conventional PIV methods. In this paper, a basic axisymmetric jet flow is used as a benchmark case yet similar flow conditions occur in many aerodynamic and industrial engineering applications.

Using multiple pulse separation (MPS) acquisition in combination with a new criterion for the local optimal pulse separation, this paper presents a new time-resolved high dynamic range (HDR) PIV methodology. The optimality criterion is based on maximizing a heuristic vector quality metric combining the correlation peak ratio with the estimated local displacement uncertainty and magnitude, expressed as a local signal-to-noise ratio $s_{mag}/\Delta s$. Minimal user intervention is required; a choice of kernel size determining the spatiotemporal resolution of the method and an exponent determining the balance between correlation strength and signal-to-noise ratio.

The method is demonstrated in this paper in its simplest form, requiring no specialized pulse timing system but only a standard time-resolved double-pulsed PIV system. The vector fields evaluated from double-frame cross-correlation and those evaluated from time-series cross-correlation are combined, resulting in an increase in dynamic velocity range of 34:1 compared to conventional best practice double-frame PIV. Significant enhancements are shown in the measured turbulence intensity (see Fig. 1) and estimated signal-to-noise ratio (see Fig. 2) throughout the flow field, but especially in the entrainment region and the outer shear layer of the jet flow.

Hot-wire anemometry is used in selected characteristic locations in the flow field as independent reference for the PIV measurements. The results presented in the paper show that time-resolved HDR method automatically selects the most optimal pulse separation in each vector location, as a function of time.

The HDR PIV method is implemented entirely based on readily available data and hardware, although it could be further improved by incorporating alternative uncertainty estimation methods [3, 4], and using more advanced pulse timing systems. The HDR processing can be carried out at a moderate computational cost. Since it is implemented as a post-processing routine, it is fully compatible with all conventional vector evaluation algorithms, such as those implemented in commercial PIV software packages.

References