Decomposition of time-resolved tomographic PIV

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An experimental study has been conducted on a transitional water jet at a Reynolds number of Re = 5000. Flow fields have been obtained by means of time-resolved tomographic particle image velocimetry (TR-TOMO PIV) capturing all relevant spatial and temporal scales. The three-dimensional flow fields have then been postprocessed by the dynamic mode decomposition (DMD) which identifies coherent structures that contribute significantly to the dynamics of the jet. Where the jet exhibits a primary axisymmetric instability followed by a pairing of the vortex rings, two dominant dynamic modes have been extracted which describe these flow features low-dimensionally. The experiments have been performed in the water jet facility at the Aerodynamic Laboratories of the TU Delft (Violato *et al.*, 2009).

The jet exits from a round nozzle of diameter D = 10mm into an octogonal water tank of 600 mm diameter and 800 mm height whose Plexyglass sides allow full optical access to the illumination and tomographic imaging. For a Reynolds number of Re = 5000 a jet exit velocity of U = 0.5m/s has been chosen. Image sequences are acquired by a PIV system at a kilo-hertz rate over a three-dimensional measurement domain of 50mm×50mm×32mm. The volumetric light intensity is reconstructed using a volume-self-calibration procedure and a MART reconstruction algorithm. Three-dimensional velocity fields are then computed based on a spatial cross-correlation of two subsequent volumes (Elsinga *et al*. 2006).

The dynamic mode decomposition (DMD) is a data-based decomposition technique that identifies the dominant coherent motion in a flow field by constructing and subsequently analyzing an approximate linear mapping between time-resolved measurements (Schmid *et al.*, 2009). The underlying principle of the dynamic mode decomposition is the fact that for a sufficient number of observations (snapshots) the dominant flow dynamics can be expressed approximately by a linear combination of the hitherto observed samples.

A mapping is constructed by splitting the measurement sequence into two data-sets shifted by one time-step. A general linear mapping S between the two data-sets is then assumed, and the resulting least-squares problem for S is solved by the standard QR-technique. The spectrum of of the identified linear mapping S then contains information about the frequencies w and decay rates s of the flow captured within the processed snapshot sequence. A sequence of time-resolved snapshots, each consisting of 107×62×62 three-dimensional velocity vectors have been processed by the dynamic mode decomposition. The most dominant dynamic mode (beside the mean flow) is displayed in figure 1. It shows strong vertical structures near the edge of the jet about four diameter downstream from the nozzle, corresponding to vortex rings. The Strouhal number of this dynamic mode, based on its frequency, the jet diameter and the jet velocity, is determined as St = 0.374.

References

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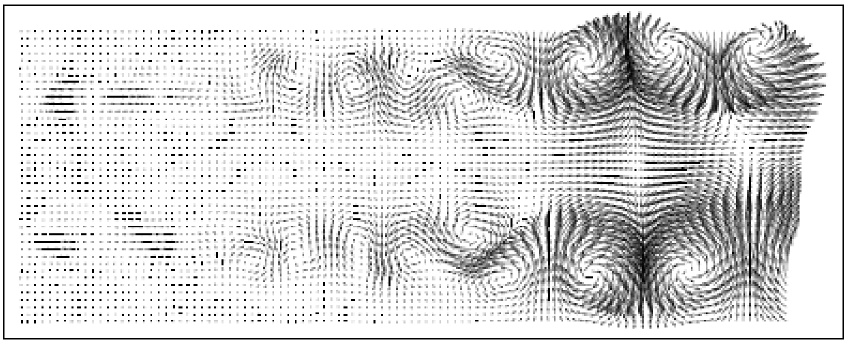

Fig. 1 Decomposition of a three-dimensional low-Mach number jet at Re = 5000. Most dominant dynamic mode (DM), beside the mean flow mode.