VORTEX GEOMETRY OF A JET-IN-CROSSFLOW DISCHARGE

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The jet-in-crossflow discharge formed as the single circular jet issuing normally into a crossflow, frequently called "transverse jet" or "jet in crossflow" (JICF), represents one of the basic jet-flow configurations with a wide variety of engineering and environmental applications (e.g. Margason 1993). The JICF phenomenon is closely associated with buoyant jets and plumes where density distribution (due to initial jet-to-crossflow difference and/or crossflow stratification) plays a crucial role (e.g. Jirka 2004). Though the JICF is characterized in the near field by a relatively complex vortical structure consisting of both steady and unsteady coherent vortical structures, it is well known that the dominant vortical mean-flow feature is a secondary-flow contrarotating vortex pair (CVP) schematically depicted in Fig. 1 (the origin of the coordinate system is at the centre of the jet exit). The CVP occurs as a result of the impulse of the jet on the crossflow, forming itself in the near field and becoming dominant in the far field (e.g. Fric and Roshko 1994, Kelso, Lim and Perry 1996). This dominant vortical structure is naturally responsible for convective entrainment of the JICF. This entrainment effect is expected to persist far downstream depending on the CVP decay by the (usually turbulent) vorticity transport between its vortex cores across the plane of symmetry.

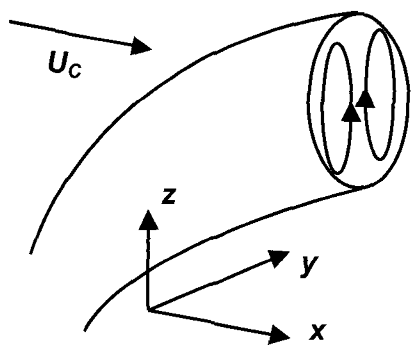

Fig. 1 Sketch of the CVP and coordinate system (U_C denotes crossflow velocity).

While many papers have studied various fluid-dynamical aspects of the JICF in detail, the description of the CVP structure in terms of vorticity fields is relatively scarce in open literature. Moreover, though vorticity appears as the primary quantity for the description of vortical structures, it has been recently well recognized that vorticity does not provide a true vortex geometry because of not distinguishing the effect of a "background shearing" from the "actual swirling motion of a vortex". In the present work, a novel approach (Kolář 2004) to vortex core identification based on the triple decomposition of the local relative motion near a point is applied to the above mentioned CVP. Though the vorticity itself is not suitable for the identification of a vortex core, the present paper demonstrates that a specific portion of vorticity provides a proper physical quantity for the detection of vortex cores. In this regard, the vorticity is decomposed into two parts, *shear* vorticity and *residual* vorticity. The *residual* vorticity is associated with the local *residual* rigid-body rotation near a point obtained after the extraction of an *effective* pure shearing motion.

Though the CVP mean flow is generally of 3D nature, the downstream bending of the jet to the crossflow direction results in a relatively small slope of the jet in the far field. Consequently, velocity gradients in crossflow direction are relatively small and for the analysis of the flow in cross sections perpendicular to the crossflow direction the triple-decomposition algorithm specialized to 2D velocity fields can be employed.

The experimental data of mean-flow velocity fields of the turbulent JICF (for jet-velocity/crossflow-velocity ratio of 8, jet-based $Re_J \approx 4.6 \times 10^4$) are analyzed in seven equidistant rectangular cross-sections located at x/D = 10, 12.5, 15, 17.5, 20, 22.5 and 25. The CVP vortex cores are identified in terms of the *residual* vorticity, see Fig 2. The main result regarding the JICF vortex geometry clearly indicates that while the CVP vorticity distribution is characterized by the well-known prolonged contours, the vortex-core geometry described by the *residual* vorticity (after extracting an *effective* pure shearing motion) is nearly circular.

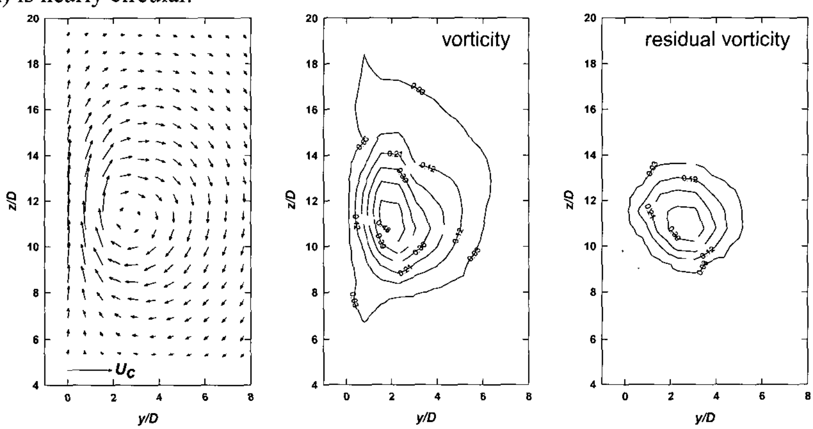

Fig. 2 Velocity, (negative) vorticity and *residual* vorticity for x/D = 15.

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