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Visualization of Streamwise Vortex Pairs in an Indeterminate Origin (IO) Nozzle Jet

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The shape of the indeterminate origin (IO) nozzle, which is a truncated, conical 4-peak nozzle, is shown in Fig. 1.

Fig. 1. Geometry of the IO nozzle.

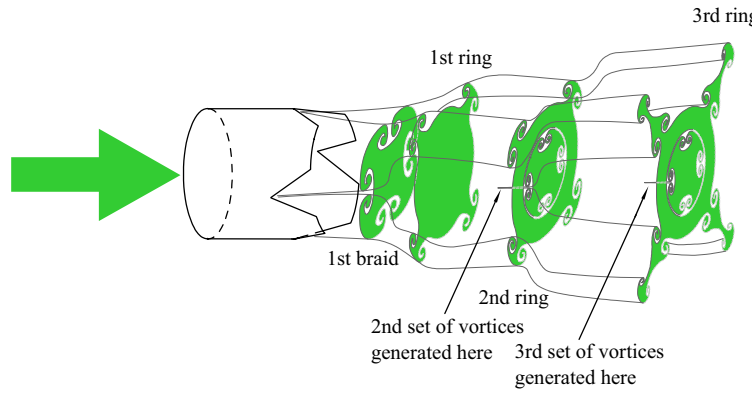

Fig. 2. Sketch of streamwise vortex structures in the IO nozzle jet.

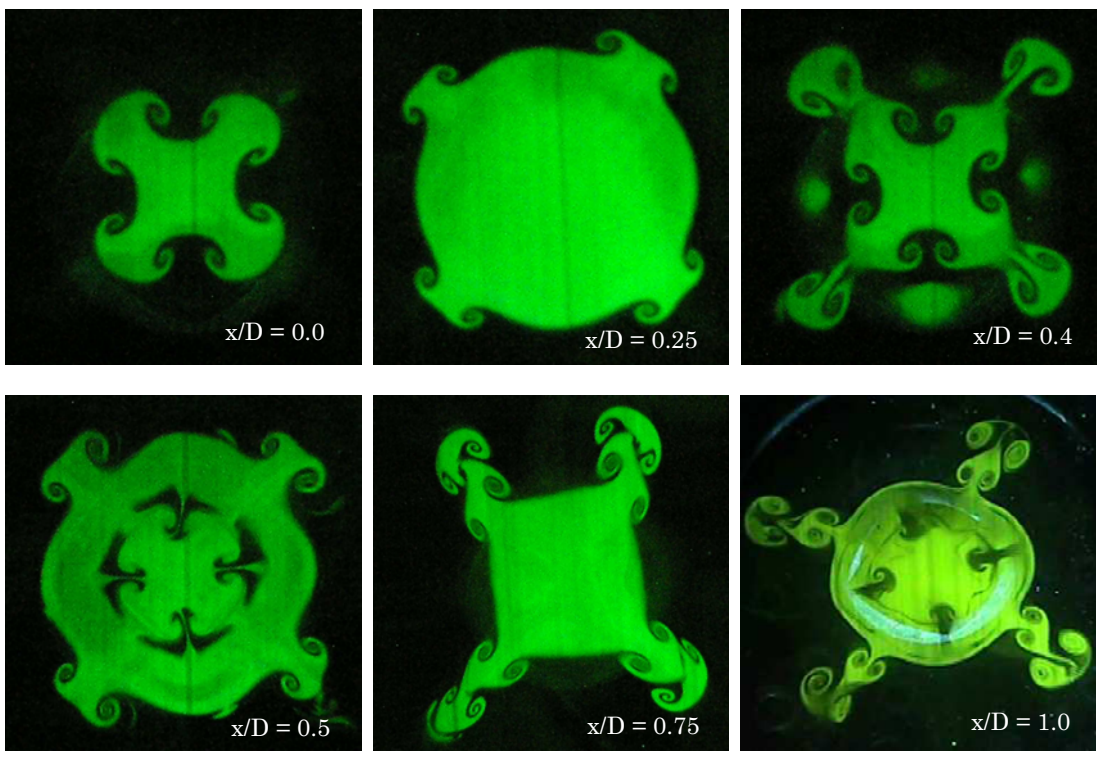

Fig. 3. Cross-sectional LIF flow visualizations at different downstream locations in the near-nozzle region.

"Incursion" streamwise vortex pairs are generated near the nozzle valley locations in braid regions of the jet. They entrain ambient fluid into jet core. These vortex pairs are confined in the jet core, and because of their close proximity, they reorganize to form the "excursion" vortex pairs, which expel the jet fluid into surroundings. The reorganization consists of streamwise vortices from adjacent pairs joining to form a different pair.

New sets of vortices are generated in each braid region. These vortices are initially incursion pairs and develop into excursion vortex pairs after reorganization. Up to three sets of vortex pairs in the radial direction were observed in the experiment before the jet transitioned to turbulence.