Reynolds Number Dependence of Vortex Ring Formation by Transient Jet Ejection

PAUL S. KRUEGER, SMU — Vortex ring formation by the sudden ejection of a jet from tube and orifice openings is investigated numerically for jet Reynolds number ($Re$) in the range $10 - 2000$ and jet slug length-to-diameter ratios ($L/D$) in the range $0.5 - 6.0$. This $Re$ range brackets nearly inviscid behavior (vortex sheet roll-up) at the high end and highly diffusive behavior at the low end. The present investigation is motivated by how the enhanced role of viscosity at low $Re$ affects the development and properties of the resulting vortex rings. The results for $Re = 2000$ show classical behavior, namely, compact vortex rings at low $L/D$ and a leading vortex ring followed by a trailing jet for $L/D$ sufficiently high. As $Re$ decreases below 100, viscous diffusion leads to rapid radial growth of the vortex ring trajectories, and rapid decay of total circulation and kinetic energy. For all $Re$, the ratio of the impulse obtained during jet ejection to that from a steady, uniform jet of the same duration increases with $L/D$ until a trailing jet appears. The maximum impulse ratio achieved increases as $Re$ decreases for the tube configuration, but the opposite trend is observed for the orifice configuration.

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