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Patterns for efficient propulsion during the energy evolution of vortex rings

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Abstract

Compared with steady-jet propulsion, pulsed-jet propulsion can exhibit more efficient by manipulating the unsteady formation of vortex rings in the near wake. That is, energy is much better transferred and used in the form of vortices to generate propulsive force rather than a steady jet. This study is aimed at analyzing the energy evolution of vortex rings and revealing the patterns for efficient propulsion during the energy evolution. Of particular importance to the energy evolution of vortex rings is the pinch-off mechanism, which is owing to the limiting effects of energy and causes that vortex rings cannot grow indefinitely. Canonical vortex rings are generated by using a piston-cylinder apparatus and their time-dependent flow fields are measured using digital particle image velocimetry. During the energy evolution of vortex rings, overpressure and fluid flux at the exit plane are found to significantly contribute to their energy. Moreover, overpressure is the dominant pattern contributing to the energy of vortex rings and has a greater contribution than fluid flux at the early evolution stage, whereas the contribution of overpressure nearly disappears once vortex rings pinch off. By contrast, fluid flux continuously contributes to the energy of vortex rings until they physically separate from the trailing vortices. Based on the hyperbolic LCSs, distinguishable flow patterns are detected to correspond to the energy evolution of vortex ring. The appearance of a newly disconnected

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