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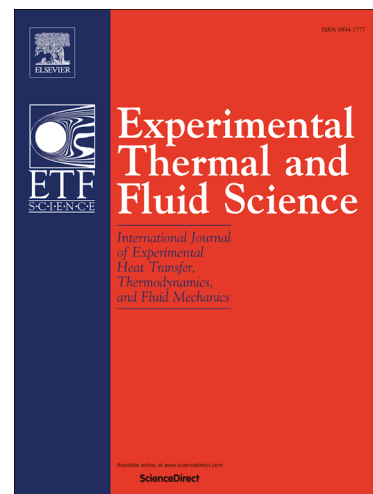
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Quantitative analysis of vortex added-mass and impulse generation during vortex ring formation based on elliptic Lagrangian coherent structures

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Abstract

In many propulsive systems operating with the generation of large-scale vortices, the enhanced performance is achieved and closely related with the effects of vortex added-mass. However, quantitatively analysing vortex added-mass is difficult, particularly when the vortex is significantly deforming, because identifying a physical vortex boundary is difficult. Recently, a physical vortex boundary is defined by the elliptic Lagrangian coherent structures (LCSs), which are sought as closed stationary curves of the averaged Lagrangian strain. In this study, a canonical vortex-ring flow is investigated to analyze the evolution of vortex added-mass by examining the evolution of elliptic LCSs. A vortex ring is produced experimentally by employing a piston-cylinder apparatus, and the time-dependent flow fields are recorded by particle image velocimetry technique. Elliptic LCSs are computed with high-precision algorithms. Compared with the streamline pattern and ridges of the finite-time Lyapunov exponent, elliptic LCSs can more precisely and quantitatively determine a vortex boundary that acts as a material surface in fluids. In terms of elliptic LCSs, vortex added-mass coefficient is computed and demonstrates a decreasing tendency from approximately 1.3 to 0.88 during vortex ring formation. Correspondingly, the overpressure contribution to the vortex impulse exhibits the same decreasing tendency

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