Cavity flow stability analysis with space phase-averaged velocity fields

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ABSTRACT

An open cavity flow is strongly dependant on its geometry and Reynolds number, yielding to development of different types of instabilities. The shear layer between the external and the inner cavity flow is able to give rise to a Kelvin-Helmholtz-like instability, coupled with the shear flow impingement on the downstream cavity wall. The velocity gradient, between external and internal flows and the wall confinement, induce a recirculation inside the cavity. A centrifugal Taylor-Görtler-like instability, originating from that flow curvature, is also subject to appear, for particular parameters [1]. The aim of the study is to provide better understanding of the coupling between the shear-layer and the occurrence of centrifugal instabilities.

Time-resolved PIV velocity fields do not show large enough shear layer wave amplification for squared cross-section cavities (aspect ratio, defined as length L over depth D, equals one). For $L/D = 2$, the shear layer growth shows the development of a shear layer vortex growing toward the downstream cavity edge and injected inside the cavity flow recirculation. The location where this vortex gets its larger space expansion is taken as a reference for phase-locked averages over successive shear-layer oscillations. The resulting phase-averaged velocity fields show that the shear layer vortex periodic motion interacts with the cavity recirculation providing a circular motion of the center of the recirculation vortex. The generation of the centrifugal instability is discussed with measurement of Rayleigh discriminate η [2], considering each phase-locked average as a basis state. The regions of potential creation of Taylor-Görtler-like instability are associated with positive values of η and correspond to the external boundary of the recirculation vortex, which is not affected by the periodic shear-layer oscillations.

A parametric analysis of the Rayleigh discriminate with cavity geometry shows the increase of η with Reynolds number. Comparison of these values with flow visualizations provides a unique threshold for the development of Taylor-Görtler-like instability, depending on the recirculation radius and confinement. Inside the recirculation vortex, a viscous stability parameter C is defined as the ratio of destabilizing centrifugal effects over stabilizing viscous effects [3]. The values of C measured in the present case of a shear layer driven cavity are compared with the ones obtained in the case of a lid-driven cavity. In the shear-layer cavity flow, the centrifugal instability is observed for a lower Reynolds number than for the lid-driven cavity. The unstable state, resulting in recirculation flow curvature, is then enhanced by the shear-layer oscillation.

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