Secondary instability of centrifugal vortices in a cavity shear flow

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ABSTRACT

We are interested in the development of centrifugal instabilities in an open cavity flow. Several works deal with cavity flows but very often these studies concern the shear layer and the acoustic of that two dimensional instability. We present here the development of a three dimensional instability, resulting in Taylor-Görtler-like vortices which are created by the curvature of the recirculation and its confinement by the walls. This primary instability manifests itself in the form of pairs of counter-rotating tori and the dynamic of these structures depends on experimental parameters - Reynolds number based on the cavity depth and the aspect ratio. For distinctive values of parameters, that primary instability exhibits a spanwise drift. A parametric study has been realized with flow visualization [1] and revealed, for different parameters, a secondary instability. In flow visualizations, that instability shows axial movement out of phase between vortices of the same pair.

We want to characterize quantitatively this secondary instability. For that purpose, we study a case with the secondary instability and its spanwise drift.

In order to detect the vortices and to characterize their behaviors, Particle Image Velocimetry (PIV) measurements have been carried out. PIV fields are obtained with an optical flow algorithm [2]. This algorithm calculates continuous and differentiable fields so it is adapted for flows with strong velocity gradient. The study is realized in a plane parallel to the background of the cavity and located 30% below the upstream edge in order to visualize the vortices. A criterion for detecting structures in movEment, named Γ_2, has been used and applied to the PIV fields and allows to track a vortex over time providing the vortices spanwise drift and size.

The results show, for the configuration with secondary instability, a significant acceleration of the spanwise drift for the same Reynolds number. The size modifications and velocity modulation of these vortices are also identified. To understand the spanwise drift, the contribution of the Taylor-Görtler vortices on the velocity fields is studied. This work permits to characterize the modulation generated by the secondary instability on the velocity modulation provided by the vortices. This contribution is obtained from subtraction of the averaged velocity from instantaneous fields. The result highlights the link between that velocity modulation which is synchronized with the evolution of the spanwise drift but also with the fluctuation of the size of the vortex.

We present the parameters which lead to the secondary instability and the features of this one.

REFERENCES

[1] T.M Faure, L.R Pastur, F. Lusseyran, Y. Fraigneau, D. Bisch *Three-dimensional centrifugal instabilities development inside a parallelepipedic open cavity of various shape*, Exp Fluids **47**, 395-410, 2009.

[2] G. Quénot, J. Paklezoi, T.A. Kowalewski *Particle image velocimetry with optical flow*, Exp Fluids **25**, 2936-2946, 1998.