Self-sustained Three-dimensional Low Frequency Nonlinear Dynamics in Incompressible Open-Cavity Flow

- BIFD2011 -

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ABSTRACT

The emergence of unsteadiness in a flow past an open-cavity has been widely studied during the last fifty years because of its practical interest and because of the variety of theoretical questions. A feedback process sustains coherent oscillations in the shear layer developing above the cavity, while a complex low frequency three- dimensional dynamics leads to large scale coherent structures inside the cavity, and couplings between them remain largely unknown. Flow conditions are controlled by the cavity aspect ratio R = L/D, the boundary layer displacement thickness $\delta^\star$, the Reynolds number based on cavity length Re_L and the spanwise extent. We propose to analyse the dynamics of an open-cavity defined by $R = 1$ at Reynolds number $Re_L = 3000$ and with $\delta^\star/L = 0.157$ at the leading edge of the cavity. A 3-D global linear stability analysis [1] exhibits the occurence of several transverse low frequency modes whose the most unstable one is stationnary (Fig. 1). 3-D global modes are compared to the fully non-linear saturated regime, as observed from 3-D direct numerical simulations (DNS). A spectral analysis of the nonlinear flow based on the calculation of Koopman modes [2] is achieved. The nonlinear dynamics shows the appearance of a self-sustained low frequency three-dimensional mechanism inside the cavity (Fig. 2).

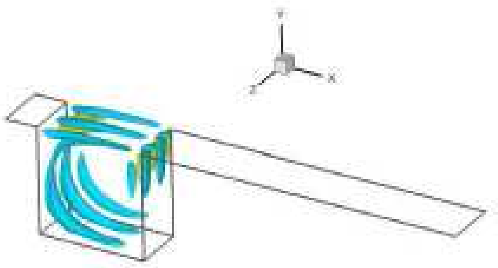

Figure 1: Stationnary 3D global mode: spanwise perturbation.

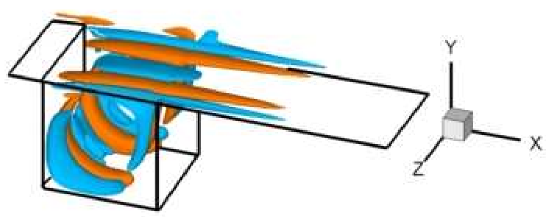

Figure 2: 3D-DNS: spanwise velocity component.

REFERENCES

[1] Tuckerman L.S, Barkley D. *Bifurcation analysis for timesteppers.* In Numerical Methods for Bifurcation Problems and Large-Scale Dynamical Systems, Doedel E, Tuckerman LS (eds) Springer: Berlin, **453566**, 2000.

[2] C. W. Rowley et al. *Spectral analysis of nonlinear flows*, J. Fluids Mech., vol. **641**, pp. 115–127, 2009.