PROPOSITION DE STAGE – MASTER 2 DET
Dynamique des fluides, Énergétique et transferts
Université Toulouse 3 Paul Sabatier – Toulouse INP – INSA Toulouse – ISAE-SUPAERO – IMT Mines Albi

Titre : Linear stability analysis of cavity flows at very high Reynolds number.

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Lieu du stage : Département aérodynamique, énergétique et propulsion, ISAE-SUPAERO

Durée / période : Six months

Candidature [CV, lettre de motivation, références] à envoyer à : michael.bauerheim@isae-supaero.fr

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Sujet

Background

The coupling between hydrodynamic instabilities and acoustic waves in cavity flows leads to a resonance mechanism that takes place on a broad range of flow conditions. Such resonance may lead to undesirable structural vibration and/or strong tonal noise. Understanding the dynamics of this aeroacoustic phenomenon is of great interest for the aeronautic industry, since cavities are a common feature of many aircraft geometries. In deep cavities (for which the depth-to-width ratio is high), the resonant mechanism is underpinned by a coupling between a standing wave inside the cavity and a hydrodynamic instability in the shear-layer above the cavity, as sketched in fig. 1.

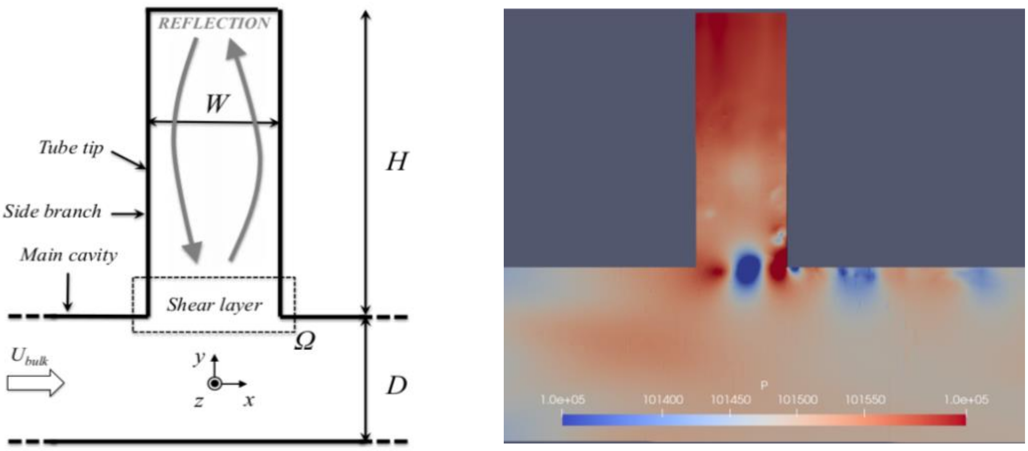

Figure 1: Left : Sketch of a deep cavity resonant mechanism, from [1]. Right: pressure snapshot from a large-eddy simulation. The signature of large-scale instabilities can be seen in the shear-layer region.

Linear stability analysis has been proven to be quite successful in modelling such mechanism (see Figure 1) in academic configurations for which the incoming boundary layer is thin compared to the cavity length. However, no studies so far have explored regimes where the boundary layer is thicker than the cavity, which is typical of industrial applications. In this internship we wish to assess linear instability mechanisms in cavity flows under such incoming flow conditions. Stability analysis of the compressible Navier-Stokes system will be carried out about the turbulent mean flow, as in [3]. The mean flow, which will be provided to the student, is obtained through large-eddy simulations (LES) computed with the IC3 solver developed at Supaero. A locally-parallel approach will be pursued [3], wherein the flow is assumed to be homogeneous in the streamwise and spanwise directions. The main focus of the internship will be on instabilities of the hydrodynamic field (which can be depicted in the LES results of fig. 1), aiming at characterising their growth rates, convection speeds and spatial organisation at frequencies around the resonant regime. Special attention will be given to the effect of Mach number and spanwise modulation of flow disturbances on the stability characteristics. The internship is therefore expected to contribute to a better understanding of linear mechanisms in such high-Reynolds-number regimes and the results are expected to be relevant to both fundamental and practical applications.

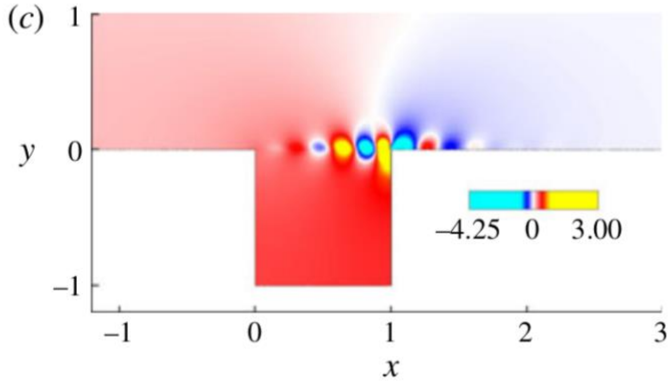

Figure 2: Spatial distribution of pressure computed from a linear stability analysis [2]. The pressure mode has an underlying structure which is similar to pressure fluctuations observed in the LES (fig.1).

Program of internship

The research program will follow the different steps described below.

1. Familiarization with the mean-flow database.
2. Familiarization with the linear stability solver, developed in [3] for a round jet. Adaptation of the linear operator and boundary conditions for the cavity configuration.
3. Analysis of the effect of Mach number and spanwise wavenumber on stability characteristics: growth rates, convection speeds and spatial organisation.
4. Comparison of stability modes with coherent structures educed from the LES through modal decompositions, such as Spectral Proper Orthogonal Decomposition (SPOD) [4] using codes currently available at the lab.

References

[1] M. Bauerheim, E. Boujo, N. Noiray. Numerical analysis of the linear and nonlinear vortex-sound interaction in a T-junction. AIAA Aviation Forum, 2020, Virtual Event, United States.

[2] S. Yamouni, D. Sipp, L. Jacquin. Interaction between feedback aeroacoustic and acoustic resonance mechanisms in a cavity flow: a global stability analysis. Journal of Fluid Mechanics, 717, pp. 134-165. 2013.

[3] I. A. Maia, G. Brès, L. Lesshafft, P. Jordan. The effect of a flight stream on turbulent subsonic jets. ArXiv paper number arXiv:2208.07975, 2022.

[3] M. Fiore, H. Parisot-Dupuis, B. Etchebane, R. Gojon. Spectral proper orthogonal decomposition of coupled hydrodynamic and acoustic fields: application to impinging jet configurations. Computer & Fluids, 241(1):105484, 2022.