

Postdoc position, 12 to 24 months

STABILITY OF CAVITY FLOWS AT HIGH REYNOLDS NUMBERS.

Dr J. Fontane, jerome.fontane@isae-superaero.fr

Dr J. Gressier, jeremie.gressier@isae-superaero.fr

Dr T. Jardin, thierry.jardin@isae-superaero.fr

Institut Supérieur de l'Aéronautique et de l'Espace (ISAE)
Département Aérodynamique Énergétique et Propulsion (DAEP)

1 Context

The control of cavity flows has been a topic of interest for many years as evidenced by review articles published in the early 2000s (Cattafesta *et al*, 2003; Rowley & Williams, 2006). Recently published work shows that the interest is still relevant (Prudhomme *et al*, 2021; Luo *et al*, 2018; Liu & Gómez, 2019; Ohmichi & Yamada, 2021). The recent test campaign by Prudhomme *et al* (2021) to characterise the response of the cavity flow to passive control systems (rod perpendicular to the main flow direction or sawtooth spoiler) in transonic flight conditions ($M = 0.9$ and $M = 1.1$) clearly indicates the need to characterise the flow dynamics for these high speed regimes. This type of passive control is still preferred because of its simplicity of implementation for aeronautical applications compared to active systems for which the need for a power source is often a difficulty for an on-board solution. Beyond the classical passive control systems tested by Prudhomme *et al* (2021), the modification of the rear shape of the cavity is a promising avenue for the suppression of oscillations via the modification of the aeroacoustic properties of the cavity (Luo *et al*, 2018; Liu & Gómez, 2019).

The design of these control systems requires a preliminary characterisation of the flow dynamics to quantify its receptivity to external perturbations and to identify the regions of sensitivity where the positioning of a control system will be most effective (Ohmichi & Yamada, 2021). The global stability analysis of the adjoint Navier–Stokes system allows this characterisation and the application of this type of approach to cavity flow is still largely confined to two-dimensional cavity configurations for which the three-dimensional perturbations are assumed to be periodic in the transverse direction (Brès & Colonius, 2008; Sun *et al*(2017; Theofilis, 2017). This limitation to bi-global stability analyses is often dictated by the prohibitive numerical cost of fully three-dimensional configurations, especially when the linearised equations are solved explicitly by the solver. The recent study by Ohmichi & Yamada (2021) is the first and only three-global stability analysis of cavity flow to date. The approach used is based on time-stepping methods which allow to get rid of the explicit calculation of the linear operator and are thus well adapted to very large problems (Tesuka & Suski, 2006; Rolandi *et al*, 2021). Nevertheless, this study is conducted on a low Reynolds number flow regime ($Re = 1500$) in a compressible subsonic regime ($M = 0.6$). The need to extend this type of analysis to higher Reynolds numbers and in the transonic regime therefore

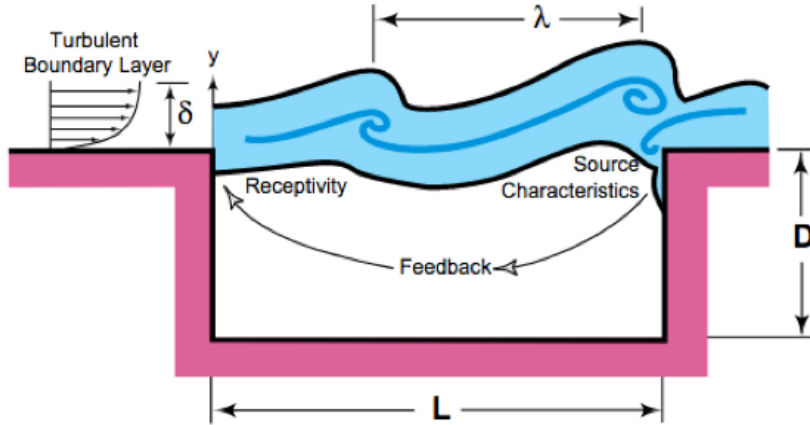


Figure 1: Sktech of the resonance phenomenon at play for a cavity flow (Rowley & Williams, 2006).

remains.

The extension of this stability analysis to higher Reynolds numbers implies to take into account the turbulent nature of the upstream boundary layer flow and to carefully consider the response of the cavity to these continuous external perturbations. Recent studies based on numerical simulations of the LES type (Boujo *et al.*, 2018; Liu & Gaitonde, 2021) have addressed this problem of forcing the cavity by the turbulent boundary layer at high Reynolds numbers ($Re = 150\,000$ and $Re = 10\,000$ respectively) but they only consider a two-dimensional approach.

2 Scientific objectives

The present Postdoctoral study therefore aims to address the problem of characterising the linear dynamics of cavities in response to external perturbations in a three-dimensional configuration for turbulent flow regimes at high Reynolds numbers and for Mach numbers up to the transonic regime. The study will be carried out by means of a linear stability analysis based on direct and adjoint Navier–Stokes systems to characterise the receptivity and sensitivity of the cavity flow with a view to controlling the oscillations of the sheared layer, whether self-sustained or forced directly by the turbulent boundary layer. In particular, the influence of the geometry of the rear face of the cavity (slanted rear wall, rounded rear edge...) will be considered in order to modify its aeroacoustic properties and suppress the acoustic excitation leading to the oscillations of the sheared layer. This work will be performed with the numerical solver IC3, a high-order compact compressible code developed at ISAE-SUPAERO.

The project is scheduled as follow:

1. Implementation and validation of the linearised adjoint equations in IC3.
2. Stability analysis of the cavity flow in weakly compressible regime (up to $M = 0.5$): 3D laminar flow, 2D and 3D turbulent regime.

3. Stability analysis of the cavity flow in transonic and low supersonic regimes ($M \in [0.8; 1.2]$): 3D laminar flow, 2D and 3D turbulent regime.

3 Application

This project is funded by the French Ministry of Defence through financial support of the Agence Innovation Défense and therefore **only candidate with European citizenship** can apply. The candidate has a PhD with a strong background in stability analysis of fluid flows and/or CFD. Coding skills (Python and C++) are expected. Oral and writing skill in English is mandatory. Please send a cover letter, a CV, a list of relevant publications as well as recommendation letters to jerome.fontane@isae-superaero.fr.

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