RÉPUBLIQUE FRANÇAISE
Liberté
Égalité
Fraternité

ONERA
THE FRENCH AEROSPACE LAB

www.onera.fr

PROPOSITION DE STAGE EN COURS D'ETUDES

Référence : **DMPE-2025-08**
(à rappeler dans toute correspondance)

Lieu : Toulouse

Département/Dir./Serv. : DMPE / STAT

Tél. : +33 5 62 25 25 27

Responsable(s) du stage : Javier Sierra-Ausin

Email. : Javier.sierra_ausin@onera.fr

DESCRIPTION DU STAGE

Thématique(s) : Acoustique : Sources; Propagation et impact & Écoulements réactifs

Type de stage : ☒ Fin d'études bac+5 ☒ Master 2 ☐ Bac+2 à bac+4 ☐ Autres

Intitulé : Linearized solver for wave propagation in complex environments

Sujet : In the aeronautics sector, the simulation of acoustic, hydrodynamic, and combustion phenomena plays a crucial role in optimizing system performance and predicting stability. These simulations are essential for both reducing engine noise and managing combustion instabilities, which are particularly challenging in modern systems using alternative fuels.

In aeroacoustics, passive materials known as acoustic liners, which function based on the principle of resonators, are employed to mitigate engine noise. The mathematical representation of these liners relies on a quantity called impedance. However, indirect measurements sometimes question the definition of impedance, which should ideally be intrinsic to the material itself.

In the field of combustion, the complex interactions between hydrodynamics, acoustics, and the unsteady heat release from flames can lead to dangerous instabilities, which, in turn, generate substantial noise. These instabilities can become more prevalent with the use of novel types of fuel, which demands for the integration of advanced control strategies to mitigate their effects. And, more specifically for tools to efficiently predict the flame behavior, for instance the growth rate and frequency of the instability or the flame transfer function.

In both cases, modeling hinges on accurately capturing wave propagation in complex environments (shear grazing flow, reactive flow, or shock-boundary layer interaction). When perturbations to the mean flow field are small, the governing equations can be linearized for tractability.

Objectives:

The primary goal of this internship is to develop a Computational Fluid Dynamics (CFD) solver to address the linearized Navier-Stokes equations (LNSE), with potential extensions to reactive flows (R-LNSE). The key objectives include :

1. **Development and validation** of a 2D LNSE solver for non-reactive cases. The intern may base his/her developments on an in-house LNSE code [1].
2. **Incorporation of impedance boundary conditions** in both frequency and time domains [2].
3. **Extension to 3D cases**, exploring preconditioners [3] for optimizing the linear system resolution.
4. **Linearization of reactive flows**, conducting 2D tests of global reactions with one or two steps on laminar cases [4,5].

Methodology:

To achieve the above objectives, the internship will follow these steps:

1. **Testing of an existing 2D solver**: Perform validation on benchmark cases to establish accuracy and robustness.
2. **Integration of impedance boundary conditions**: Implement impedance models in both the frequency and time domains to simulate realistic acoustic environments.
3. **Extension to 3D simulations**: Extend the solver to handle 3D cases. Study and implement preconditioning strategies to optimize solver performance.
    a. A first publication could be started at this point if time allows.
4. **Reactive flow simulations**: Implement linearization of reactive flows, focusing initially on 2D laminar cases to assess performance and stability.

Required skills:

- Strong proficiency in **numerical methods** for fluid dynamics. A previous experience with Finite Element would be a plus.
- Expertise in **scientific programming**, particularly in Python.
- Solid understanding of **solving linear systems** (LU, Krylov methods).
- Basic knowledge of **acoustics** and **fluid dynamics**.
- Experience with **high-performance computing (HPC)** is desirable but not essential.

Expected outcomes:

1. A validated and robust **2D LNSE** solver for **non-reactive subsonic flows**.
2. Development and validation of a **3D LNSE solver**, including performance optimization and preconditioning strategies.
3. Preliminary results from the **R-LNSE solver** for 2D reactive flows.
4. Potential for **scientific publication**, particularly focusing on impedance in sheared flows, in collaboration with project partners.

Supervision and collaboration:

The internship will be supervised by researchers at ONERA specializing in waves, stability and numerical methods. The intern will also engage with ongoing theses and projects, promoting scientific and technical exchange. Depending on the outcomes, the opportunity to continue with a **PhD thesis** may be evaluated.

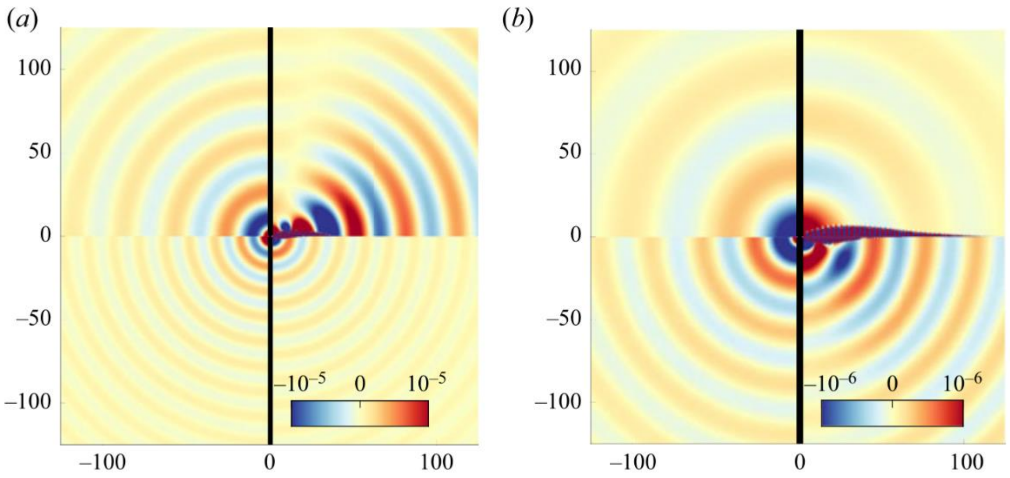

Figure 1 Real part of the pressure component of neutral eigenmode at M=0.05 for two different thickness to diameter ratios.

References

[1] Sierra-Ausin J, Fabre D, Citro V, Giannetti F. Acoustic instability prediction of the flow through a circular aperture in a thick plate via an impedance criterion. *Journal of Fluid Mechanics*. 2022;943:A48. doi:10.1017/jfm.2022.417

[2] Remi Roncen, Jose Cardesa Duenas, Thomas Marchal. Developments of the time-domain impedance boundary condition for combustion problems. *SoTiC (Symposium on Thermoacoustics in Combustion: Industry meets Academia) 2023*, Sep 2023, Zurich, Switzerland.

[3] Moulin, Johann, Pierre Jolivet, and Olivier Marquet. "Augmented Lagrangian preconditioner for large-scale hydrodynamic stability analysis." *Computer Methods in Applied Mechanics and Engineering* 351 (2019): 718-743.

[4] Douglas, Christopher M., Wolfgang Polifke, and Lutz Lesshafft. "Flash-back, blow-off, and symmetry breaking of premixed conical flames." *Combustion and Flame* 258 (2023): 113060.

[5] Wang, Chuhan, Lutz Lesshafft, and Kilian Oberleithner. "Global linear stability analysis of a flame anchored to a cylinder." *Journal of Fluid Mechanics* 951 (2022): A27.

Est-il possible d'envisager un travail en binôme ? Non

Méthodes à mettre en oeuvre :

☒ Recherche théorique ☐ Travail de synthèse

☐ Recherche appliquée ☒ Travail de documentation

☐ Recherche expérimentale ☐ Participation à une réalisation

Possibilité de prolongation en thèse : Oui

Durée du stage : Minimum : 5 mois Maximum : 5 mois

Période souhaitée : 5 mois

PROFIL DU STAGIAIRE

Connaissances et niveau requis :	Ecoles ou établissements souhaités :
Applied mathematics Fluid mechanics Flow instabilities (Global stability, resolvent method)	Engineering school or enrolled in a Master's degree in engineering, physics or applied mathematics