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# PROPOSITION DE STAGE EN COURS D'ETUDES


Référence : **DAAA-2025-15**
*(à rappeler dans toute correspondance)*

Lieu : ONERA Châtillon

Département/Dir./Serv. : DAAA / AKOU

Tél. : 01 46 73 48 11

Responsable(s) du stage : Majd Daroukh

Email. : majd.daroukh@onera.fr


## DESCRIPTION DU STAGE

Thématique(s) : Acoustique : sources, propagation et impact

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

**Intitulé : Development of a multimodal method for the modeling of sound radiation from jet exhausts**

Sujet :

The noise emitted by aircraft turbofan engines can be described into two successive stages: 1/ the generation of sound by acoustic sources due to the flow unsteadiness and 2/ the propagation of sound inside the engine and through the intake or the exhaust. In this internship, the emphasis will be on the acoustic propagation stage. The acoustic waves propagate inside ducts with complex geometries, acoustic treatments and inhomogeneous flows, before radiating to the far field. Standard computational methods can be used to simulate such problems but they often require significant computational resources. The admittance multimodal method is a dedicated numerical approach that has been developed to accelerate these simulations.

Originally proposed by Pagneux et al. in 1996 [1] for classical acoustics, this method has been recently extended during a PhD thesis at ONERA to account for inhomogeneous potential flows, as would be encountered in an engine intake [2]. In its current form, this method can consider axisymmetric geometries and can include acoustic treatments over the duct walls, free-field radiation from the intake and azimuthal flow distortion due to a non-zero angle of attack (see the example of simulations below). This method has been shown to be accurate and much faster compared to standard numerical simulations [3].

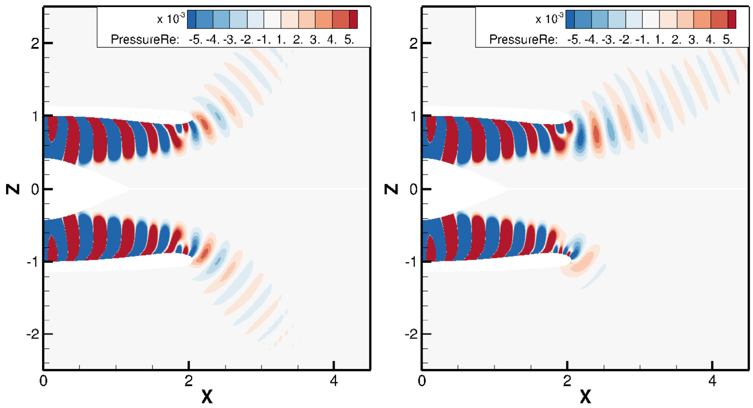


*Figure 1 – Effect of flow distortion on acoustic radiation from intake obtained with the multimodal method: baseline case (left) and distortion case (right). Reproduced from [3].*

The purpose of this internship is to further extend the domain of applicability of the method, with a special focus on the acoustic radiation from engine exhausts. The specificity of the exhaust case is the jet flow, characterized by strong mean flow gradients in the shear layer, that significantly modify the noise radiation. Including this shear layer in the modeling is therefore required to capture the refraction effects. To this end, Gabard and Li recently proposed a model with a thin vortex sheet between the jet and the ambient flows solved by a mode-matching formulation, assuming straight ducts and uniform flows [4]. The objective of the internship is to extend this model to account for slow variations of the duct geometry and flow using the multimodal method, and to implement it in a dedicated Python code. This model will then be used to evaluate the refraction effects due to the shear layer, and the influence of a varying geometry and flow on these effects.

The internship is to be pursued with a PhD thesis, with the objectives of extending the above model by accounting for realistic heterogeneous flow and developing an adjoint formulation in the multimodal framework that could be used for shape optimization and/or source identification.

**References**

[1] Pagneux, V., Amir, N., & Kergomard, J. (1996). A study of wave propagation in varying cross-section waveguides by modal decomposition. Part I. Theory and validation. The Journal of the Acoustical Society of America, 100(4), 2034-2048.

[2] Mangin, B., Gabard, G., & Daroukh, M. (2024). In-duct flow computation and acoustic propagation using the admittance multimodal formulation. The Journal of the Acoustical Society of America, 155(5), 3461-3474.

[3] Mangin, B. (2023). Modelling acoustic propagation in modern turbofan intakes using a multimodal method. PhD Thesis, Le Mans Université.

[4] Gabard, G., & Li, K. (2024). A Mode-Matching Model for Sound Radiation From Jet Exhausts With Liners. In 30th AIAA/CEAS Aeroacoustics Conference, 2024-3329.

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

**Méthodes à mettre en œuvre** :

- ☒ Recherche théorique
- ☒ Recherche appliquée
- ☐ Recherche expérimentale
- ☐ Travail de synthèse
- ☐ Travail de documentation
- ☐ Participation à une réalisation

Possibilité de prolongation en thèse : Oui

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

Période souhaitée : à partir de février 2025

## PROFIL DU STAGIAIRE

| Connaissances et niveau requis : | Ecoles ou établissements souhaités : |
| --- | --- |
| Fluid mechanics | Engineering schools |
| Computational methods | Master 2 |
| Aeroacoustics | |
| Python programming | |