www.onera.fr

PROPOSITION DE SUJET DE THESE

Intitulé : Multimodal methods for the study and optimization of sound radiation from jet exhausts

Référence : **MFE-DAAA-2025-05**
(à rappeler dans toute correspondance)

Début de la thèse : 01/10/2025	**Date limite de candidature : 15/06/2025**

Mots clés

Fluid mechanics, acoustic propagation, admittance multimodal method, adjoint method

Profil et compétences recherchées

In the last year of a Research Master or Engineering School, you have a strong background in fluid mechanics and computational methods. Some notions in aeroacoustics, applied mathematics and optimization would be a plus. You are interested in physical modeling and numerical methods. You are familiar with Python programming. You demonstrate a good sense of critical analysis and autonomy, as well as excellent oral and written communication skills in English. Proficiency in French would be an advantage for everyday communication in the workplace, but is not mandatory.

Présentation du projet doctoral, contexte et objectif

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 PhD thesis, 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].

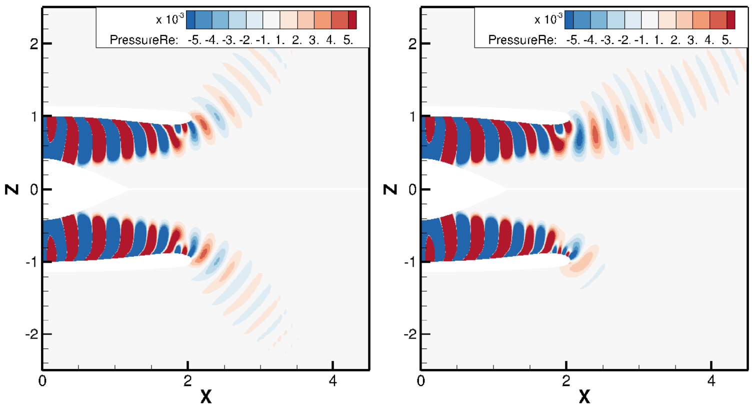

Figure 1 – Effect of flow distortion on acoustic radiation from intake obtained with the multimodal method: baseline case (left) and distortion case (right). Reproduced from [3].

The purpose of this PhD thesis is to further develop the admittance multimodal method, with two main objectives. The first objective is to 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. Two options are envisaged. The first one consists in including a varying geometry and flow in the newly proposed formulation of Gabard and Li [4], which uses a thin vortex sheet between the jet and the ambient flows. The second approach consists in a complete description of the shear layer in the model by solving non-potential equations such as the linearized Euler equations or the Pridmore-Brown equation. The developed model will be evaluated against a standard aeroacoustic solver (linearized Euler equations solver with finite difference methods) on academic and realistic turbofan geometries.

The second objective of the thesis is to develop an adjoint formulation in the multimodal framework that could be used for shape or acoustic treatment optimization and/or source identification. This is a prospective work and the best strategy is yet to be determined (i.e. continuous vs discrete adjoint). The complexity of the model will be increased successively, starting from the acoustic propagation inside a duct without flow, and moving towards the acoustic propagation and radiation from an engine intake or exhaust in the presence of a inhomogeneous flow. The adjoint method is particularly attractive as the sensitivity of an objective function (e.g. the radiated acoustic power) to the control variables such as the acoustic treatment or the geometry of the duct are accessible in a single simulation. This sensitivity can then be used to guide an optimization process to identify the ideal duct shape that minimizes a given objective function or determine the sound source given measurements on a limited space region. A demonstrative optimization of the nacelle shape of a turbofan engine will be conducted, and the source identification procedure will be applied on real measurements of turbofan noise.

A special attention will be given to the dissemination of the above developments. Therefore, the PhD student will be expected to present his/her work in international conferences and to publish in peer-reviewed scientific journals.

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.

Collaborations envisagées

Collaboration avec le Laboratoire d'Acoustique de l'Université du Mans (LAUM)

Laboratoire d'accueil à l'ONERA

Département : Aérodynamique, Aéroélasticité, Acoustique

Lieu (centre ONERA) : ONERA Châtillon

Contact : Majd Daroukh

Tél. : 01 46 73 48 11

Email : majd.daroukh@onera.fr

Directeur de thèse

Nom : Gwénaël Gabard

Laboratoire : Laboratoire d'Acoustique de l'Université du Mans
(LAUM, UMR CNRS 6613)

Tél. : 02 43 83 35 53

Email : gwenael.gabard@univ-lemans.fr

Pour plus d'informations : https://www.onera.fr/rejoindre-onera/la-formation-par-la-recherche