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PROPOSITION DE SUJET DE THESE

Intitulé : Porous Inserts for Passive Flow Control and Airframes Noise Mitigation at Its Source

Référence : **MFE-DAAA-2026-18** *(à rappeler dans toute correspondance)*	
Début de la thèse : octobre 2026	**Date limite de candidature : mai 2026**

Mots clés : Turbulence, Matériaux poreux, Aéro-acoustique

Profil et compétences recherchées

Master de recherche en Mécanique des Fluides.

Expérience souhaitée en mécanique des fluides et CFD (maillages, schémas numériques), modélisation physique et programmation (Fortran, Python, C++…).

Expérience dans le domaine des essais en soufflerie, et/ou intérêt important pour ce domaine.

Mobilité possible pour une partie de la thèse en visite à l'université de Bristol

Présentation du projet doctoral, contexte et objectif

The advent of high-bypass ratio engines has significantly reduced jet noise in modern aircraft. As a result, airframe noise has emerged as the dominant contributor during approach and, increasingly, during take-off after thrust reduction [1-3]. Airframe noise is generated when turbulent flow interacts with aircraft structures, producing local pressure fluctuations that radiate as acoustic waves. This effect is particularly strong around geometrical singularities such as slats, flaps, landing gears, and cavities, which are recognized as the primary airframe noise sources as shown in Fig. 1.

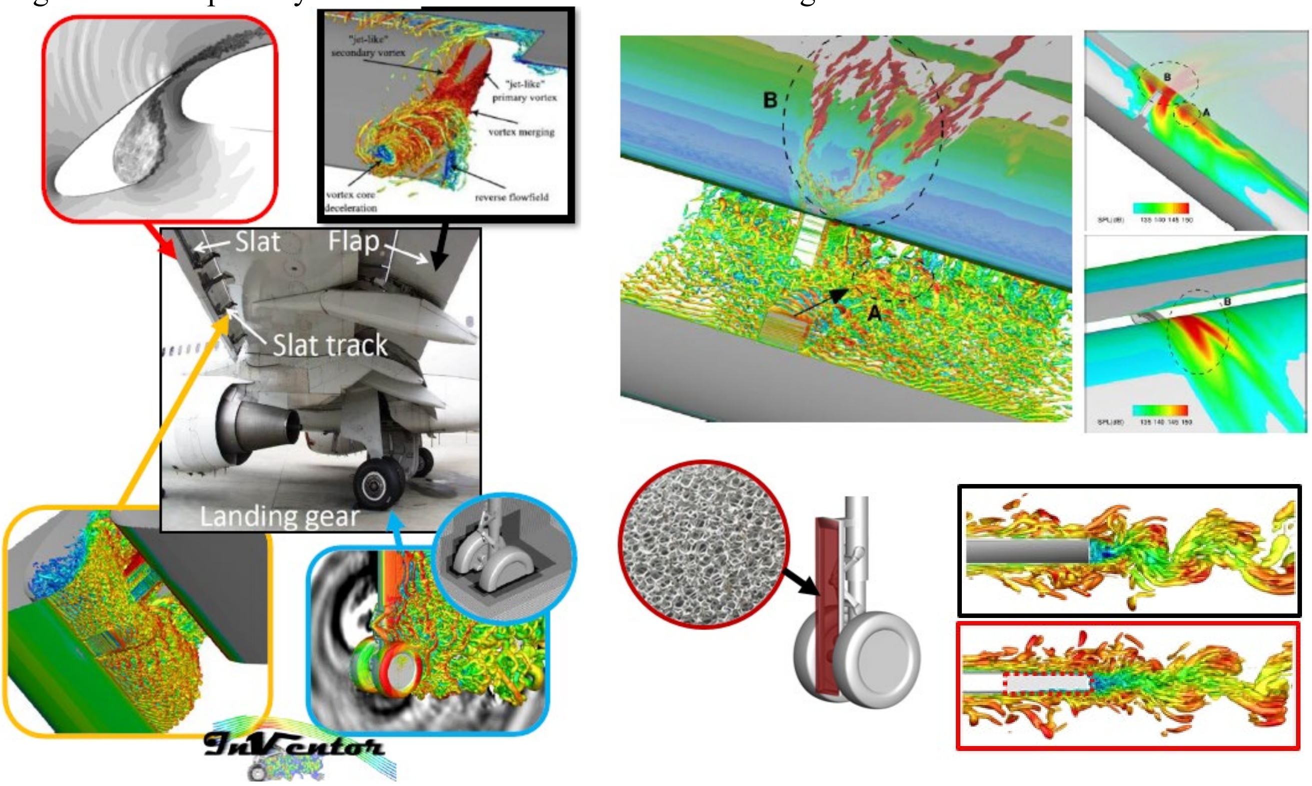

Fig. 1: Schematic of the airframe noise generation including slat, slat track, flap side edge, trailing edge and landing gear noise

In this context, porous inserts represent a promising passive flow control and noise mitigation technology. By altering boundary-layer development, dissipating turbulent structures, and reducing pressure fluctuations at flow–structure interfaces, porous materials (e.g., metallic foams) can potentially attenuate both broadband and tonal noise at its sources.

However, the physical nature of the employed materials introduces very small pores within these inserts, whose direct simulation remains computationally prohibitive. Consequently, this PhD will aim to evaluate numerical models based on a macroscopic representation of the porous medium through a homogenization technique. In practice, these models rely on the introduction of local source terms into the Navier-Stokes equations. For instance, Breugem and Boersma [4] suggested accounting for porosity using a volume-averaged method instead of explicitly resolving the porous geometry. In this framework, a linear friction contribution, referred to as the Darcy term, is combined with a nonlinear Forchheimer term.
ONERA and UOB have developed strong expertise in airframe noise simulation, experimentation and identification, with particular focus on landing gear and high-lift devices [2-3,5-6]. Recent work at ONERA has introduced Volume-Averaged Navier–Stokes (VANS) approaches for porous media modelling, incorporating Darcy–Forchheimer terms into finite-volume Navier–Stokes solvers, where preliminary numerical tests yielded particularly encouraging results [7] with respect to existing numerical databases [8][9].

The purpose of this PhD thesis is to develop, analyze and validate porous inserts as passive flow control devices with a particular focus on airframe noise mitigation. The concept is to embed porous materials into selected regions of the airframe to disrupt coherent flow structures responsible for acoustic radiation, thereby reducing noise at the source without significant aerodynamic penalties.

This project will be structured around three objectives, distributed between ONERA and the University of Bristol.

Numerical Modelling of Porous Inserts with VANS-Based Approaches:
The first phase conducted at ONERA will employ advanced numerical methods to capture the flow-porous material interaction. This study will rely on the use and development of a finite-volume Navier–Stokes solver using the VANS approach, including Darcy–Forchheimer corrections. Building on previous studies at ONERA, the study will focus on improving modelling capabilities at high Reynolds numbers, including coupling with wall-modelled LES and hybrid RANS/LES frameworks. Numerical predictions will be used to analyze how porous inserts modify mean flow, turbulence statistics, and acoustic source terms in canonical configurations. A key point to address will be to quantify how the porous medium modifies the turbulent characteristics of the flow (energy cascade, turbulent scales and anisotropy…). The objective is to increase our physical knowledge of the turbulence/porous insert interaction, in order to propose appropriate properties (location, shape, size, porosity…) for the porous inserts, depending on the turbulence and mean flow characteristics, in order to successfully control the flow and reduce the noise at its source.

Experimental Investigation of Porous Treatments in Simplified Geometries:
Based on the numerical findings, targeted experiments will be conducted at university of Bristol on simplified configurations to validate modelling strategies and quantify turbulence modification and noise reduction potential. Detailed flow and acoustic measurements (surface pressure as well as PIV and microphones) will be employed to assess modifications in turbulence, spectral content, and far-field radiation in simplified geometries such as flat plate and aerofoil LE/TE treatments. In addition, laboratory experiments could be conducted in the Refractive-index matched facility to perform measurements of the flow inside the porous medium itself (see Fig. 2). This data alongside existing experimental data already acquired in former European projects will be used to validate the numerical models.

Extension to Complex Airframe Configurations and Noise Mitigation Assessment:
Depending on the timing and success of the two previous phases, the final phase could extend the investigation to more representative airframe components, such as for instance multi-element wing sections with porous inserts. Numerical and experimental results could then be combined to perform a physical analysis of the flow and acoustic modifications induced by porous treatments.

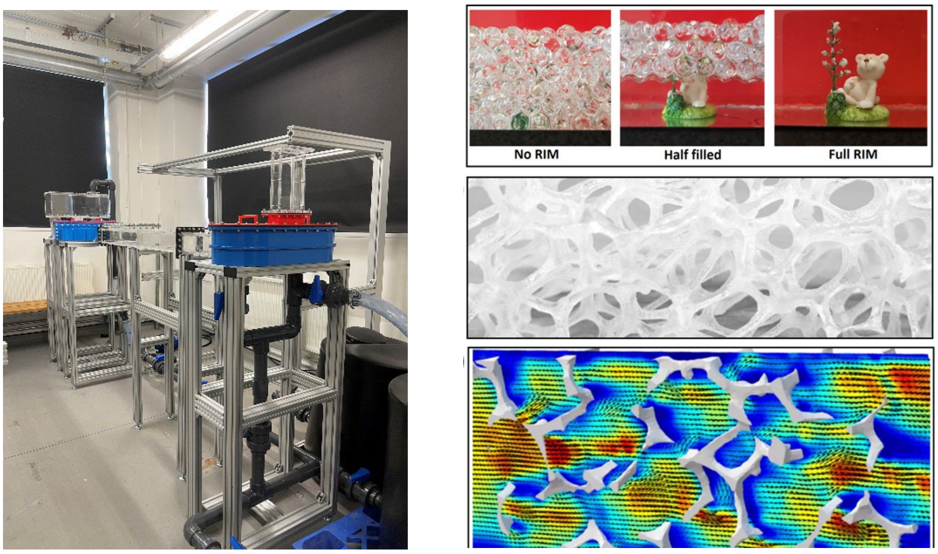

Fig. 2: Refractive Index Matching (RIM) test rig, University of Bristol.

References

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Collaborations envisagées : Université de Bristol (UoB)

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