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PROPOSITION DE SUJET DE THESE

Intitulé : Experimental characterization and numerical prediction of the interaction of a normal shock on a flexible panel in response to an external forcing

Référence : **MFE-DAAA-2025-06**
(à rappeler dans toute correspondance)

Début de la thèse : October 2025	**Date limite de candidature :** 30/6/2025

Mots clés

Fluid-structure interaction (FSI), shock wave/boundary layer interaction (SWBLI), supersonic air intake, buzz

Profil et compétences recherchées

Master 2 (+ Engineering School)

Fluid mechanics

Présentation du projet doctoral, contexte et objectif

The air intake is a crucial component in the aerobic propulsion of super and hypersonic aircrafts, ensuring a stable and efficient supply of air to the engine. However, under certain conditions, the airflow in the intake can become unstable, leading to a phenomenon known as "**buzz**," characterized by significant oscillations of the terminal shock-wave (see Figure 1), potentially causing engine failure. The current trend of reducing vehicle mass by using lighter materials results in lower structural rigidity, which can trigger fluid-structure interaction problems, particularly the early onset of buzz compared to rigid structures [1]. Since structural flexibility affects buzz, strategically designed flexible panels [2,3] may help improve the buzz margin or mitigate its effects.

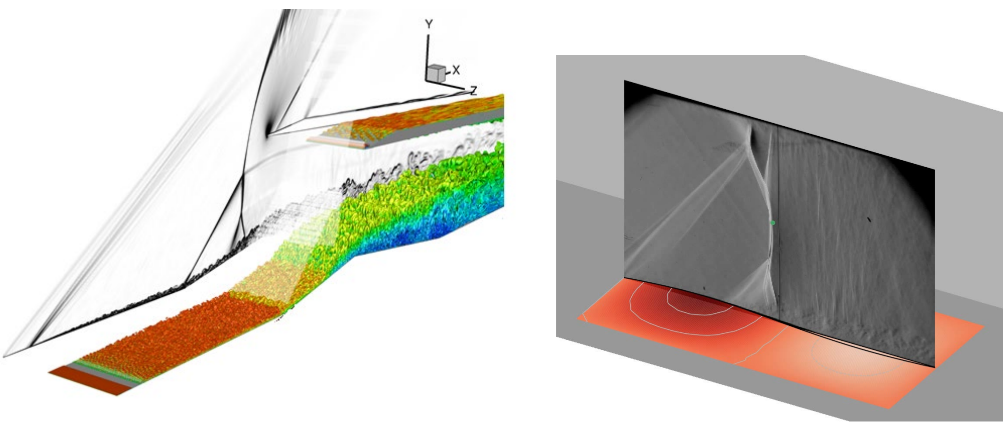

Figure 1 Left: Numerical simulation of buzz [4] and Right: Schlieren visualization of shock-wave interaction over a flexible panel [2]

The thesis has two main objectives :

The first goal is to **understand the response of a strong shock-wave interacting with a flexible panel to an external excitation** at the shock-wave/boundary layer interaction. When big buzz is fully established, the oscillation of the terminal shock is due to the successive emptying and filling of the subsonic diffuser of the air intake, rather than the intrinsic unsteadiness of the interaction of the shock with the turbulent boundary layer. An existing setup in the S8Ch research wind tunnel at ONERA, previously used in a PhD thesis [2], will be adapted to generate external excitation. To do so, downstream pressure perturbations are induced by a periodic variation of the second throat section thanks to a rotating elliptical shaft located in the middle of the channel, the motion of the shaft producing a forced oscillation of the shock-wave [5]. Thus, the coupled dynamic of the shock-wave interacting with a flexible panel will be investigated. This will leverage recent advancements in metrology for fluid-structure interaction in compressible flow, such as the measurement of 3D panel deformation and dynamic pressure using Pressure Sensitive Paint (PSP), will be used to accurately characterize the interaction region.

The second objective is to **numerically predict the flow response to this forcing**. In a first instance, this will allow a more complete understanding of the interaction investigated by the experimental campaign. More in perspective, this will enable the design and characterization of flexible panels on an air intake which avoid the fluid structure coupling observed in [1]. The design by simulation is often necessary since (i) experimental methods are costly and limited for industrial applications and (ii) a correct scaling in the experimental set-up becomes even more complicated as multiple physics (structural and fluid dynamics, in this case) are to be taken into account.

Using the numerical tools already available at ONERA for simulating fluid-structure interaction (elsA, MIMAS chain), the first goal of the numerical work will be to reproduce the experimental setup in order to quantify the predictive capability of these tools by comparing the results with unsteady measurements obtained in the wind tunnel. With the numerical tools developed during this PhD thesis, the **flow behavior in a real air intake will eventually be computed and analyzed**.

[1] Ye, K., Zhou, X. & Ye, Z. Buzz Characteristics Under Fluid–Structure Interaction of Variable-Geometry Lip for Hypersonic Inlet. AIAA Journal 62, 1662–1682 (2024).

[2] Moreno, C. R., Couliou, M., Fabbiane, N., Bur, R. & Marquet, O. Synchronized shock wave and compliant wall interactions: Experimental characterization and aeroelastic modeling. Journal of Fluids and Structures 128, 104142 (2024).

[3] Gramola, M. , Bruce, P. J., Santer, M., Off-design performance of 2D adaptive shock control bumps, Journal of Fluids and Structures 93 102856 (2020)

[4] Grenson, P. & Beneddine, S. Large-Eddy Simulation of a Supersonic Air Inlet in Subcritical Regime. in 55th 3AF International Conference AERO2020+1 (2021).

[5] Bur, R., Benay, R., Galli, A., & Berthouze, P. (2006). Experimental and numerical study of forced shock-wave oscillations in a transonic channel. *Aerospace science and technology*, *10*(4), 265-278.

Collaborations envisagées

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