[2023 – Stage M2 ou 3A Ingénieur] Aero-acoustic modeling and characterization of a convergent ventilated silencer based on the Acoustic Black Hole Effect.

Tutors:

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- Dr. Teresa Bravo, Tenure Research Scientist at CSIC, Spanish Council for Scientific Research, teresa.bravo@csic.es,

Dates: Start date between 01/02/2023 and 01/04/2023 – Duration 5 months

Location: Laboratory of Mechanics and Acoustics (LMA) – Sounds Group, Marseille, France. Possibility of short research stay at CSIC (Madrid).

Payment: academic rate funded by The Institute of Mechanical Engineering of Aix-Marseille University (Project "Metamaterials").

Problematic: One of the challenges encountered in the field of aeronautical and surface transports is to design compact lightweight liners or silencers able to significantly reduce the transmission and back-reflection of low-frequency noise sources (combustion noise, fan noise…) that propagate in a low-speed ducted flow. The interest of reducing back-reflections of acoustic waves towards the combustion chamber is to keep a high combustion efficiency of thermal engines (fuel, hydrogen). Silencers also have to maintain a constant flow rate and minimum pressure drop.

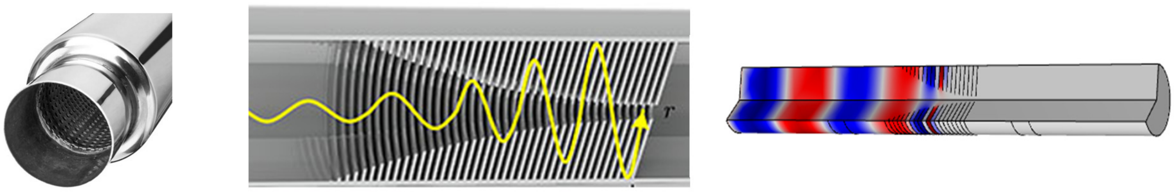

Figure 1 – (left) Perforated inlet of a typical exhaust muffler; (middle) schematic of a slightly open ABH (from Mi et al., Appl. Phys. Lett., 2021); (right) FEM simulation of the sound pressure field inside a slightly open ABH (from Bravo and Maury, 2021).

State-of-the-art silencers are expansion chambers filled with porous materials shielded from the flow by perforated cylinders [Fig. 1, left]. These quarter-wavelength resonators are only efficient above 1 kHz to reduce noise transmission over a limited bandwidth, and with significant back-reflections. They would require unrealistic large cross-sectional volumes (resp. axial lengths) to achieve low-frequency (resp. broadband) noise attenuation. Innovative "engineered silencers" [Fig. 1, middle] based on the Acoustic Black Hole (ABH) effect are a promising alternative. They should be able to slow down and trap sound waves within their internal shaped cavities, and to fully absorb the incident energy through visco-thermal dissipation. Broadband absorption is achieved due to merging of the individual cavities resonances. As a result, only the incident wave field propagates without back-reflections, nor transmission [as simulated in Fig. 1, right]. Strategies such as micro-perforations can be implemented to downshift the bandwidth of absorption towards low-frequencies while keeping a compact device.

However, these types of ABH mufflers obstruct the flow and cannot be used as such in a flow duct. The question of designing fully- or adequately-open ventilated silencers based on the ABH principle with high aero-acoustic performance is not yet solved and is the subject of this Master internship.

Objective: To model and design a compact ventilated ABH silencer able to absorb 80% of the incident energy over 400 Hz – 1000 Hz in presence of a low-speed flow (max. 30 m/s) and with minimal pressure drop. A convergent ABH silencer geometry, as shown in Fig. 2, will be studied.

Methodology: Bibliography (M1) – Analytical (transfer matrix) and numerical (Finite Element or Lattice Boltzmann) modeling (M1-M2) – Parametric studies and optimization (M2-M3) – Printing of the ABH prototype* (M3) – Characterization of the ABH aeroacoustic performance on dedicated test benches (M4-M5).
*3D-Printing will be achieved by LMA technical service or a company.

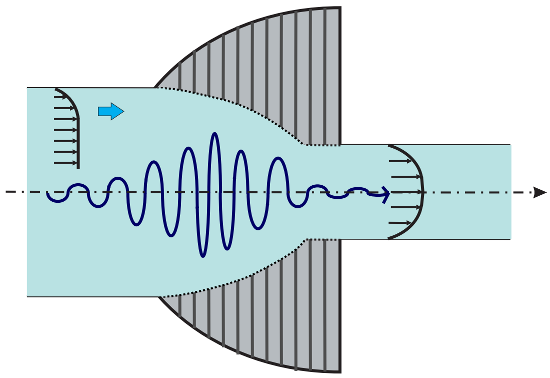

Figure 2 – Convergent ABH Silencer

The candidate profile should be mainly in Acoustics, with knowledge/practice of the finite element method, and interests in modeling and using acoustical experimental techniques.

- If sufficient results are obtained that go beyond the state-of-the-art, **the student will be included as a co-author in an international conference paper.**
- **A PhD 3-years doctoral grant has been requested for a follow-up to this study.**

References:

- Y. Mi, W. Zhai, L. Cheng, C. Xi, X. Yu, "Wave trapping by acoustic black hole: Simultaneous reduction of sound reflection and transmission", Applied Physics Letters 118(11) 114101, (2021).
- F. Anselmet and P.-O. Mattei, "Acoustics, Aero-acoustics and Vibrations", John Wiley and Sons, 2016.
- T. Bravo, C. Maury, C. Pinhède, "Optimisation of micro-perforated cylindrical silencers in linear and non-linear regimes", J. Sound Vib. 363, 359-379, (2016).
- T. Bravo, C. Maury, "Optimised micro-perforated panels for broadband absorptivity", Proceedings of the 26th International Congress on Sound and Vibration (ICSV26), 7-11 July, Montreal, Canada, (2019).

- T. Bravo, C. Maury and C. Pinhède, Absorption and transmission of boundary layer noise through flexible multi-layer micro-perforated structures, Journal of Sound and Vibration, 395(12), 201-223, 2017.