Aeroacoustic black holes for the reduction of sound emissions and fine particles in the atmosphere: Numerical and experimental study

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Summary of the research work:

The goal of zero emissions in the transport and energy sectors is the key to achieving an urban environment that is more resilient to climate change and with a lower impact on the health of the population. This notably involves reducing two factors: noise emissions and the emissions of ultrafine particles into the atmosphere from vehicles and industrial infrastructures.

This dual objective is part of the multidisciplinary international research project AERMES: "Aero-acoustic metamaterials for the reduction of noise and aerosols in the atmosphere" (n° AMX-22-RE-AB-157) funded by the AMU A*MIDEX foundation, bringing together the Laboratory of Mechanics and Acoustics (LMA), the Spanish National Research Council (CSIC) and the Institute for Research on Non-Equilibrium Phenomena (IRPHE).

The objective of this doctoral thesis is to simulate, optimize and characterize the performance of silencers such as aero-acoustic black holes (ABH) in order to effectively attenuate sound emissions while improving the agglomeration of fine particles into aerosols of larger size, readily filtered by traditional techniques. The idea is to exploit the effective slow-down of sound waves entering the ABH, in order to produce nucleation zones of the ultra-fine particles convected by the flow.

The study will be based on modeling (Finite Element Method, Lattice Boltzmann Method) and global optimization methods (particle swarms), which enabled to reveal the trapping and total dissipation of acoustic waves within ABH structures, experimentally validated on an acoustic test bench. The simulation of this effect is illustrated in the Figure above. The thesis tasks will be as follows:

- to analyze under which conditions the ABH effect is robust to the presence of low Mach number flows.
- to understand the particle agglomeration mechanisms induced by the trapping and slow-down of acoustical waves.
- to optimize the geometric shape of the silencer to maximize the ABH effect and particle agglomeration while minimizing the pressure and viscous drags.
- to design and validate an eco-friendly ABH prototype on an aero-acoustic test bench.

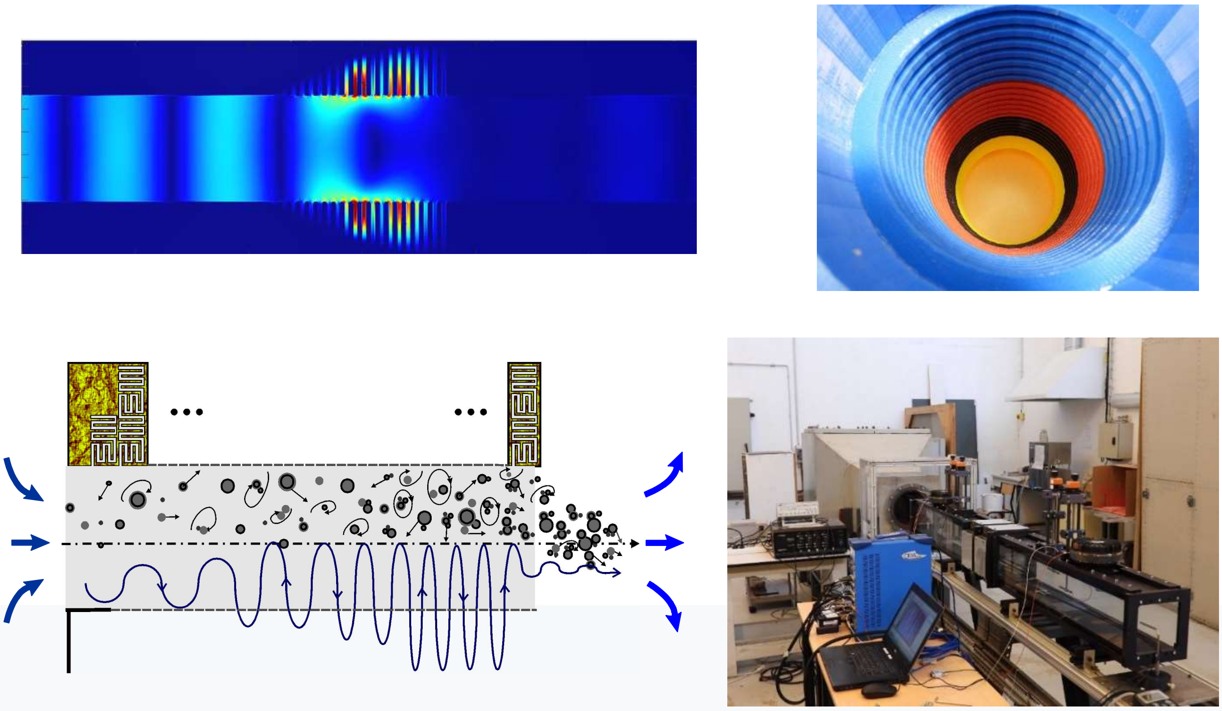

Figure 1. Top: LBM simulation of the ABH effect (left) and interior view of an acoustic ABH (right) – Bottom: particle agglomeration diagram (left) and aero-acoustic test bench (right);

Candidate profile: Holding a Master 2 or a post-graduate engineering school diploma, the candidate will have skills in acoustics and fluid mechanics as well as an interest in computational modelling and experimental methods. Good level in English (read, spoken, written).

Publications:

Ng BF, Xiong JW, Wan MP (2017) Application of acoustic agglomeration to enhance air filtration efficiency in air-conditioning and mechanical ventilation (ACMV) systems. PLoS ONE12(6): e0178851. https://doi.org/10.1371/ journal.pone.0178851

Deaconu M, Radulescu D, Vizitiu G (2018) Acoustic study of different mufflers based on metamaterials using the black hole principle for aircraft industry, In: Proceedings of Euronoise 2018, pp. 2271–2276, Heraklion, Greece.

Bravo T, Maury C (2023) Broadband sound attenuation and absorption by duct silencers based on the acoustic black hole effect: Simulations and experiments. Journal of Sound and Vibration 561:117825. https://doi.org/10.1016/j.jsv.2023.117825

Maury, C, Bravo, T (2023) Vibrational Effects on the Acoustic Performance of Multi-Layered Micro-Perforated Metamaterials. *Vibration, 6*, 695-712. https://doi.org/10.3390/vibration6030043

Maury, C, Bravo T, Mazzoni D (2021) Absorption and transmission of boundary layer noise through micro-perforated structures: measurements and modellings. In: FLINOVIA - Flow-Induced Noise and Vibrations Issues and Aspects - III, pp. 227–258, Springer Nature, Switzerland. https://doi.org/10.1007/978-3-030-64807-7_11

Professional insertion after thesis :

- Public: teaching and/or research in universities, engineering schools, research organizations (CNRS, ONERA, etc.).

- Private: research & development and/or consulting companies in transport, energy and environmental sectors.