Master 2 Internship Proposal – 2025

Sound Attenuation and Particle Agglomeration by Acoustic Black Holes

Tutors: Cédric Maury (Ecole Centrale Méditerranée, LMA, cedric.maury@centrale-med.fr) – Teresa Bravo (CSIC, Spain, teresa.bravo@csic.es)

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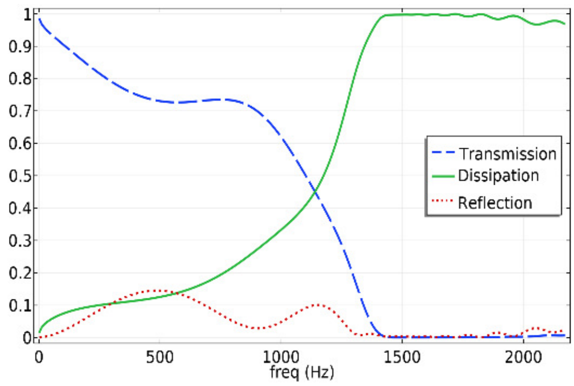
Duration: up to 6 months as from February 2025

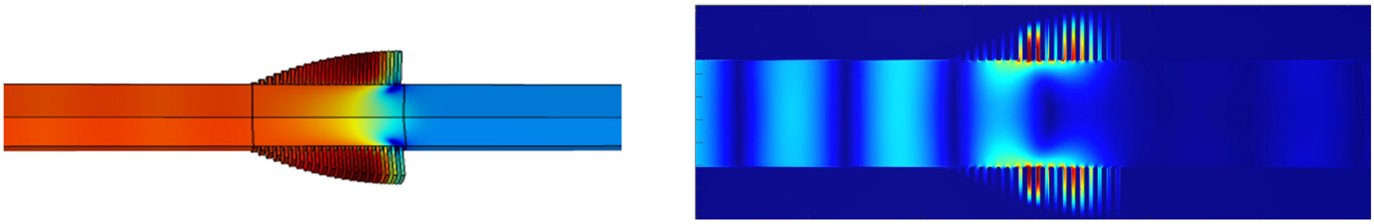
Background: One of the major contributors to air pollution in urban environments is the transportation system [WHO, Transport and health, 2021]. The submicron size particles emitted by vehicles, but also by industrial power plants, present a longer residence time in the air and consequently a larger exposure period. These aerosols are usually convected in a flow duct (exhaust, chimneys) before being released in the atmosphere. An eco-friendly solution is proposed in this internship: a graded acoustic metamaterial lining the duct walls, so-called **Acoustic Black Hole** (ABH), designed not only to **attenuate sound emissions over a broad bandwidth**, but also to **agglomerate very fine particles into larger sized aerosols**, that can then be easily eliminated by standard filters. Up to now, efficient sound attenuation is mostly narrowband and acoustic agglomeration requires significant electrical energy consumption. For instance, it can be achieved by generating ultrasonic standing wave fields involving very high levels of acoustic intensity to be efficient [Riera *et al.*, 2003] or electrostatic particle agglomerators [Lin *et al.*, 2020]. The developed ABHs will be passive **augmented silencers**, 3D printable, with expected high beneficial effects on the health and the environment, as they contribute to global zero-emissions in transport and energy supply industries. An acoustic-only ABH prototype with full dissipation, zero transmission and zero reflection above 1500 Hz is shown in Fig. 1.

Fig. 1. (left) inner view of a 3D printed ABH and (right) its acoustical performance (bottom).



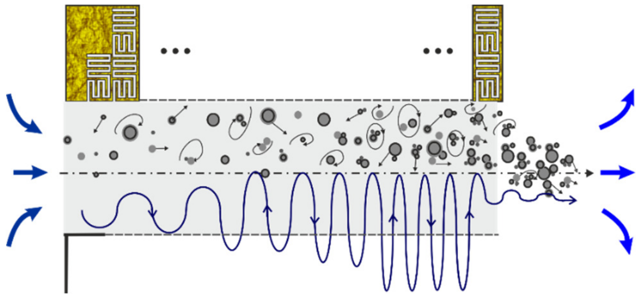
Objectives: The main objective of this internship is to design from numerical simulations an augmented silencer, based on the slow sound properties of **Acoustic Black Holes** (ABH), to achieve broadband **sound attenuation and fine particle agglomeration** when traversed by a low-speed flow seeded with ultrafine particles. Two main phenomena will be analyzed: the ability of the ABH to trap and fully dissipate incident sound energy (Fig. 2 left) as well as the local increase of acoustic velocity inside the ABH (Fig. 2 right), prone to the grouping and agglomeration of sub-micron sized particles. A numerical proof-of-concept will propose an ABH geometry that can be additively manufactured and further tested in a low-speed wind-tunnel facility. As illustrated in Fig. 2, ABH modellings (Finite Element Method – FEM, Lattice Boltzmann method - LBM) have been developed [Bravo and Maury, 2023] with ultra-broadband properties towards low-frequencies [Bravo and Maury, 2024]. They showed that ABHs are able to fully dissipate incident energy over a broad frequency range by visco-thermal effect through the cavities.

Fig. 2. Sound field inside opened ABHs when calculated by FEM (left) and LBM (right).



As shown in Fig. 2, the acoustical wave trapped inside an ABH will increase its amplitude in a localized area, so that **the fluid particles will be likely to collide and agglomerate** due to the high-amplitude oscillations inside the ABH. An illustration of this effect is given by Fig. 3. The specific objective is **to achieve noise attenuation in a low-speed subsonic flow while agglomerating ultrafine particles (UFP, 0.1µm diameter) and fine particles (FP, 2.5µm diameter) into aerosols of larger sizes.**

Fig. 3. Aerosol agglomeration induced by the ABH effect in a low speed duct flow.



Methodology:

- Bibliography on ABHs and aerosol agglomeration
- Development of analytical (Matlab) and numerical (Comsol or ANSYS) aero-acoustic models for sound propagation and agglomeration in a ABH traversed by a flow – the models build upon several previous projects
- Parametric analysis of the factors favoring sound attenuation and aerosol agglomeration
- Participation to wind-tunnel measurements to experimentally validate the concept

Research team: Cédric Maury (Professor LMA – ECM) – Teresa Bravo (Tenure Scientist – CSIC) – David Francoz (PhD student – LMA)

Candidate profile: Master 2 or final year engineering school student with a good background in acoustics and mechanics, an interest towards numerical modelling / experimental characterization of innovative systems with environmental applications.

References:

[1] WHO, Transport and health, https://www.euro.who.int/en/health-topics/environment-and-health/Transport-and-health/transport-and-health, (2021).

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