Internship Proposal – Semester 4 - 2024

Green Acoustic Black Holes for Sound Trapping and Aerosol Agglomeration: Numerical and Experimental Study

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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 present a longer residence time in the air and consequently a larger exposure period. The design of **Green Aeroacoustic Black Holes** (GABH) that can efficiently attenuate sound emissions, but also provide through agglomeration an increase in the particle size distribution (easily filtered out by standard filters), can strongly contribute to reduce the health and environmental effects associated with vehicle and industrial emissions.

Up to now, acoustic agglomeration has been achieved by generating ultrasonic standing wave fields, but they require very high levels of acoustic intensity to be efficient [Riera *et al.*, 2003]. Electrostatic particle agglomerators [Lin *et al.*, 2020] have shown a great efficiency, but they also require significant electrical energy consumption.

Objectives: The general objective of this project is to design a novel type of silencer that exploits the slow sound properties of **Acoustic Black Holes** (ABH) to develop both aeroacoustic and air purifying devices for **sound attenuation and particle agglomeration.** It has a high environmental impact as it contributes to global zero-emissions in transport and energy supply industries. As illustrated in Fig. 1, modellings (Finite element method - FEM, Lattice Boltzmann method - LBM) and measurements on ABHs have been developed [Bravo and Maury, 2023]. They showed that ABHs are able to fully dissipate incident energy over a broad frequency range by visco-thermal effect through the cavities. In other words, they do not transmit, nor reflect acoustic waves.

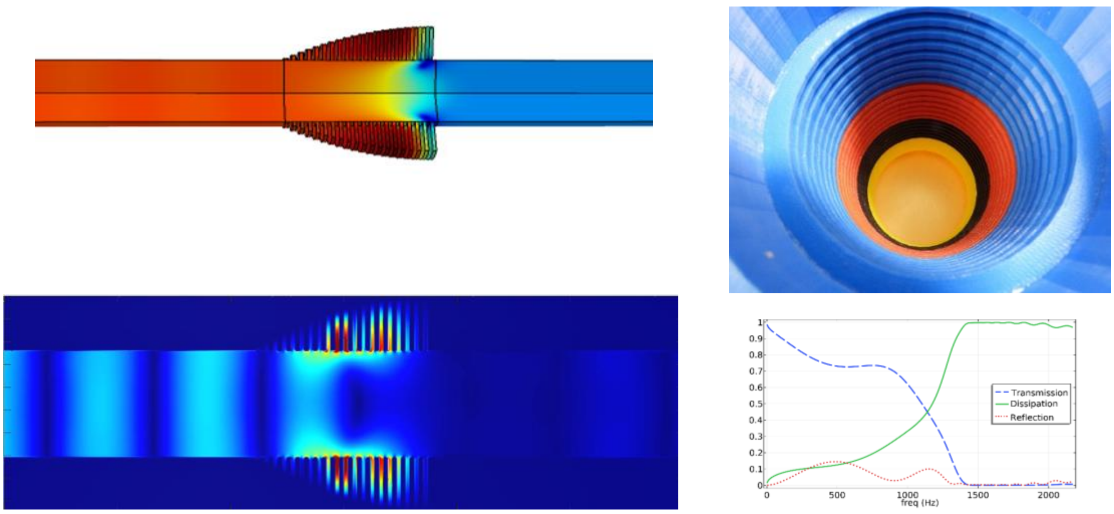


Fig. 1. (left) Acoustic performance of open ABHs calculated by FEM (top) and LBM(bottom); (right) inner view of a 3D printed ABH (top) and simulated acoustical performance (bottom).

As shown in Fig. 1(left), 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. 2. 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.**

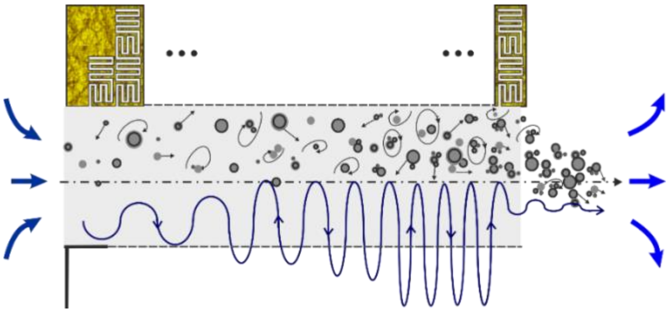
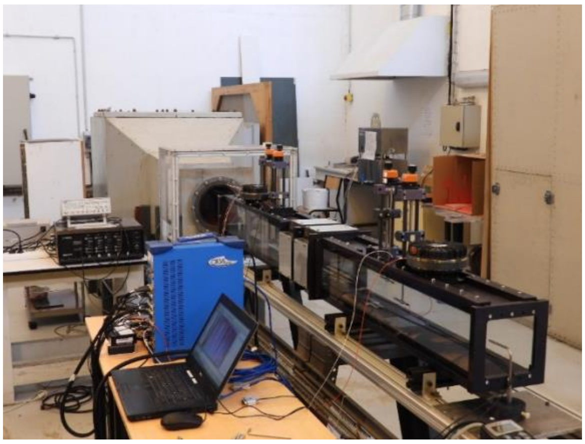


Fig. 2. Aerosol agglomeration induced by the GABH effect in a low speed duct flow.

Methodology:

- Bibliography on ABHs and aerosol agglomeration
- Development of analytical (Matlab) [5] and numerical (Comsol, ANSYS, Palabos) [4] aero-acoustic models for sound progatation in a GABH in presence of flow
- Theoretical and numerical analysis of aerosol agglomeration
- Experimental characterization of the noise attenuation and particle agglomeration of a Green ABH prototype on an aeroacoustic test bench at IRPHE (see Fig. 3).
- Analysis of the performance/limitations of the prototype for future stakeholders.



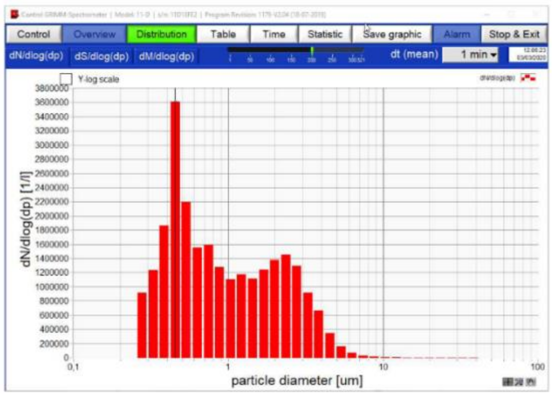


Fig. 3. (left) Aeroacoustic test bench; (right) aerosol spectrometer and particle size counting.

References:

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