Acoustic Porous Resonant Materials For Rotor Insulation

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Abstract

The objective of our research is to develop a fairing for UAVs and other VTOL (Vertical and Take-Off Landing) aircrafts capable of significantly reduce its noise emissions. In order to achieve this objective, acoustic metamaterials developed at Capgemini Engineering, tested in the context of noise insulation of new workspaces, will be used to create liners specific of these fairings. These reconfigurable metamaterials are designed with a porous matrix printed by the FDM (Fused Deposition Modeling) method in which resonant elements are included. Different printing configurations are explored, including patterns and fill densities to obtain interesting performances in the targeted frequency ranges. Tests are performed to compare the noise emissions between each acoustic fairing configuration.

1 Introduction

Unmanned aerial vehicles (UAVs) and vertical and take-off landing vehicules (VTOL) are emerging technologies in urban landscapes. Already widely used for leisure and photography/videography, small UAVs are now finding potential applications in the heart of urban areas. Although they offer outstanding features in terms of practicality, energy efficiency and compactness, the noise they emit has until now been considered annoying, which is not an ideal characteristic for devices likely to operate in close proximity to the public.

UAV models vary in size, weight, number of propellers, and intended use, and with this varies their sound emission characteristics. UAVs and VTOL achieves flight thanks to propellers arranged in various ways that produce thrust towards the ground and lift for the drone to fly. The propellers serve both for propulsion and control. To achieve complicated maneuvers, each propeller can vary its rotating speed and sometimes its inclination, controlled by the user or a piloting program.
The main noise sources in UAVs can be traced to the rotors, propellers, and lift fan system. These are sources of aerodynamic noise, which is defined as sound generated from the relative motion between a solid body and the surrounding medium. UAVs produce both tonal and broadband aerodynamic noise. [7] [1] [3].

It is in this context that our team is looking to develop an acoustic material capable of adapting to several configurations. In this regard, the materials developed as part of our internal research program seem relevant. These porous materials obtained by additive manufacturing are easily reconfigurable.

They were developed in response to the problems presented in Fig. 1. In a transport configuration such as a bus, car or flying object, noise sources can be multiple. These can include engine noise, road and rail noise, aerodynamic noise and noise from the environment outside the vehicle. These different noise sources present different sound signatures that can be targeted by a configurable material. Similarly, this material can be used to create acoustic panels suitable for collaborative workspaces.

In this extended abstract, after this first section on the background to our work, we'll look at the results obtained with additively manufactured porous acoustic materials and the work in progress around this theme. We'll then add resonant elements to these porous materials to take advantage of the additional absorption effects.

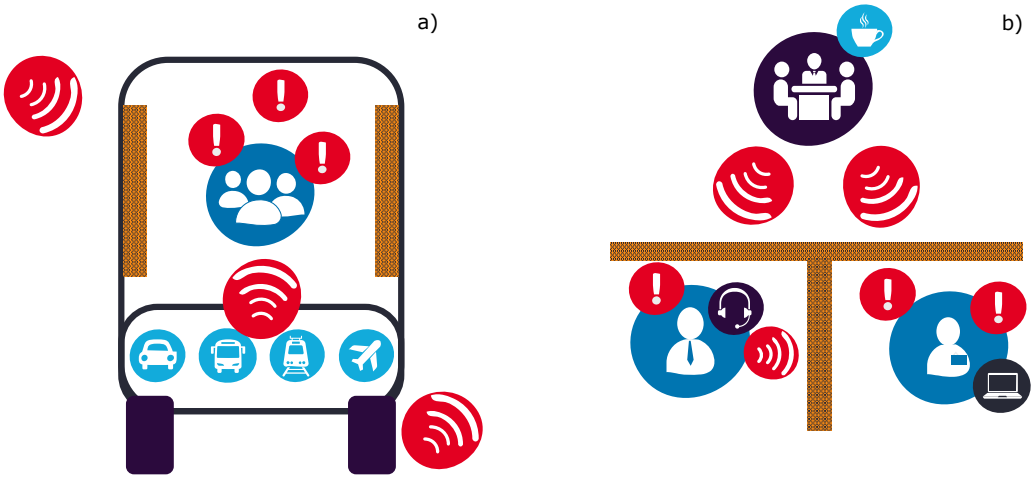

Figure 1: Configurations where the application of porous resonant materials has been considered in the context of our work: a) In the context of passenger transport. b) In the context of the workplace.

2 Additively manufactured porous material

The manufacture of porous materials using Fused Deposition Modelling (FDM) is based on various research projects. Work on materials with controlled porosity gradients [2] (Fig. 2(a)) shows the prospects for using additive manufacturing techniques to obtain materials with parameterized acoustic characteristics. An important point when working in the industry [8], Fig. 2(b) shows that the results obtained for a given structure are reproducible with relatively few differences whatever the printing machine used, meaning that a material developed in rapid prototyping will have the same results once it goes into production. Articles [6] and [4]show the effect of including a resonant element in a porous foam-like material (Fig. 2(c)) and in a matrix obtained by additive manufacturing (Fig. 2(d)). Finally, the use of resonant elements can be adapted to UAV rotors to control rotor noise emission [5], (Fig. 2(e)).

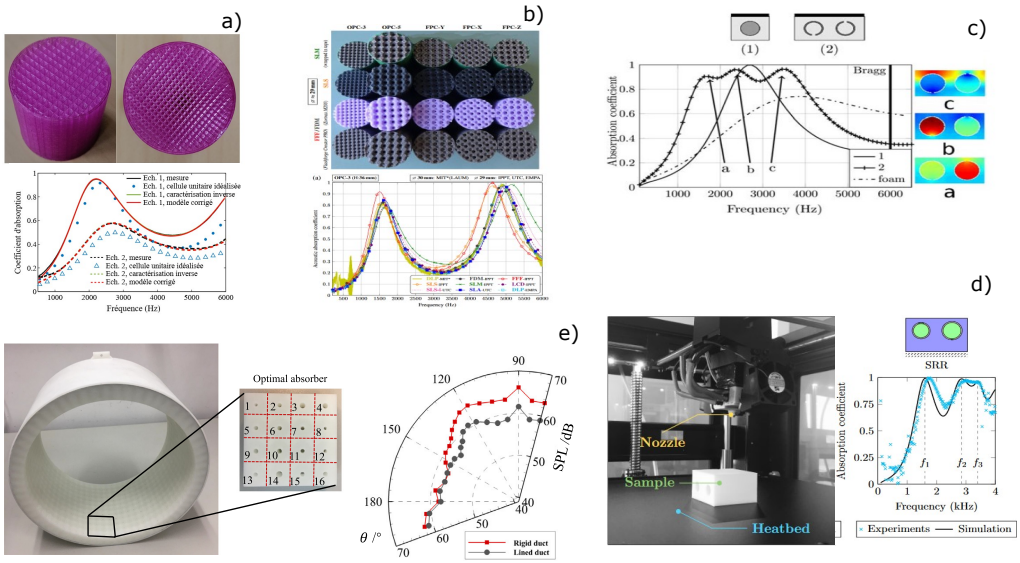

Figure 2: Controlled porosity gradient materials and the absorption curves enabled by these materials[2](a).Repeatability of the absorption coefficient as a function of the machine used to produce the samples [8](b), study carried out by several laboratories. Effects of resonator inclusions in foam-like materials [6](c). Inclusion of sonic ring resonator (SRR) elements in an FDM-printed porous matrix [4] (d). The use of resonators to create a drone propeller fairing and noise reduction as a function of microphone angle of incidence[5] (e).

Initially, we chose to produce cylinders for measuring the absorption coefficients of various samples using an impedance tube. The resonators are directly embedded in the porous matrix during printing (Fig. 3(a)). Two types of material are used:

- Porous materials composed of a gyroid structure controlled by wavelenght and thickness, Fig. 3(b),(c),(d),(e) show examples of materials that have been manufactured.

- Materials with Helmohltz resonators embedded in a matrix of porous materials. A material with a rectilinear structure and 3 Helmohltz resonators is produced, Fig. 3(f). A material with a gyroid structure and 4 resonators is manufactured, Fig. 3(g).

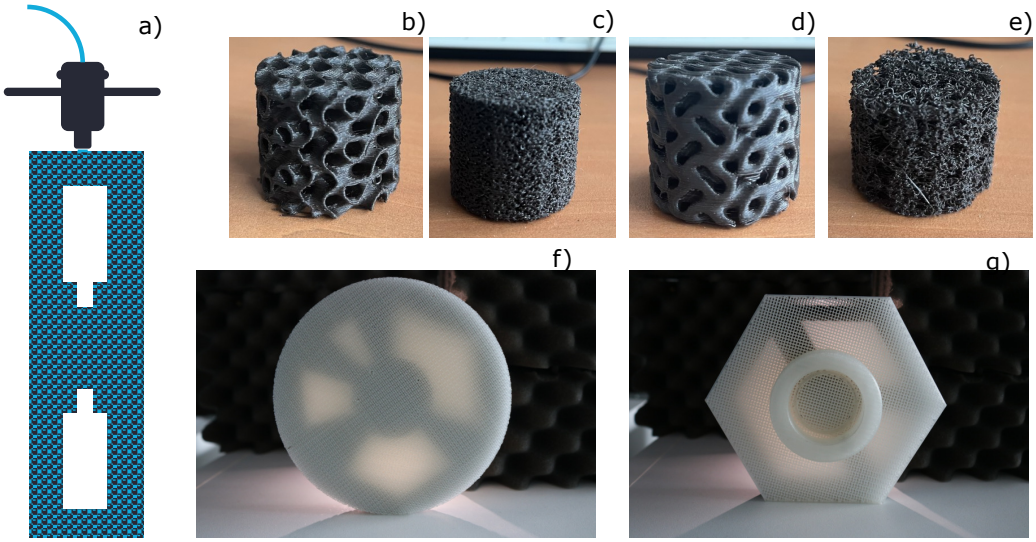

Figure 3: FDM scheme of porous with inclusion of Helmholtz resonators (a). Example of porous sample (b, c, d, e). Example of porous material with resonators (f, g)

Figure 4 shows the results for 2 porous materials. Porosity is controlled by several parameters, the first being the choice of structure, in this case a gyroid pattern, the second being wavelength, which controls pattern spacing, and finally thickness, which controls cell size.

Sample 2, Fig. 4(a)has the following characteristics, Wavelength= 2 mm, Thickness= 2 mm. This sample targets frequencies around 1000 Hz and around 3500 Hz. Sample 5, Fig. 4(b),has the following characteristics, Wavelength= 1 mm, Thickness= 1.5 mm. This sample targets frequencies around 800 Hz and around 3000 Hz.

A series of samples is taken in order to set up an experimental design linking the wavelength and thickness parameters to the absorption coefficient obtained for one or more target frequencies.

The absorption provided by our additively manufactured porous materials is generally weak at low frequencies. The inclusion of resonant elements in a porous matrix enables us to target the specific frequencies we wish to add to our materials. Or use a series of resonators to add low-frequency absorption effects.

3 Resonants Porous Material

Figure 5 compares the absorption coefficients obtained for a porous material and a porous material with resonator inclusion. The porous material consists solely of a gyroide filling occupying 50% of the available volume. This porous material becomes effective from 1500 Hz but doesn't allow much absorption below that. Adding 4 resonators to this material improves absorption in the frequency range below 1500 Hz.

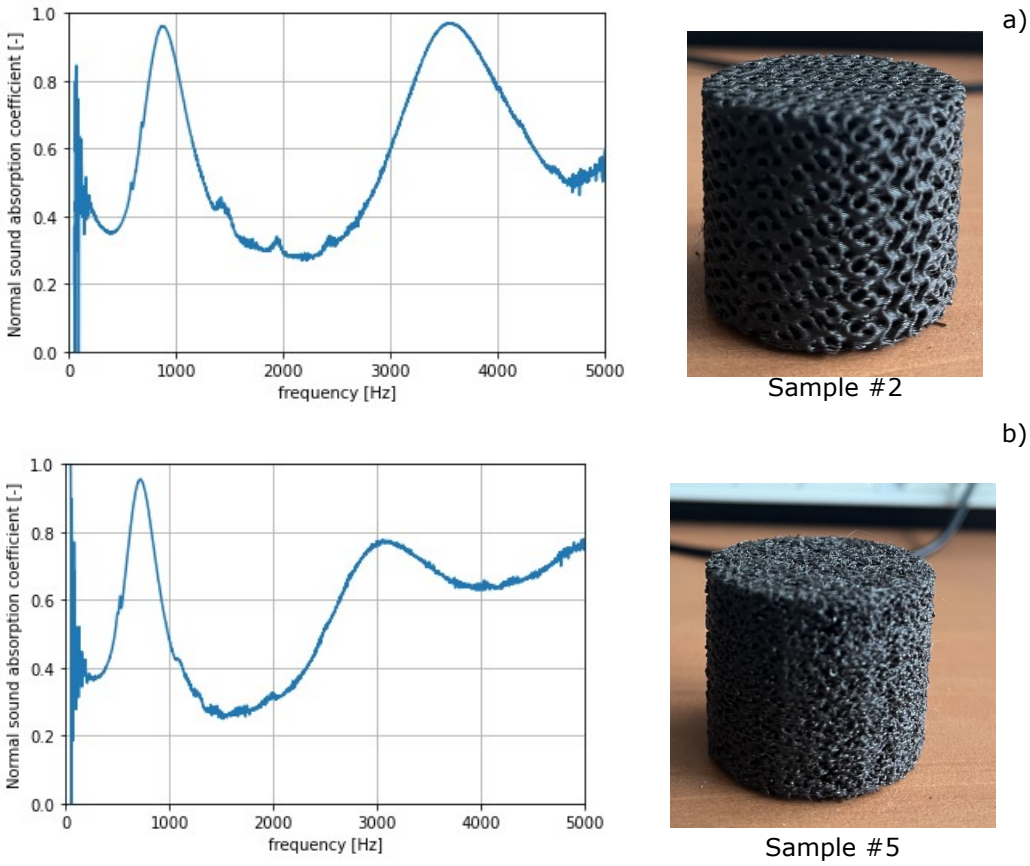

Figure 4: Absorption curve of an additively manufactured porous gyroid material with the following characteristics, Wavelength= 2 mm, Thickness= 2 mm (a). Absorption curve of an additively manufactured porous gyroid material with the following characteristics, Wavelength1 mm, Thickness= 1.5 mm (b)

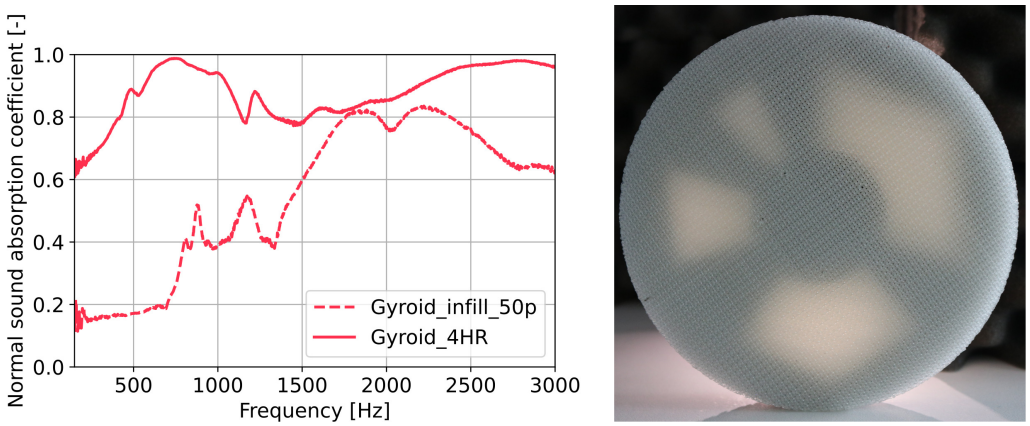

Figure 5: Absorption curve of an additively manufactured porous gyroid material with (—-) and without (- - -)inclusion of 4 resonators

4 Conclusions & Perspectives

The work presented in this extended abstract shows that it is possible to obtain materials that can be configured to meet different constraints, enabling absorption in different frequency ranges. However, this work has so far been carried out using impedance tube measurements. The next step is to build a prototype drone fairing using the concepts developed. This step will enable us to validate whether the work developed as part of this study makes it possible to achieve a significant reduction in the noise disturbance emitted by the rotor without affecting its performance.

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