



**HAL**  
open science

## Metamaterial made of poroelastic lamellas for sound attenuation in duct

Ke Li, Nicolas Dauchez, Benoit Nennig, Emmanuel Perrey-Debain

► **To cite this version:**

Ke Li, Nicolas Dauchez, Benoit Nennig, Emmanuel Perrey-Debain. Metamaterial made of poroelastic lamellas for sound attenuation in duct. Forum Acusticum, Dec 2020, Lyon, France. pp.3-4, 10.48465/fa.2020.0523 . hal-03240280

**HAL Id: hal-03240280**

**<https://hal.science/hal-03240280>**

Submitted on 30 May 2021

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

# METAMATERIAL MADE OF POROELASTIC LAMELLAS FOR SOUND ATTENUATION IN DUCT

Ke LI<sup>1</sup>

Nicolas DAUCHEZ<sup>1</sup>

Benoit NENNIG<sup>2</sup>

Emmanuel PERREY-DEBAIN<sup>1</sup>

<sup>1</sup> Sorbonne Universités, Université de technologie de Compiègne, Laboratoire Roberval, FRE CNRS 2012, CS 60319 Compiègne cedex, France

<sup>2</sup> Institut Supérieur de Mécanique de Paris (SUPMECA), Laboratoire Quartz EA 7393, 3 rue Fernand Hainaut, 93407 Saint-Ouen, France

nicolas.dauchez@utc.fr

## ABSTRACT

Sound attenuation performances of a duct silencer made of a metamaterial composed of a set of poroelastic lamellas, are investigated numerically and experimentally. The lamella arrangement is designed so that skeleton elastic resonances appear at low frequency. In addition, the air gap between the lamellas induces pressure diffusion effects commonly encountered in highly contrasted double porosity media. The configuration of the silencer also exhibits strong anisotropy. A 3D finite element model of the silencer has been developed in order to identify the different mechanisms taking place in the silencer. Numerical results are shown to match well with experimental data for different lamella orientations. By exploiting the geometrical periodicity of the silencer, a Bloch waves analysis is realized and a parametric study is conducted. This reveals strong model dispersion and interaction due to lamella elastic resonances. It is shown that certain design parameters can be tuned in order to achieve large attenuation and absorption at low frequency.

## 1. INTRODUCTION

The low frequency noise in the automotive, aircraft and building industries is still a challenging problem. In many cases, the noise is produced by various airflow systems and transmitted through ducts. The traditional passive treatments, including acoustic liners and dissipative silencers [1–3] usually made of porous material are not always sufficiently light, compact or effective at low frequencies.

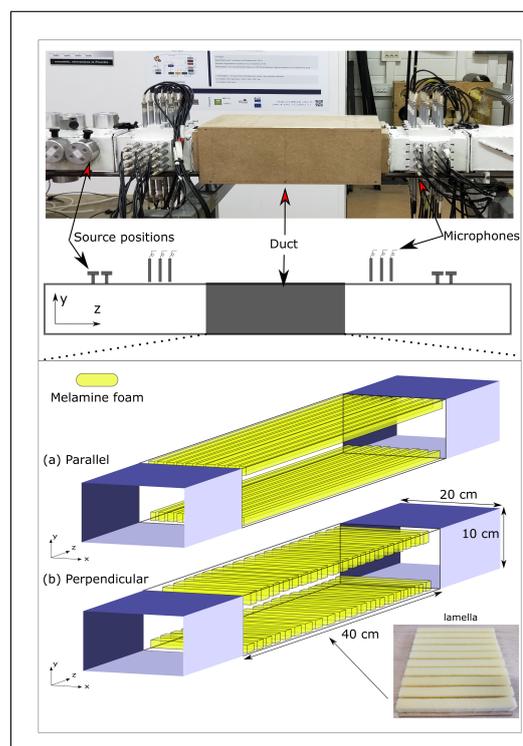
In the past twenty years, acoustic metasurfaces and metamaterial have been through a robust development and caught much attention from scientists because they present novel dynamical property like mass density and bulk modulus with negative value [4–6]. Metaporous, composed of sub-wavelength acoustic resonators such as Helmholtz resonator inserted into porous medium [7–10], have been also proposed. They combine the wideband viscothermal losses of porous materials and the sound absorption achieved by the resonators at low frequency.

Dauchez *et al.* [11] studied sound absorption of a large scale poroelastic lamella network under oblique incidence

in free field. Results show that this type of structured material, which bears similarity with Christensen *et al.* [12], permits to gain extra absorption in the low frequency range by taking advantage of the resonance of the elastic frame of the foam.

The aim of this work is to investigate experimentally and numerically the role of frame elasticity for passive sound control in ducts.

## 2. EXPERIMENT



**Figure 1.** Experimental setup for transmission loss measurement and lamellas orientations (a-b).

The poroelastic lamellar metamaterial is made up of several melamine foam strips. Each lamella has a nominal thickness  $h_1 = 25$  mm along the  $y$ -axis, a width  $w_1 = 15$  mm and a length of 200 mm. The air gap between two

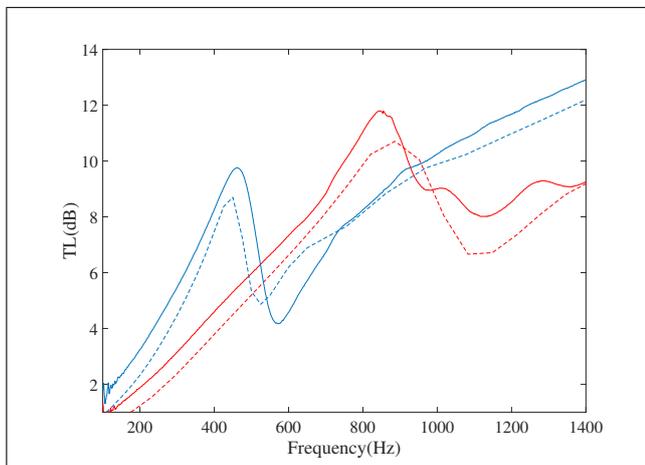
lamellas is 5 mm. There are ten parallel strips glued on a 20 cm × 20 cm stiff plate. Four samples are fabricated and two configurations named *parallel* and *perpendicular*, as shown in Fig. 1, are tested for the different orientations of lamellas.

### 3. FEM MODEL

A Finite Element Model (FEM) corresponding to the experimental configurations has been established to understand and interpret the experimental results. The role of viscous, thermal and structural dissipation can be observed more clearly. The wave propagation in porous  $\Omega_p$  and air  $\Omega_a$  domain are governed by Helmholtz and Biot equation respectively.

The comparison in Fig. 2 between experimental and FEM numerical results for parallel and perpendicular cases indicates that a good agreement is achieved.

For the parallel case, a peak, related to the cutoff fre-



**Figure 2.** Comparison of experimental (solid line) and FEM (dashed line) results for parallel (in blue) perpendicular (in red) configurations.

quency of Lamb-like waves is visible in Fig. 2 around 850 Hz. A similar peak around 440 Hz is also observed for perpendicular configuration due to the excitation of first bending mode of the lamellas [11].

### 4. CONCLUSION

The sound attenuation of a silencer consisting of a lamella network is investigated numerically and experimentally. Two arrangements, parallel and perpendicular to the duct axis, are considered. Results indicate that the perpendicular configuration yields strong sound attenuation peaks at low frequency due to the excitation of the lamella first bending mode whereas, in the parallel configuration, attenuation peaks are found to result from shear waves resonances across the width of the lamella. Though acoustic attenuation is mainly due to viscous dissipation as expected, the relative contribution from structural dissipation plays a noticeable role near the resonance.

### 5. REFERENCES

- [1] R. Kirby, P. T. Williams, and J. Hill, “A three dimensional investigation into the acoustic performance of dissipative splitter silencers,” *J. Acoust. Soc. Am.*, vol. 135, no. 5, pp. 2727–2737, 2014.
- [2] R. Binois, E. Perrey-Debain, N. Dauchez, B. Nennig, J.-M. Ville, and G. Beillard, “On the efficiency of parallel baffle-type silencers in rectangular ducts: prediction and measurement,” *Acta Acust. United Ac.*, vol. 101, pp. 520–530, 2015.
- [3] B. Nennig, R. Binois, E. Perrey-Debain, and N. Dauchez, “A homogenization method used to predict the performance of silencers containing parallel splitters,” *J. Acoust. Soc. Am.*, vol. 137, no. 6, pp. 3221–31, 2015.
- [4] Z. Yang, J. Mei, M. Yang, N. H. Chan, and P. Sheng, “Membrane-type acoustic metamaterial with negative dynamic mass,” *Phys. Rev. Lett.*, vol. 101, nov 2008.
- [5] N. Fang, D. Xi, J. Xu, M. Ambati, W. Srituravanich, C. Sun, and X. Zhang, “Ultrasonic metamaterials with negative modulus,” *Nat. Mater.*, vol. 5, no. 6, pp. 452–456, 2006.
- [6] X. Hu, K.-M. Ho, C. T. Chan, and J. Zi, “Homogenization of acoustic metamaterials of Helmholtz resonators in fluid,” *Phys. Rev. B*, vol. 62, p. 30, 2008.
- [7] C. Boutin, “Acoustics of porous media with inner resonators,” *J. Acoust. Soc. Am.*, vol. 134, no. 6, pp. 4717–4729, 2013.
- [8] J.-P. Groby, C. Lagarrigue, B. Brouard, O. Dazel, V. Tournat, and B. Nennig, “Enhancing the absorption properties of acoustic porous plates by periodically embedding Helmholtz resonators,” *J. Acoust. Soc. Am.*, vol. 137, pp. 273–280, jan 2015.
- [9] J. Yang, J. S. Lee, and Y. Y. Kim, “Metaporous layer to overcome the thickness constraint for broadband sound absorption,” *J. Appl. Phys.*, vol. 117, no. 17, p. 174903, 2015.
- [10] S. Griffiths, B. Nennig, and S. Job, “Porogranular materials composed of elastic helmholtz resonators for acoustic wave absorption,” *J. Acoust. Soc. Am.*, vol. 141, no. 1, pp. 254–264, 2017.
- [11] N. Dauchez, B. Nennig, and O. Robin, “Additional Sound Absorption Within a Poroelastic Lamella Network Under Oblique Incidence,” *Acta Acust. United Ac.*, vol. 104, no. 2, pp. 211–219, 2018.
- [12] J. Christensen, V. Romero-García, R. Picó, A. Cebrecos, F. J. De Abajo, N. A. Mortensen, M. Willatzen, and V. J. Sánchez-Morcillo, “Extraordinary absorption of sound in porous lamella-crystals,” *Sci. Rep.*, vol. 4, apr 2014.