

Acoustic Response modelling of Multilayered Structures with Anisotropic Porous materials



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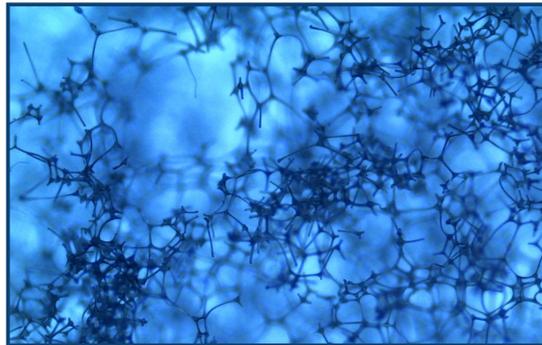
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Introduction

Motivation

- Open-cell porous materials are inherently anisotropic due to manufacturing processes, comprising a highly irregular microscopic structure.
- Need of a method for modelling the influence of the inherent mechanical and acoustic anisotropy of poroelastic materials on the acoustic transmission through multilayered structures.



Microscopic picture of a melamine foam (x20)

Objectives

- Create an accurate modelling tool for the broadband acoustic assessment of anisotropic media.
- Investigate the influence of the relative alignment of anisotropic porous materials with respect to the general coordinate system on the acoustic response of multilayered structures.

Approach

Plane wave approximation

- Every physical field can be expressed as

$$\phi(\mathbf{r}, t) = \hat{\phi} e^{i(\omega t - \mathbf{k} \cdot \mathbf{r})}$$

- The variation of the physical fields through a layer, described via a state vector \mathbf{S} composed of state variables, can be approximated as a linear combination of the same state variables,

$$\frac{\partial \mathbf{S}(z)}{\partial z} = -[\boldsymbol{\alpha}] \mathbf{S}(z)$$

- The state vector \mathbf{S} depends on the material model

Fluid layer	Solid layer	Porous layer
$\begin{Bmatrix} u_z^f(z) \\ p(z) \end{Bmatrix}$	$\begin{Bmatrix} u_x(z) \\ u_y(z) \\ u_z(z) \\ \sigma_{xz}(z) \\ \sigma_{yz}(z) \\ \sigma_{zz}(z) \end{Bmatrix}$	$\begin{Bmatrix} u_x^s(z) \\ u_y^s(z) \\ u_z^s(z) \\ u_z^t(z) \\ \hat{\sigma}_{xz}(z) \\ \hat{\sigma}_{yz}(z) \\ \hat{\sigma}_{zz}(z) \\ p(z) \end{Bmatrix}$

Material models

- Fluid layer

$$p = -K \cdot \nabla u_z^f, \quad \frac{\partial p}{\partial z} = \omega^2 \rho u_z^f.$$

- Anisotropic solid Layer

$$\boldsymbol{\sigma} = \mathbf{C} \boldsymbol{\epsilon}, \quad \nabla \cdot \boldsymbol{\sigma} = -\omega^2 \rho \mathbf{u}.$$

- Anisotropic porous layer

$$\nabla \cdot \hat{\boldsymbol{\sigma}} = -\omega^2 \tilde{\rho}_s \mathbf{u}^s - \omega^2 \tilde{\rho}_{eq} \tilde{\gamma} \mathbf{u}^t,$$

$$-\nabla p = -\omega^2 \tilde{\rho}_{eq} \tilde{\gamma} \mathbf{u}^s - \omega^2 \tilde{\rho}_{eq} \mathbf{u}^t,$$

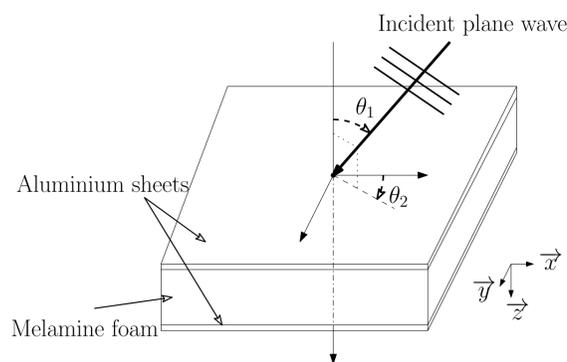
$$\hat{\boldsymbol{\sigma}} = \hat{\mathbf{H}}(\omega) \cdot \boldsymbol{\epsilon},$$

$$p = -\tilde{K}_{eq} \nabla \cdot \mathbf{u}^t.$$

Results

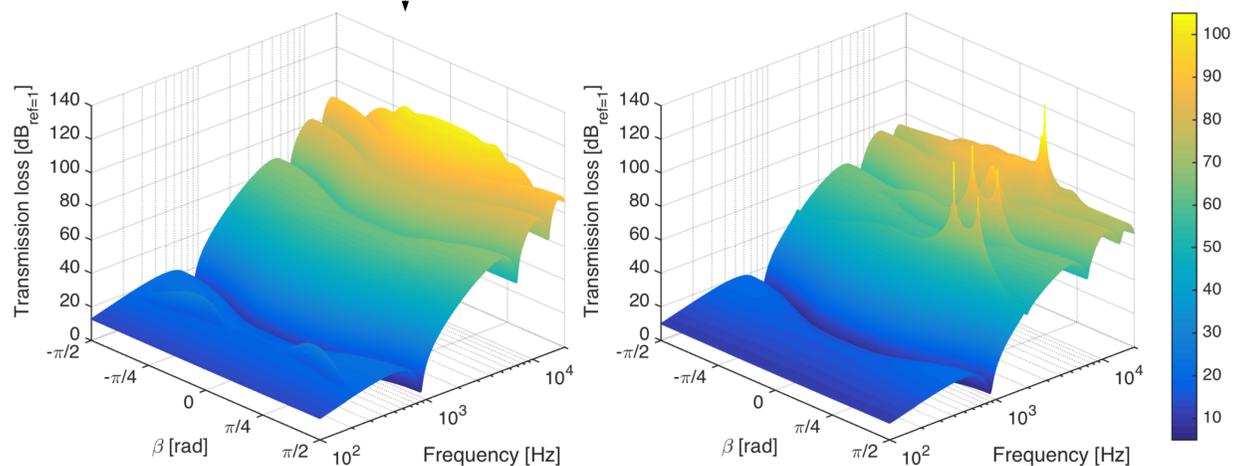
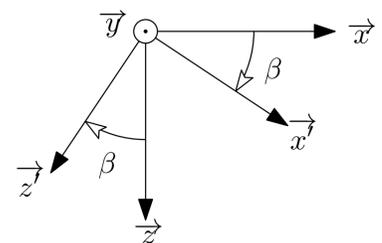
Setup

- Isotropic Aluminium facesheets
- Anisotropic melamine foam



Relative alignment

- The porous layer is rotated with respect to the general coordinate system



Normal Incidence

- Symmetry with respect to $\beta=0$ rad.
- Rotation of the poroelastic material shifts resonances and anti-resonances in frequency
- Increase of transmission loss of the overall structure for rotations around $\beta=\pm\pi/4$ rad.

Oblique Incidence

- No symmetry plane
- Rotation of the poroelastic material shifts resonances and anti-resonances in frequency
- Dramatic increase of transmission loss in mid and high frequencies for particular rotations

Conclusion / Quo vadis?

- A broadband plane wave method for the acoustic characterisation of multilayered structures composed of anisotropic poroelastic materials has been successfully implemented.

- The relative alignment of the porous layer has important influence on the acoustic transmission through the system.
- The methodology holds a potential to identify the physical phenomena behind the resonant behaviour.