Sorrento SAPEM'23 常熟

MATELYS Research Lab

On the use of an additional parameter for the characterization and the condensation of heterogeneous or non-symmetric multilayered materials

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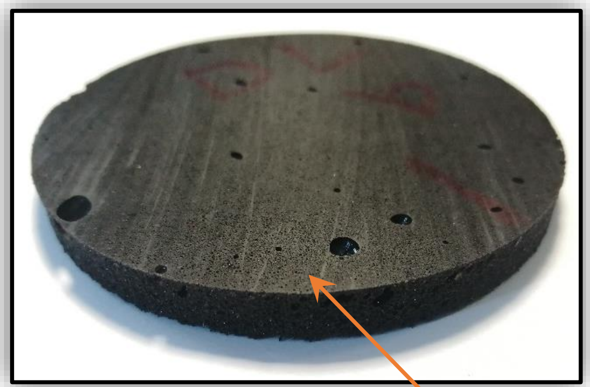
Context

Heterogeneous or multilayered foams:

Screen

- Does the screen or the “natural” skin have an impact on the acoustic properties?
- Do we need to characterize them?

Heterogeneity in the thickness

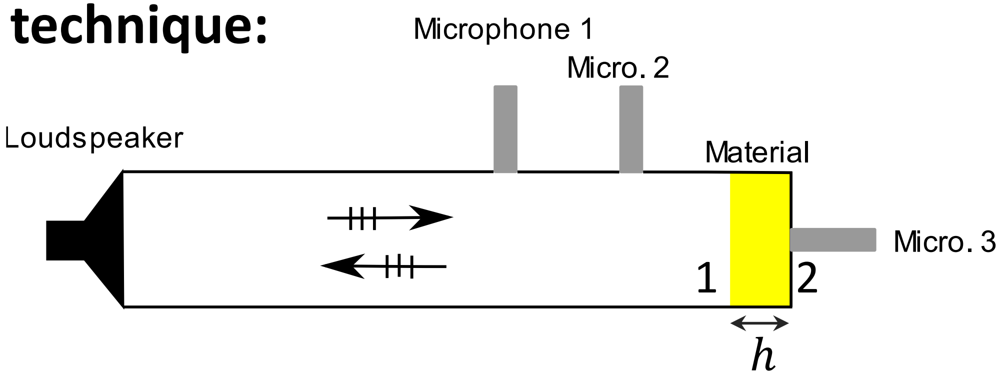


- How to quantify the heterogeneity?
- Is it possible to develop a condensed model of heterogeneous porous materials?

“Natural” skin

Characterization of homogeneous materials

3 microphones technique:



$$\begin{pmatrix} p_1 \\ v_1 \end{pmatrix} = [\boldsymbol{T}] \begin{pmatrix} p_2 \\ v_2 \end{pmatrix}$$

$$\begin{pmatrix} p_1 \\ v_1 \end{pmatrix} = \begin{bmatrix} \cos(k_c h) & \mathrm{j} Z_c \sin(k_c h) \\ \frac{\mathrm{j}}{Z_c} \sin(k_c h) & \cos(k_c h) \end{bmatrix} \begin{pmatrix} p_2 \\ v_2 \end{pmatrix}$$

$$\tilde{\rho} = \frac{Z_c k_c}{\omega} \qquad \widetilde{K} = \frac{\omega Z_c}{k_c}$$

- k_c is obtained by applying the complex acos function

  ⟶ **Requires the development of the acos function to manage discontinuities**

- $\boldsymbol{T}(1,1) = \boldsymbol{T}(2,2)$

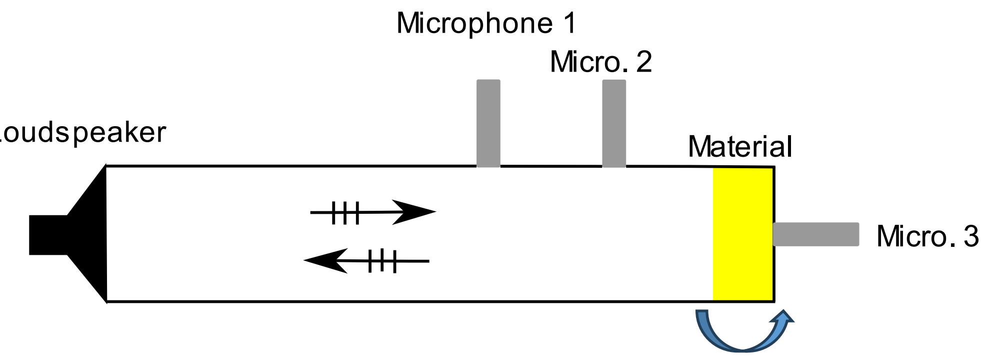
  ⟶ **Assumes that the material is homogeneous or symmetric**

Characterization of heterogeneous materials

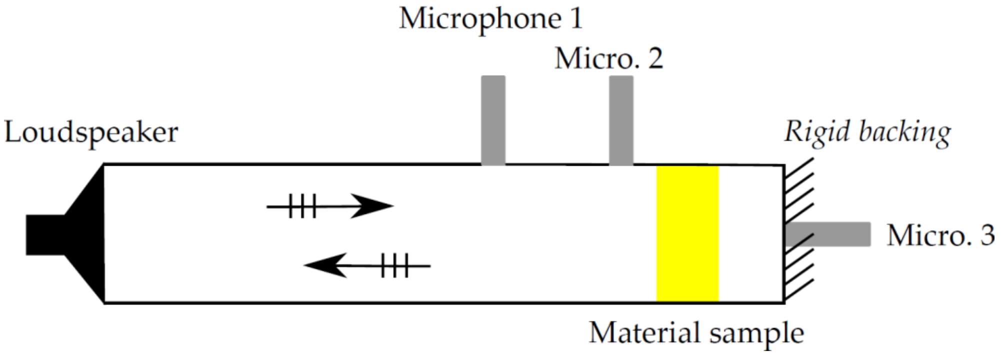
Transfer matrix at normal incidence: $[\boldsymbol{T}] = \begin{bmatrix} T_{11} & T_{12} \\ T_{21} & T_{22} \end{bmatrix}$

Identification of the transfer matrix:

Measure the sample on both sides:



Two-cavity method:



→ **Two measurements are required**

Two-cavity method used in this study

Characterization of heterogeneous materials

Stroh formalism [1]:

$$[\boldsymbol{T}] = \exp([\boldsymbol{A}]h) \quad \text{with } [\boldsymbol{A}] = \mathrm{i}\omega \begin{bmatrix} \tilde{\chi} & \tilde{\rho} \\ 1/\tilde{K} & -\tilde{\chi} \end{bmatrix}$$

[1]: Groby & al., New Journal of Physics, 2021

→ From the measured transfer matrix:

$\tilde{\chi}$ is also called Willis coupling

$$[\boldsymbol{A}] = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} = \log([\boldsymbol{T}])/h$$

$$\tilde{\rho} = \frac{A_{12}}{\mathrm{i}\omega} \qquad \tilde{K} = \frac{\mathrm{i}\omega}{A_{21}} \qquad \tilde{\chi} = \frac{A_{11}}{\mathrm{i}\omega} = -\frac{A_{22}}{\mathrm{i}\omega}$$

⟶ **$\tilde{\chi}$ gives informations on the heterogeneity of the material**

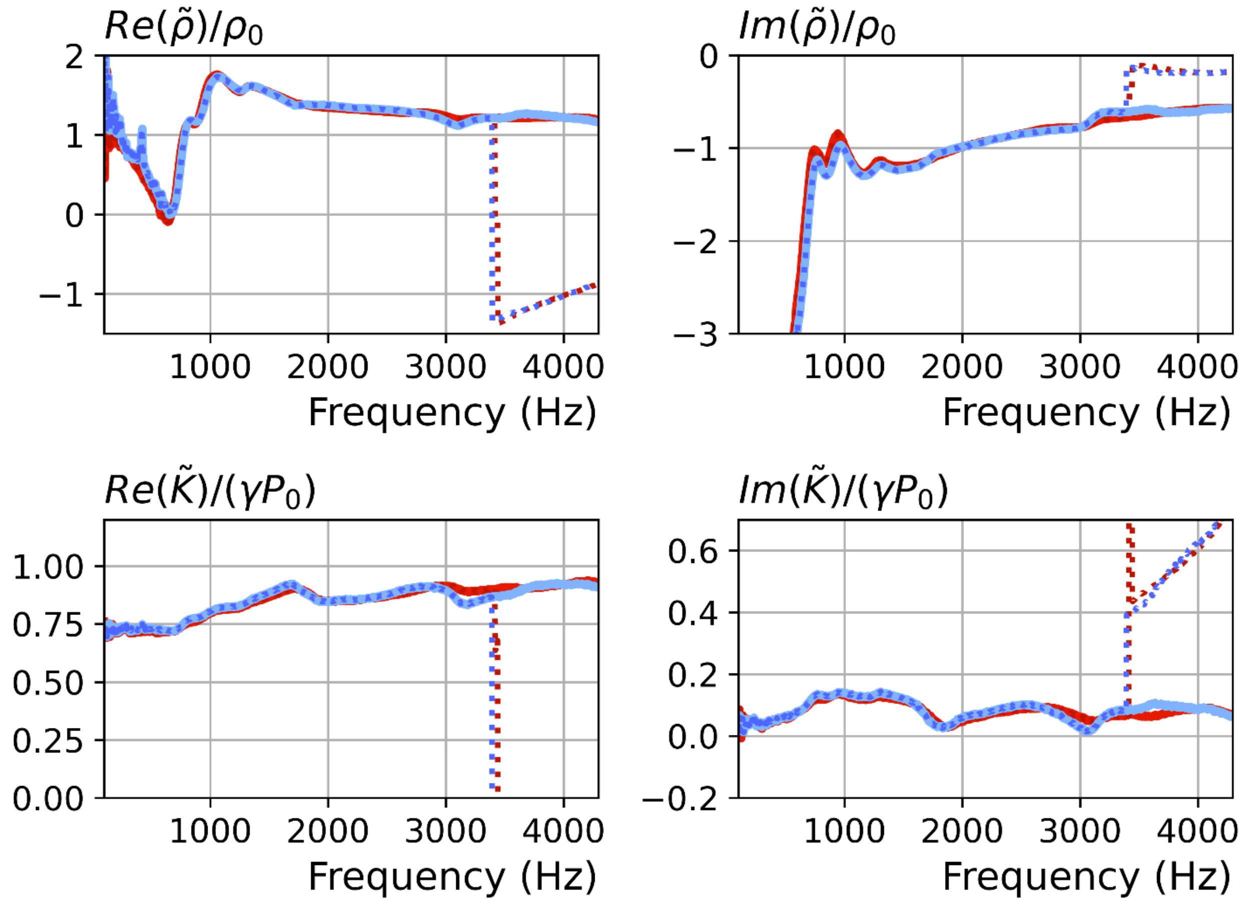
⟶ **Still need to manage discontinuities (easier than developing $acos$)**

$\tilde{\chi}$ is proportional to the inverse of a velocity

$\tilde{\chi} = 0$ for symmetric multilayered or homogeneous foams

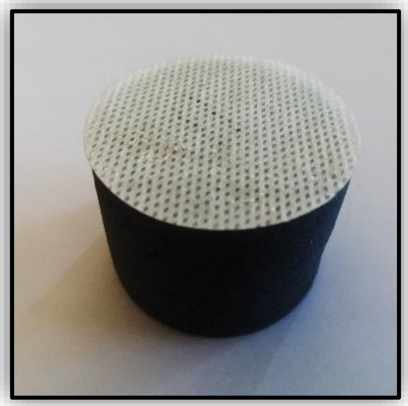
Experimental results

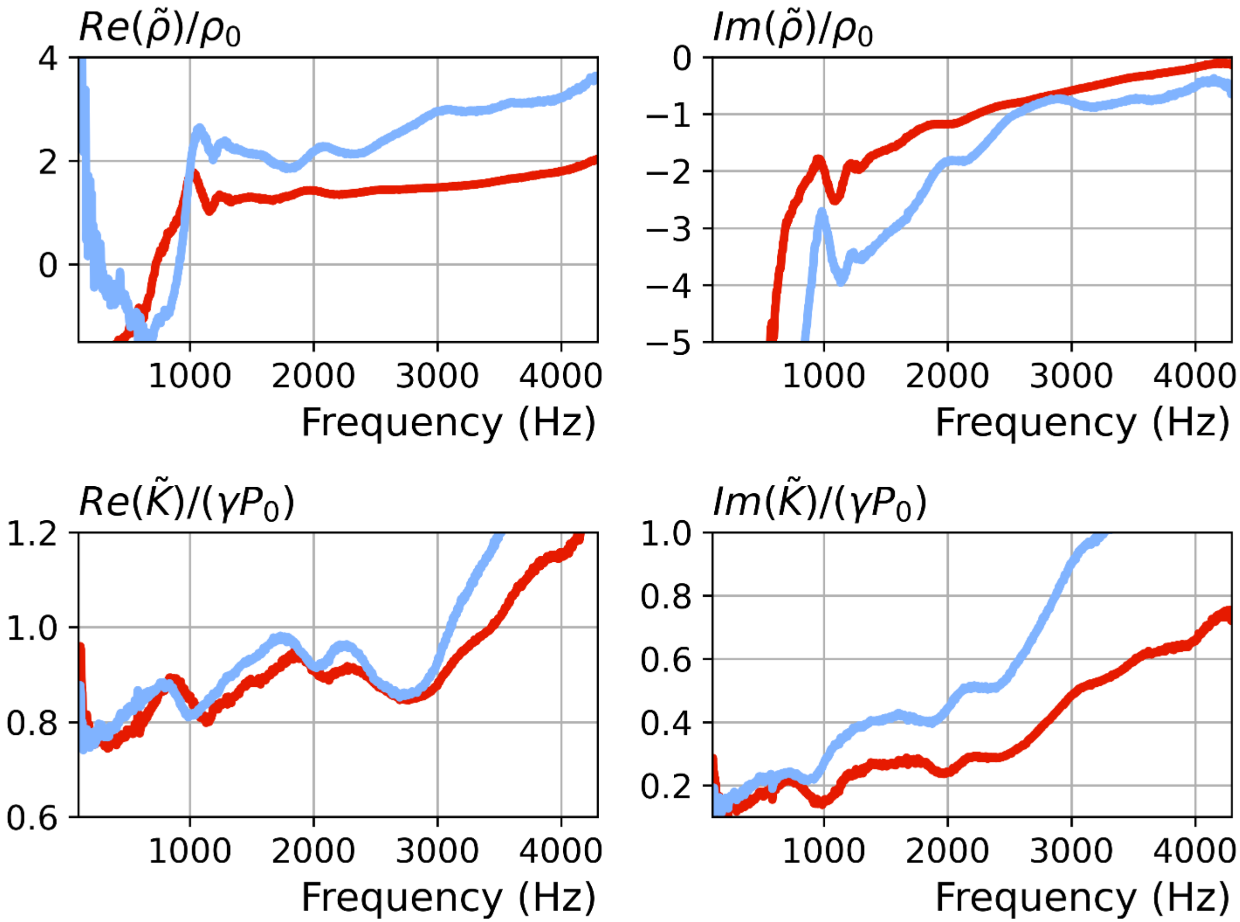
Melamine:



Experimental results

Screen + Melamine:

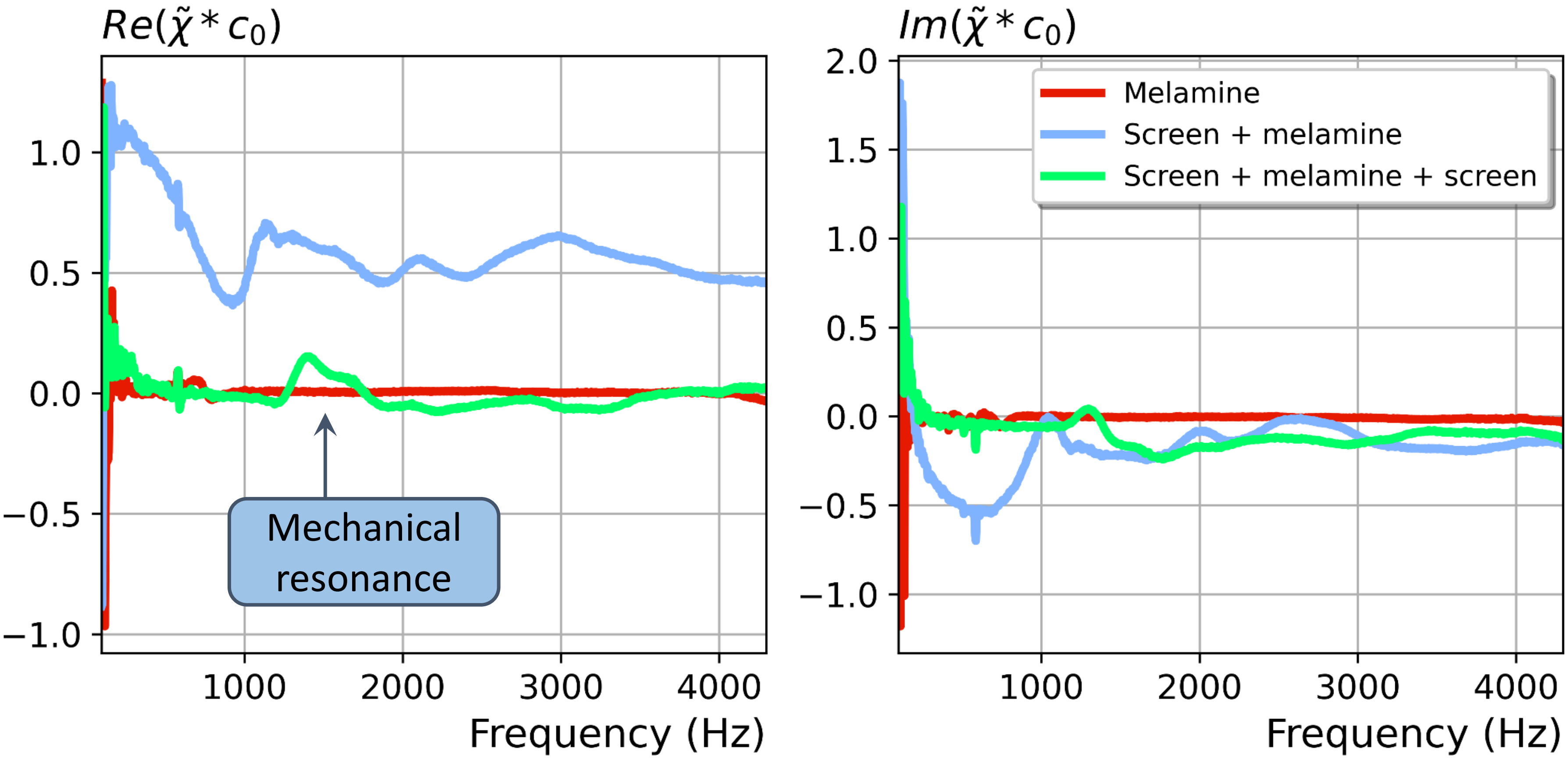




Not physical parameters!!

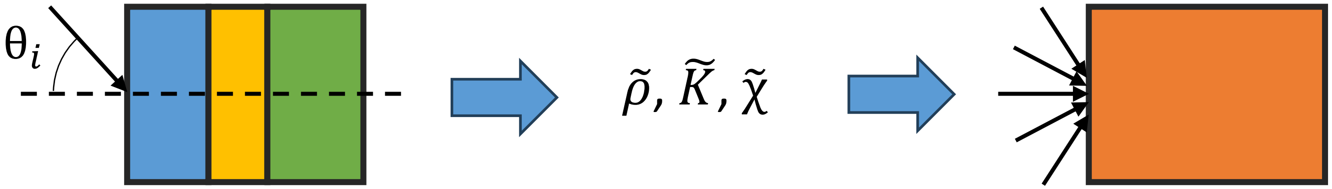
Experimental results

$\tilde{\chi}$ parameter:



Condensation of multilayer

Condensation technique:



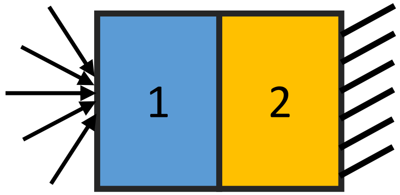
- Compute the global $[\boldsymbol{T}]$ matrix of the multilayer for an incident angle θ_i
- Identify the $[\boldsymbol{A}]$ matrix and $\tilde{\rho}, \widetilde{K}, \tilde{\chi}$ (equivalent parameters)
- Compute the $[\boldsymbol{T}]$ matrix for other incident angles by using $\tilde{\rho}, \widetilde{K}, \tilde{\chi}$
- Compute α coefficient in diffuse field

$[\boldsymbol{A}]$ at oblique incidence:

$$[\boldsymbol{A}] = \mathrm{i}\omega \begin{bmatrix} \tilde{\chi} & \tilde{\rho} \\ \frac{1}{\widetilde{K}} - \frac{k_t^2}{\tilde{\rho}\omega^2} & -\tilde{\chi} \end{bmatrix} \qquad \text{with } k_t = k_0 \sin(\theta)$$

Condensation of multilayer

Influence of $\widetilde{\chi}$:

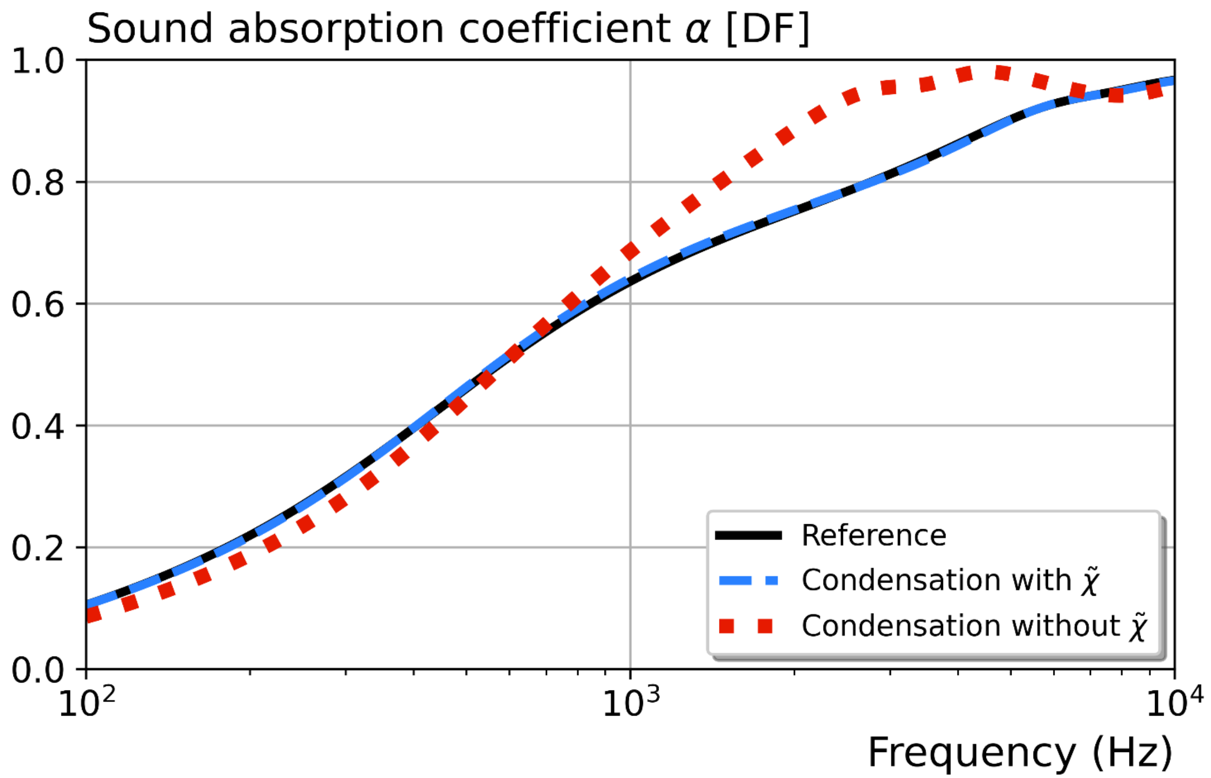


$\sigma_1 = 100000 \text{ N.s.m}^{-4}$

$\sigma_2 = 1000 \text{ N.s.m}^{-4}$

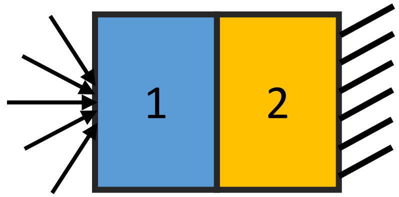
$h_1 = h_2 = 20 \text{ mm}$

Equivalent parameters characterized at $\theta_i = 45°$



Condensation of multilayer

Influence of θ_i:



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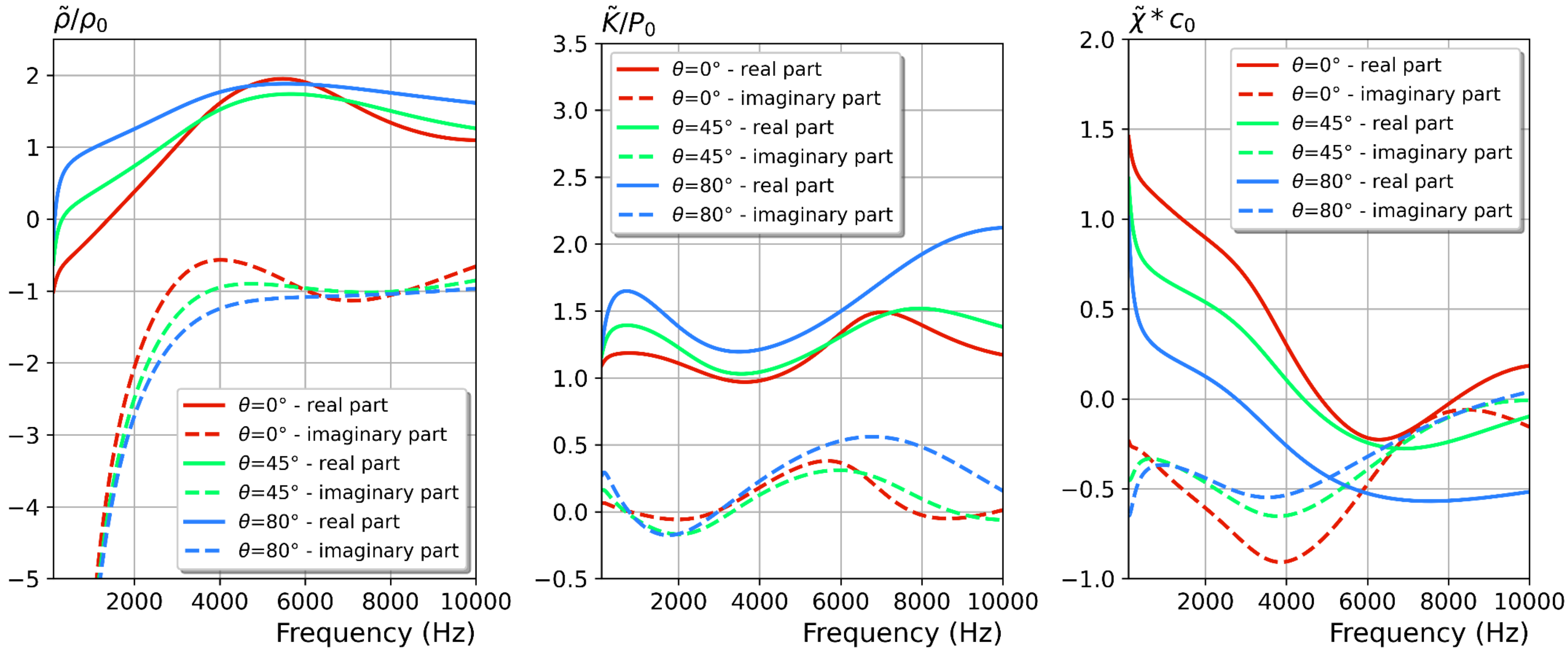
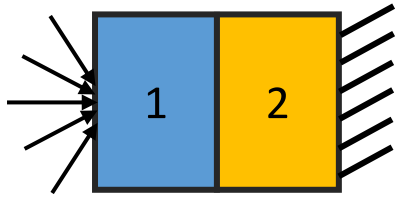


Condensation of multilayer

Influence of θ_i:



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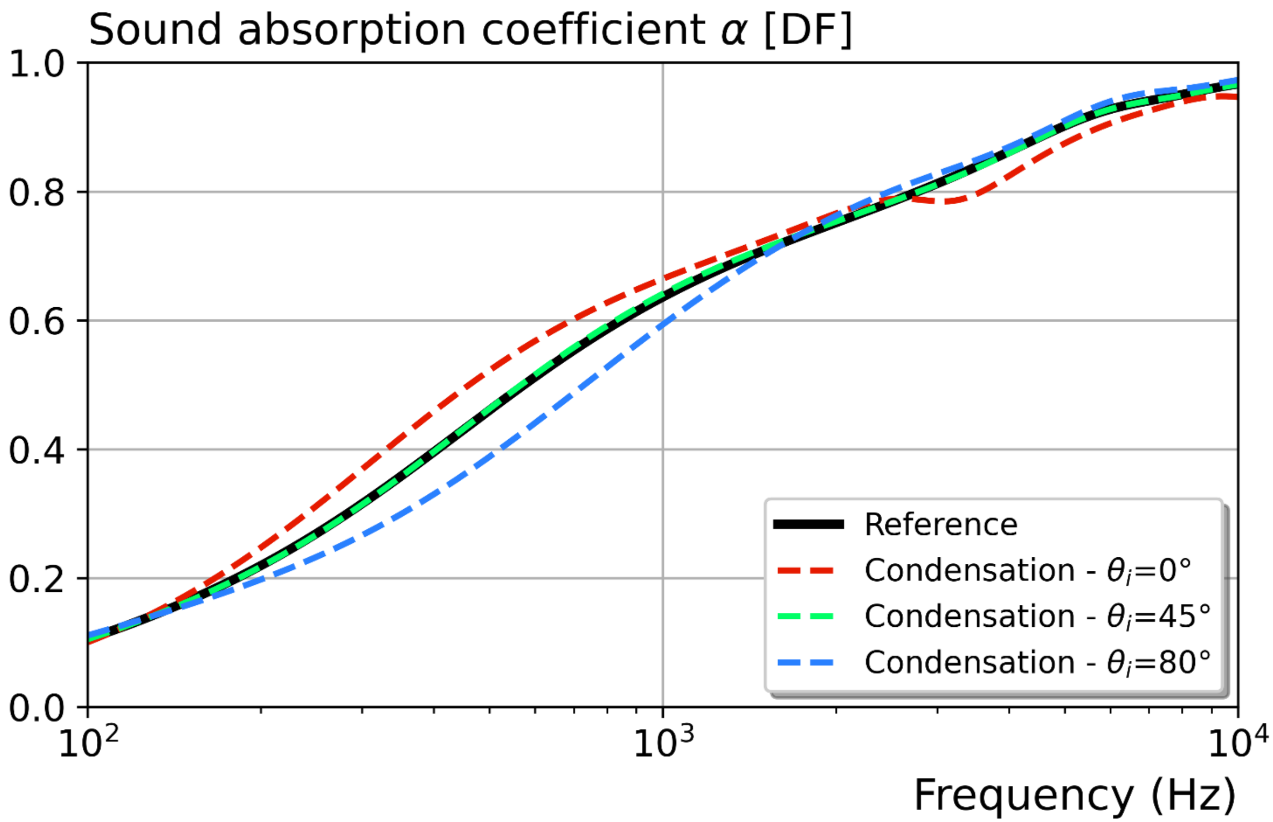
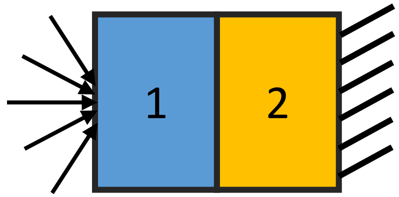


Condensation of multilayer

Estimation at another angle:



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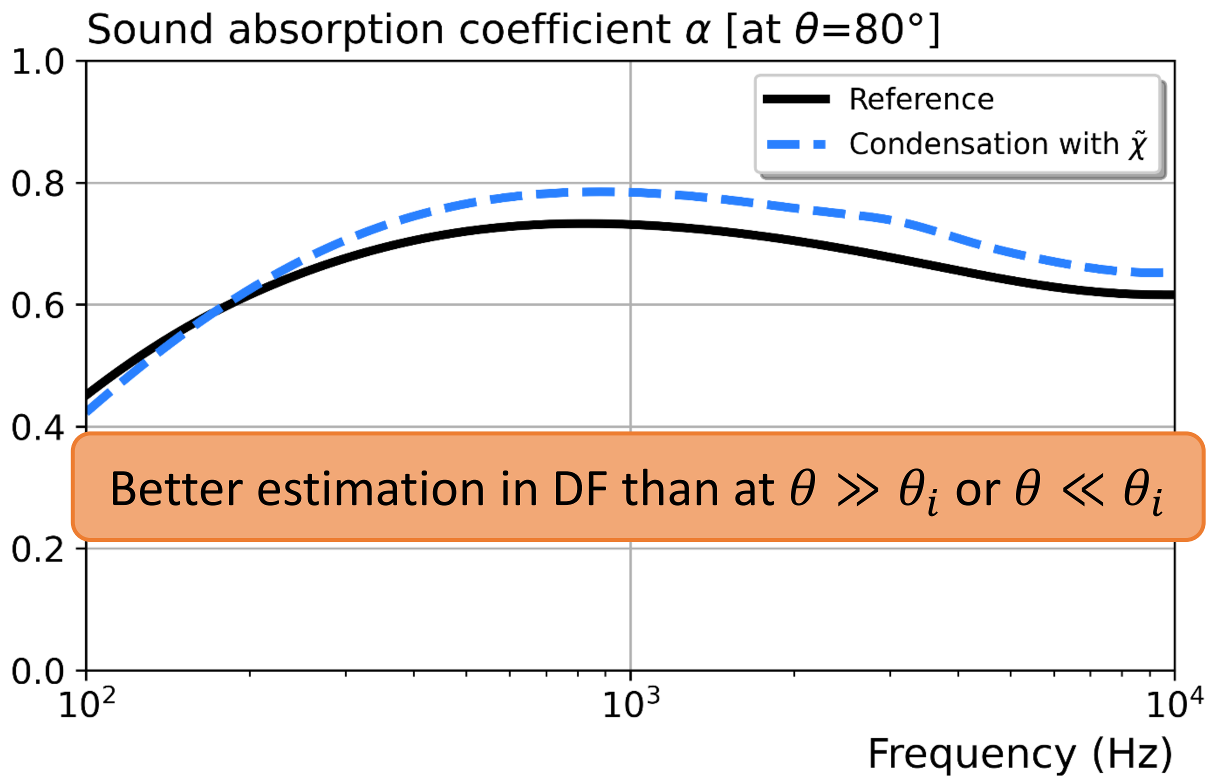
$\sigma_2 = 1000 \text{ N.s.m}^{-4}$

$h_1 = h_2 = 20 \text{ mm}$

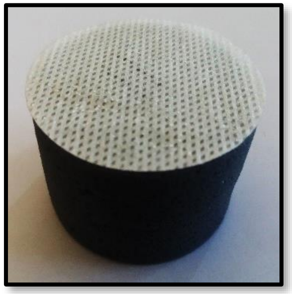
Equivalent parameters characterized at $\theta_i = 45°$



Better estimation in DF than at $\theta \gg \theta_i$ or $\theta \ll \theta_i$

Measurements vs simulations

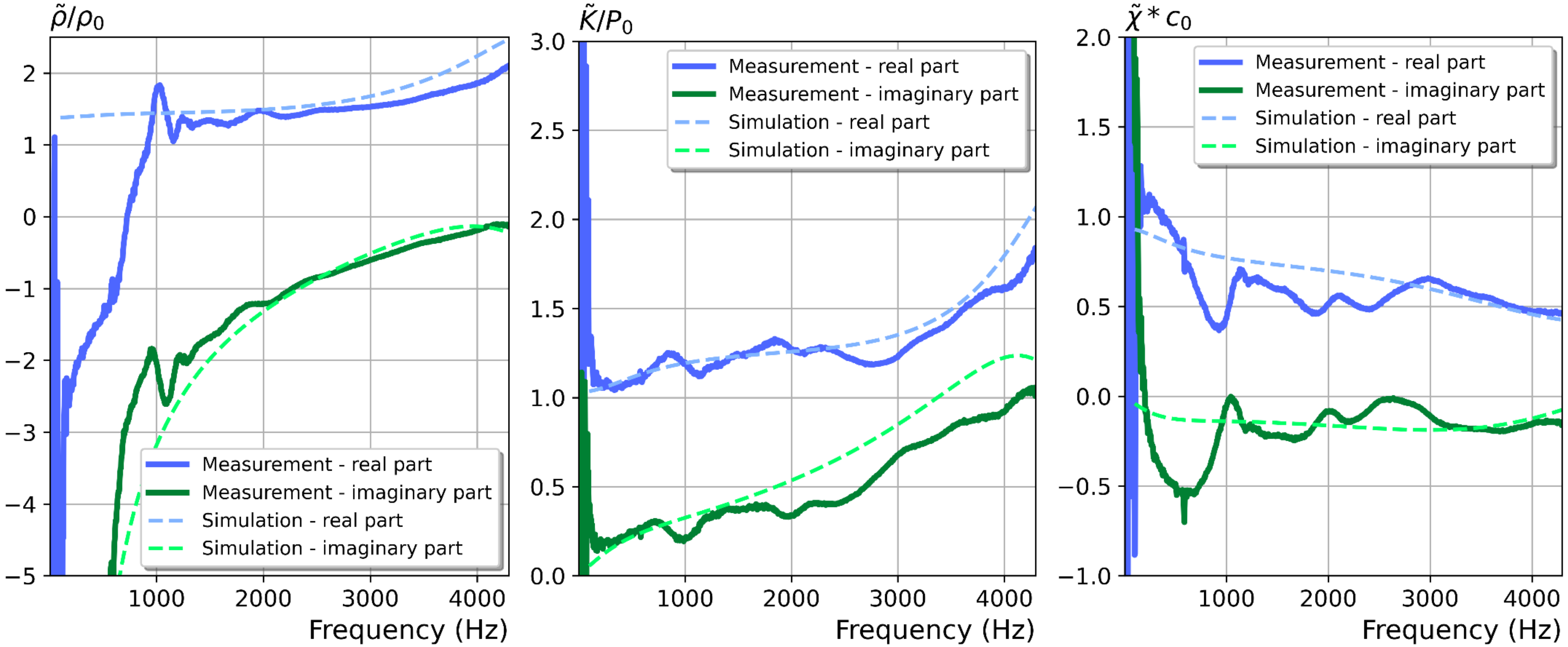
Screen + melamine:



$h_s = 0.3$ mm $\phi_s = 0.06$ $\sigma_s = 1.9e^6$ N. s. m^{-4}

$h_m = 31$ mm $\phi_m = 0.98$ $\sigma_m = 7.3e^3$ N. s. m^{-4}

Equivalent parameters characterized at $\theta_i = 0°$



Conclusions & perspectives

Conclusions

- An **additional parameter** has been used in the characterization:
  Quantify the **asymmetry** or the **heterogeneity** of the material or the **influence of a skin**
  More stable but requires 2 measurements (on both sides or 2 cavities).

- The $\tilde{\chi}$ parameter can be used to **condensed multilayered** porous materials:
  It is an approximation but it **account for the incidence** compared to locally reacting models.
  It gives good results in **diffuse field** by characterizing at $\theta_i = 45°$.

Perspectives

- Establish a **parametric study** to observe the influence of the properties of heterogeneous materials on the $\tilde{\chi}$ parameter.

- Improve the condensed model with **intrinsic equivalent parameters**

Thank you for your attention

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