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Enhancement of the low frequency performance of thin, film-faced layers of foam by surface segmentation

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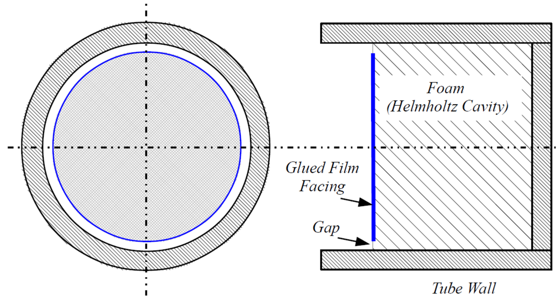
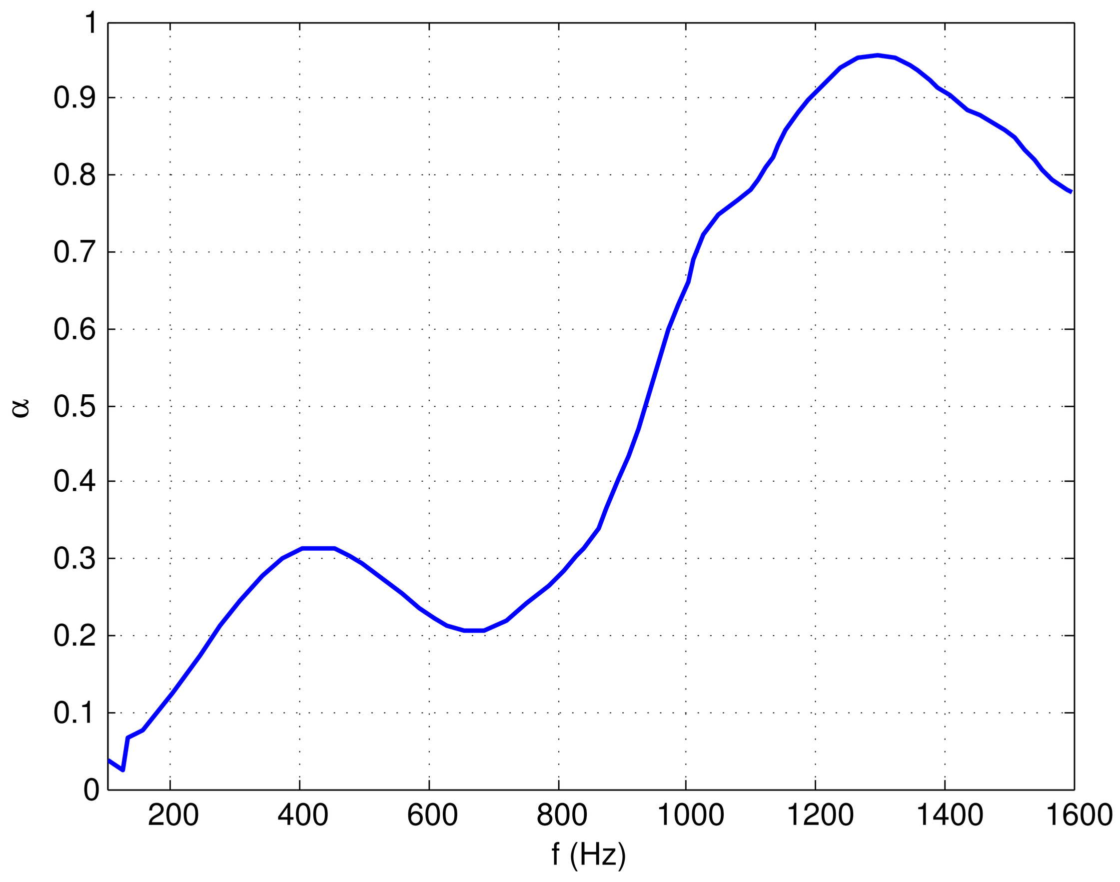
Objectives: Understand the absorption of film-faced foam with circumferential air gap





Main results :

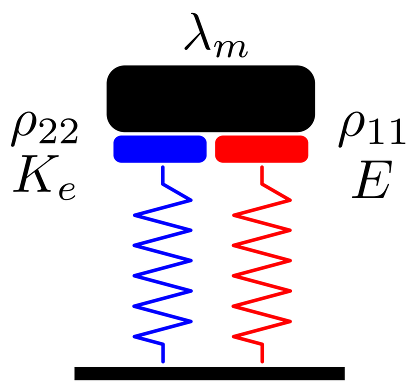
- New peak, at low frequency with viscous dissipation due to Diaphragm-Helmholtz resonator effect [1]
- Very low motion of the membrane around 400 Hz
- Membrane increases the structural dissipation
- Gap enhances also the absorption at higher frequencies when compared with airtight membrane
- Independently tunable membrane and air gap effects

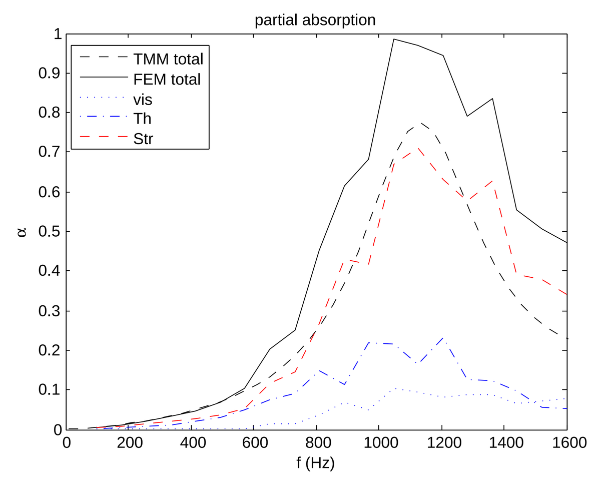
Melamine foam : $E = 50(1-0.076\mathrm{i})$ kPa, $\nu = 0.4$, $\sigma = 9000$ Nm-4s, $\phi = 0.995$, $\alpha_\infty = 1.01$, $\Lambda = 64\mu$m, $\Lambda' = 143\mu$m. Sample : radius $r = 50$ mm, height $h = 25$ mm, air gap $b = 1$ mm. Measuremant B&K impedance tube

Simplified airtight membrane model

Assumptions :

- membrane of surface mass λ_m with no stiffness
- No air leak
- 1D Biot model





An approximation of the mass-spring resonance frequency, can be obtained with Ritz method

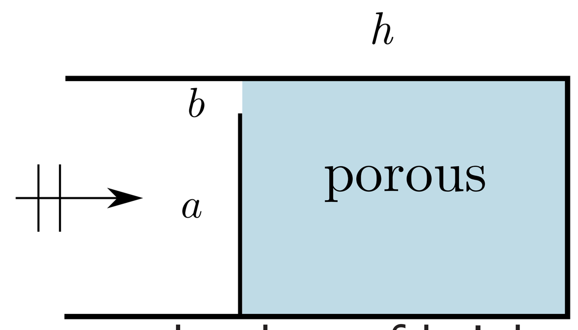
$$f_{mb} \sim \frac{1}{2\pi}\sqrt{\frac{K_{eff}/h}{(\rho_{11}+\rho_{22})h/3+\lambda_m}}. \tag{1}$$

where the effective compressibility of the material $K_{eff} = E + K_e$ is the sum of the stiffness of the fluid phase K_e and the stiffness of the solid phase E.
Here, we get $f_{mb} = 930$ Hz.

Simplified Diaphragm model

Assumptions :

- Rigid frame porous material
- Diaphragm (motionless membrane)
- Plane wave regime



The inductance L of a slit of height b in a rectangular duct of height a and of cross section $a \times d$ is given by [2, p. 487]

$$\frac{Ld}{\rho} = -\frac{2}{\pi}\ln\sin\frac{\pi b}{2a}, \quad \text{if } b \ll a. \tag{2}$$

The impedance of the porous layer is $Z_p = -\mathrm{i}\rho_p c_p \cot k_p h$ and the impedance of the diaphragm is $Z_d = -\mathrm{i}\omega LS$. Assuming the best absorption arises when the imaginary part of $Z = Z_p + Z_d$ vanishes, we get

$$f_d \sim \frac{1}{2\pi}\sqrt{\frac{K_e}{VL}}, \tag{3}$$

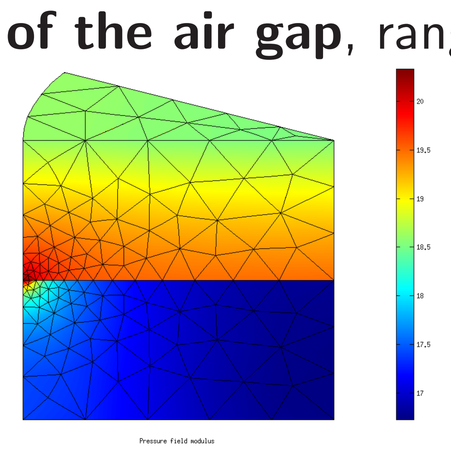
where $V = Sh$ porous material layer volume. This stiffness is the same as for the Helmholtz resonator.
Putting $\rho \approx \rho_{22}$ yields $f_d \approx 600$ Hz with is closed to the frequency of the 1st experimental peak.

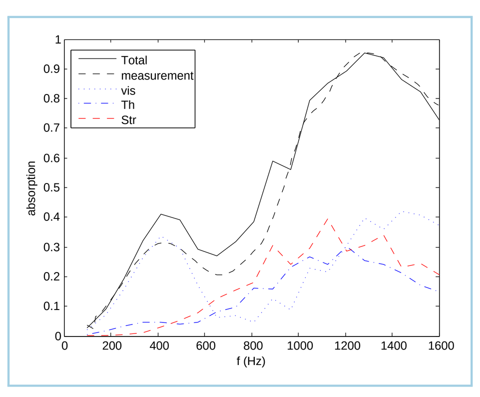
Numerical simulations

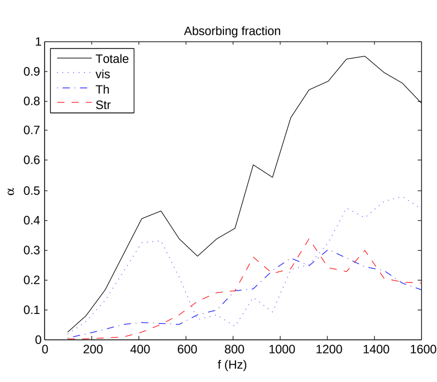
Assumptions :

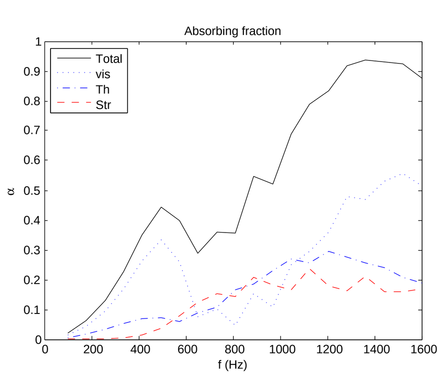
- FEM simulations with Quadratic elements [3]
- Dissipated energy computed with [4]
- Clamped boundary condition, DtN map for radiation

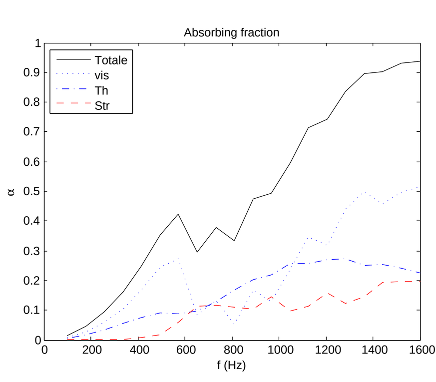
Effect of the air gap, ranging from 0.5, 1, 2, 5, 10 mm and radius $r = 50$ mm

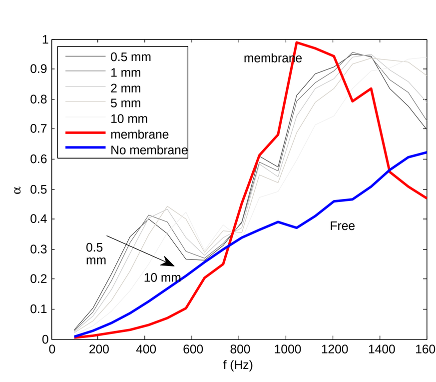




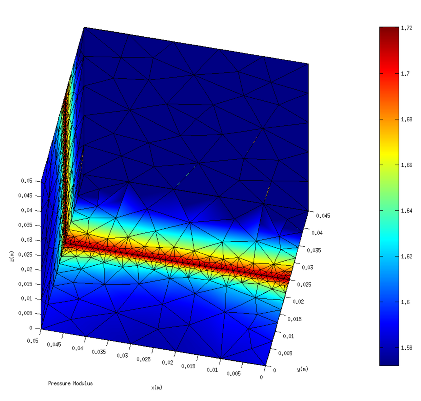


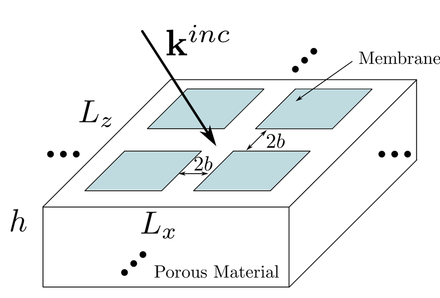


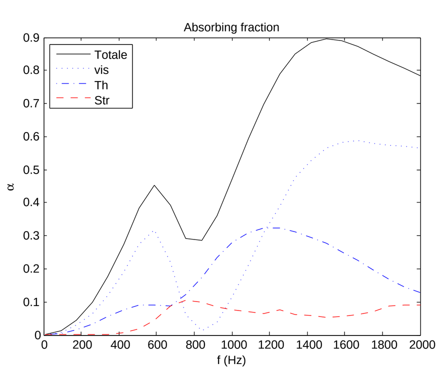




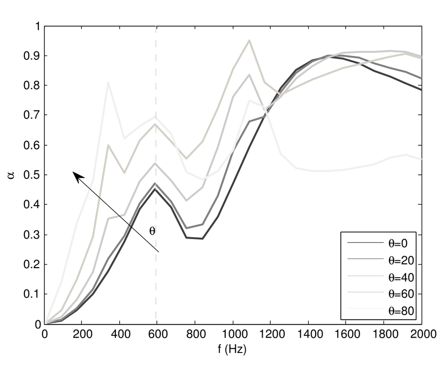
Periodic patch and oblique incidence effect : $L_x = 50$ mm, $L_z = 50$ mm, $b = 1$ mm, $h = 25$ mm







Normal incidence



Other incidences

Prospects :

- Combination with double porosity material [5]
- Combination with Cuboid [6]

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