A Method For The Inverse Characterization Of Poroelastic Mechanical Properties

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1. INTRODUCTION

Porous materials like polymer foams are widely used for sound absorption and damping vibrations in industries such as buildings construction or aeronautics.

Vibroacoustic efficiency and dissipation mechanisms of these materials depend on their dynamic properties, for assumed isotropic materials : Young's modulus E (or bending rigidity D) and the structural loss factor η. Poisson's ratio, ν, is found constant[Pritz,1994].

This work presents an experimental setup to characterize the frequency dependence of Young's modulus and structural loss factor of a poroelastic material bouded onto a aluminium plate in bending vibration by inversion with the help of an equivalent plate model. Development of such an equivalent plate is interesting to reduce numerical calculation time and memory requirement.

2. EXPERIMENTAL SETUP

A generic experimental configuration is used : the aluminium plate is simply supported and excited with a point mechanical excitation. The mean quadratic velocity of the plate treated by the material is measured over the frequency range of 20 - 820 Hz and is used for a two parameters (D, η) modal inversion.

ρ	ν	ϕ
8.85 (kg.m^{-3})	0.44	0.99

α	σ	Λ	Λ'
1.0	12600 (Nms^{-4})	78 (10^{-6} m)	192 (10^{-6} m)

Table 1. Properties of studied plastic foam.

The parameters of the studied material within the Biot theory[Allard,1993], measured from usual setup [Atalla, 2000], are reported in table 1.

In the following, subscript 1 will refer to the aluminium plate and 2 to the porous material.

3. DISSIPATION MECHANISMS IN POROUS MEDIA

In the low frequency range, among the three dissipation mechanisms occurring within the porous layer, thermal dissipation has been found negligible for various porous materials and thicknesses[Lemarinier, 1997]. Thus, in the chosen frequency range, only structural and viscous dissipations are significants.

In this frequency range, Dauchez's work[Dauchez, 1999] has shown viscous dissipation is mainly related to flow resistivity σ. For high resistivity materials, structural damping is the major dissipative mechanism, whereas for low resistivity material, viscous dissipation can be of greater influence.

Our approach is to include viscous dissipation by taking the effective density[Allard, 1993] $\tilde{\rho}_2$ in place of the material density ρ_2 and set the equivalent plate's loss factor to the material's one to account for structural damping.

4. EQUIVALENT PLATE MODEL

From previous observations, the porous layer can be considered as a monophasic viscoelastic with corrections for viscous effets and structural damping. In addition, the shear effect in the porous layer is taken into account.

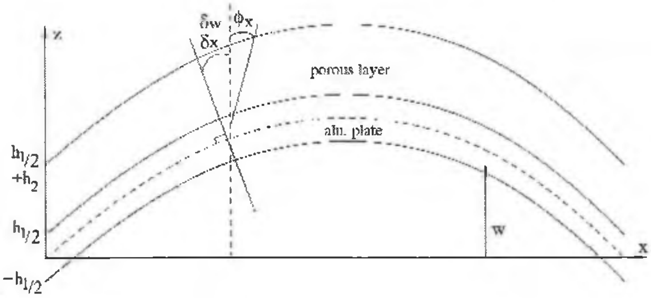

Fig. 1. Displacement components of the two layers plate of thickness h1 + h2.

Thus, displacement components for the porous layer are assumed to be of the form :

$$u_2(x,y,z,t)=-z\frac{\partial w}{\partial x}-(z-\frac{h_1}{2})\phi_x(x,y,t) \qquad (1)$$

$$v_2(x,y,z,t)=-z\frac{\partial w}{\partial y}-(z-\frac{h_1}{2})\phi_y(x,y,t) \qquad (2)$$

$$w(x,y,z,t)=w(x,y,t) \qquad (3)$$

Bending rigidity and surface density of the equivalent plate can be written :

$$D_{12}=(D_1+D_2)C_s(k_2) \qquad (4)$$

$$m_{12}=\rho_1 h_1+\tilde{\rho}_2 h_2 \qquad (5)$$

where $C_s(k^2)$ is a correction factor of the equivalent Ross-Kerwin-Ungar[Ross, 1959] bending rigidity accounting for the shear and depending on the wavenumber k.
Writing kinetic and strain energies and applying Lagrange's equations on the three variables w, ϕ_x and ϕ_y gives the two equations of motion :

$$D_{12}\Delta\Delta w-\omega^2\tilde{m}_{12}w+D_4\Delta\theta=0 \qquad (6)$$

$$D_4\Delta\Delta w+D_3\Delta\theta-\kappa^2 G_2 h_2\theta=0 \qquad (7)$$

where ω is the pulsation, θ is the variable $\delta\phi_x/\delta x + \delta\phi_y/\delta y$ and Δ is the Laplacian operator $\delta^2/\delta x^2 + \delta^2/\delta y^2$. G_2 is the shear modulus of the porous material, κ^2 its correction factor introduced by Mindlin[Mindlin, 1951]. Flexural rigidities D_3 and D_4 are :

$$D_3=\frac{E_2}{1-\upsilon_2^2}\int_{h_1/2}^{h_1/2+h_2}\left(z-\frac{h_1}{2}\right)^2 dz \qquad (8)$$

$$D_4=\frac{E_2}{1-\upsilon_2^2}\int_{h_1/2}^{h_1/2+h_2} z(z-\frac{h_1}{2})dz \qquad (9)$$

5. RESULTS AND PERSPECTIVES

Bending rigidity and loss factor of the foam are given in figure 2. This figure is a typical representation of polymers bending rigidity D and structural damping η in frequency[Corsaro, 1990]. Dimensions used in experiment are :

plate area : 0.48 x 0.42 m.
thicknesses : $h_1 = 3.175$ mm. and $h_2 = 76.2$ mm.

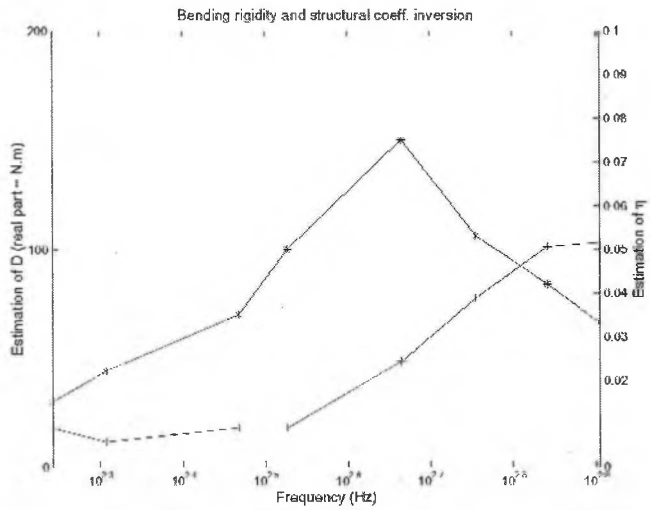

Fig 2. Bending rigidity D_2 (+) and struct. damping (*) frequency dependence of studied porous material.

Our next step is to compare these results with the temperature-frequency superposition principle[Corsaro, 1990].

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