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Layered Fibrous Treatments for Sound Absorption and Sound Transmission

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Layered Fibrous Treatments for Sound Absorption and Sound Transmission

by

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Introduction

- Porous materials are rigid, elastic or limp
- “Limp” porous material
 - in vacuo bulk stiffness less than that of air
- Fibers move as a result of viscous and inertial coupling
- Outline
 - experimental evidence of “limp behavior”
 - limp porous material theory
 - transfer matrix method for composite systems
 - optimization

Elastic Porous Material Model

- Based on the Biot Theory

Evidence of Limp Behavior

Rigid Model

$$\sigma = 1.7 \times 10^4 \text{ Rayls/m}$$

$$\phi = 0.98$$

$$q^2 = 1.2$$

Elastic Model

$$E_1 \ll \gamma P_o$$

$$\rho_b = 21.1 \text{ kg / m}^3$$

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Limp Porous Material Model

- Assume

- in vacuo bulk modulus of solid phase is zero
- bulk modulus of fiber material much greater than that of air

**Single Second Order
Wave Equation**

Efficient
and Stable

- Input Parameters

1. Flow resistivity
2. Porosity
3. Tortuosity (rigid model)
4. Bulk density

Transfer Matrix Method

- Composite System

Transfer Matrix Method

OR

- $[T]$ is the transfer matrix
- $[T]_{\text{composite}} = [T_1][T_2] \dots [T_n]$
- Absorption coefficient and transmission loss may be calculated when $[T]_{\text{composite}}$ is known
- Air spaces, porous layers, limp impermeable layers, limp resistive layers, elastic panels

$$\begin{bmatrix} p_1 \\ v_{1x} \end{bmatrix}_{x=0} = [T] \begin{bmatrix} p_1 \\ v_{1x} \end{bmatrix}_{x=d}$$

Experimental Verification

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Optimization Examples

- Accurate models allow treatments to be optimized automatically
- Optimum?
 - Specified level of acoustical performance at minimum weight, thickness and cost
- Examples
 - optimal performance for a given thickness
 - vary flow resistivity and basis weight

$$NRC = \frac{\alpha_{250} + \alpha_{500} + \alpha_{1000} + \alpha_{2000}}{4} \quad TSIL = \frac{TL_{500} + TL_{1000} + TL_{2000} + TL_{4000}}{4}$$

Absorption - *NRC* Contours

Homogeneous Fibrous Material

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Absorption

Material 1

- $NRC=0.36$
- $d=2.35$ cm
- $\rho=17.8$ Kg/m³
- $\sigma=1.6 \times 10^4$ Rayls/m

Material 2

- $NRC=0.45$
- $d=2.35$ cm
- $\rho=28.7$ Kg/m³
- $\sigma=3.9 \times 10^4$ Rayls/m

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Transmission Loss - *TSIL* Contours

1. 0.03" steel panel
2. fibrous material
- 2.50 cm
- varying basis weight and flow resistivity
3. Impermeable membrane
- 1.1 Kg/m²

Automotive Dashpanel System

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NRC Contours - Absorption

1. resistive scrim
 2. fibrous material
- 3.50 cm
 - 400 g/m²

Homogeneous Layer + Resistive Scrim

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Absorption Coefficients

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Conclusion

- Light, fibrous materials can be modeled as limp
- An efficient, stable and accurate theoretical model has been developed for this purpose
- Theory combined with transfer matrix approach offers system optimization tool
- Optimal flow resistivity exists in transmission loss applications
- Transmission loss can be increased without increasing treatment weight by choosing optimum flow resistivity