Equivalent Damping Modeling In the Framework of SmEdA

Ha Dong Hwang, Kerem Ege, Laurent Maxit, Nicolas Totaro, Jean-Louis Guyader

Vibrations, Shocks and Noise

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Highlights

- Mid-frequency vibroacoustic modeling, Viscoelastic material damping modeling, Porous material damping modeling, Mass reduction for a structure-fluid coupled system

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1. Introduction

City Lightweight Innovative Cab (project CLIC) aims at developing a new generation of lightweight trucks. Mass reduction of a structural body may necessitate extensive use of additive damping mechanisms. Statistical Modal Energy Distribution Analysis (SmEdA) [1] can be used to analyze the energy transmission of a structure-cavity system in the mid-high frequency domain. In this paper, the methodology is extended to take into account the effect of dissipative materials applied to each subsystem. This includes a characterization of the damping material as an equivalent property of treated subsystems, which greatly reduces a size of a finite element system to be solved and leads to a more efficient numerical implementation.

2. SmEdA Method For Damped Subsystems

The SmEdA modal coupling loss factor considers both spectral and spatial coupling of discretized subsystem resonances at a coupling surface. Boundary conditions of each uncoupled subsystem are well defined so that their modal information (resonant frequency and modeshape) is easily extracted with the FEM.

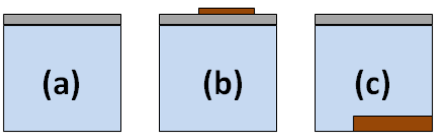

Figure 1. (a) Plate coupled to cavity. (b) Damped plate coupled to cavity. (c) Plate coupled to damped cavity

Subsystem energy levels are deduced for cases depending on different materials applied to each subsystem: (a) a bare plate coupled to a cavity, (b) a plate subsystem partially treated with a viscoelastic layer, (c) a cavity subsystem

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treated with a porous material. All three cases seen in figure 1are first numerically modeled then evaluated through laboratory experiments. The dissipative mechanisms in (b) and (c) are integrated into the subsystem as an equivalent property of the same kind. The part of a plate covered with a viscoelastic layer in (b) can be modeled as an equivalent single layer, and a porous material in (c) can be modeled as an equivalent fluid in an air-filled cavity.

2.1. Equivalent single layer modeling of a partially damped plate

An infinite plate covered with a viscoelastic layer can be modeled as a single homogenous layer that gives the same transverse displacements of a multi-layered panel [2]. As frequency dependent nature of a viscoelastic material is considered, an equivalent plate is also characterized by frequency dependent parameters e.g. Young's modulus and damping loss factor. Once such parameters are determined for an infinite plate, the damping loss factors of a partially damped finite plate can be approximated by Modal Strain Energy method (MSE) [3] while rendering a finite element calculation. The viscoelastic damping pads seen in figure 2 are applied to a plate at random places, and numerically estimated damping loss factors are compared to those experimentally estimated [4].

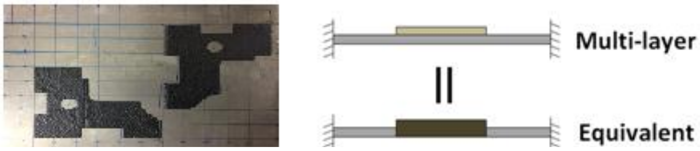

Figure 2. Steel plate damped with damping pads (left). Equivalent modeling (right)

2.2. Equivalent fluid modeling of a partially damped cavity

When a solid frame of a porous material is assumed to be motionless, it can be modeled as a fluid whose parameters are complex and frequency dependent. A fluid phase pressure fluctuation inside a porous material satisfies a standard Helmholtz equation.

$$-K_{eq}\nabla^2 p + \omega^2\left(\frac{\rho_{eq}}{K_{eq}}\right)p = 0 \qquad (1)$$

In equation 1, $k_{eq} = \omega(\rho_{eq}/K_{eq})^{1/2}$ is a wave number of the equivalent fluid where ρ_{eq} is an equivalent density, and K_{eq} is an equivalent compressibility. The complex celerity and the characteristic impedance of an equivalent fluid are respectively $c_{eq} = (K_{eq}/\rho_{eq})^{1/2}$ and $Z_{eq} = (K_{eq}\rho_{eq})^{1/2}$. Z_{eq} and k_{eq} of a porous material can be deduced from the impedance tube (Kundt tube) measurement [5]. Once the surface impedance (Z_s) of a porous material is directly measured, all necessary equivalent parameters (Z_{eq}, k_{eq}, c_{eq} and ρ_{eq}) can be deduced according to the "two-cavity-method [6]." Figure 3 shows the equivalent parameters deduced from impedance tube measurement compared to the empirical equivalent fluid model (Delany & Bazley model) which only needs a flow resistivity of a porous material [7].

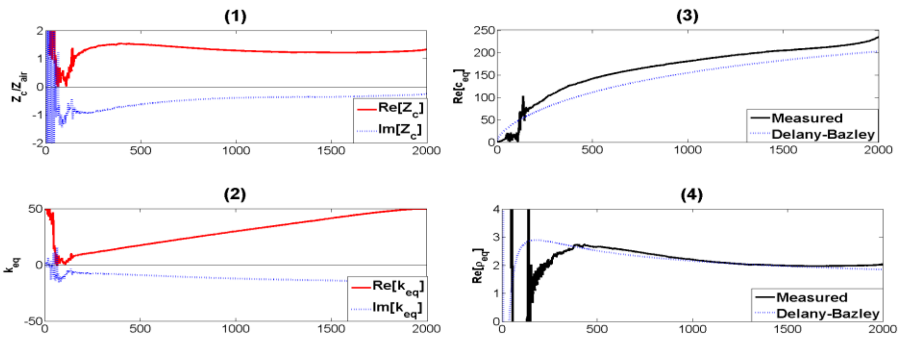

Figure 3. Equivalent fluid parameters of a porous material deduced from "two-cavity-method" of impedance tube measurement. (1) Normalized characteristic impedance, (2) Propagation constant, (3) Equivalent celerity, (4) Equivalent density

3. Energy Ratio of SmEdA Subsystem For Case (a) and (b)

A subsystem energy ratio (E_{cavity}/E_{plate}) is deduced from SmEdA and is compared to experimental results. When a plate subsystem is treated with one or two damping pads ((b) in figure 1), both numerical and experimental results agree on mere change in energy ratio compared to (a) in the mid-high domain (above 800 Hz). This clearly demonstrates that vibratory reduction on the structural subsystem has no significant influence on energy ratio. Numerical and experimental results for case (c) are currently undertaken and will be given in the symposium presentation.

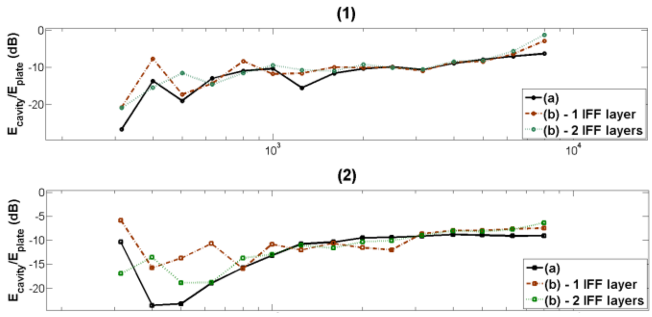

Figure 4. Subsystem energy ratio (E_{cavity}/E_{plate}). (1) Numerical result, (2) Experimental result

4. Conclusion

A plate-cavity coupled problem is investigated in the framework of SmEdA. When each subsystem is treated with dissipative materials (viscoelastic and porous), they can be modeled as an equivalent single layer and equivalent fluid respectively. It is shown that energy transmission loss from a structural subsystem to an acoustic subsystem is not significantly modified if only the structural subsystem is treated.

Acknowledgements

This work was co-funded by the French government (FUI 12 - Fonds Unique Interministériel) and European Union (FEDER - Fonds européen de développement régional). It was carried out in the framework of the LabEx CeLyA ("Centre Lyonnais d'Acoustique", ANR-10-LABX-60) and the research project CLIC (“City Lightweight Innovative Cab”) labelled by LUTB cluster (Lyon Urban Truck and Bus), in partnership with Renault Trucks, Arcelor-Mittal, ACOEM, CITI Technologies, FEMTO-ST (Univ. de Franche-Comté) and LVA (INSA de Lyon).

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