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FINITE ELEMENT FORMULATION OF SMART COMPOSITE STRUCTURE COUPLED TO ACOUSTIC FLUID

W. Larbi, J.-F. Deü and R. Ohayon

Structural Mechanics and Coupled Systems Laboratory,
Conservatoire National des Arts et Métiers,
Case 353, 292 rue Saint-Martin,
75141 Paris Cedex 03, France
e-mail: walid.larbi@cnam.fr

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In the context of noise and vibration reduction techniques by active treatments, this work presents the theoretical formulation and the finite element implementation of the specific problem of piezoelectric adaptive composite structure coupled with acoustic fluid and connected to resonant shunt circuits. The originality of this work lies (i) in the formulation and resolution of the fully coupled electro-mechanical-acoustic system using modal projection techniques, and (ii) in the development of an accurate adaptive laminated plate element.

First, a non-symmetric finite element formulation of the coupled system is derived from a variational principle involving structural displacement, electrical voltage of piezoelectric elements, and acoustic pressure in the acoustic fluid. This formulation, with only one couple of electric variables per piezoelectric layer, is well adapted to practical applications since realistic electrical boundary conditions, such that equipotentiality on the electrodes and prescribed global electric charges, naturally appear. The global charge/voltage variables are intrinsically adapted to include any external electrical circuit into the electromechanical problem and to simulate the effect of resistive or resonant shunt techniques.

The second part of this work is devoted to the introduction of a reduced-order model of the coupled problem. The proposed methodology, based on a normal mode expansion, requires the computation of the eigenmodes of (i) the structure with short-circuited piezoelectric patches, and (ii) the rigid acoustic cavity. It is shown that the projection of the full-order coupled finite element model on the uncoupled bases, leads to a reduced order model in which the main parameters are the classical fluid-structure and electromechanical modal coupling factors. Despite its reduced size, this model is proved to be very efficient for simulations of steady-state and transient analyses of coupled structural-acoustic systems with shunt damping.

In the third part, all the above developments are applied to the simulation of vibration and noise reduction by means of a resonant shunt of a composite plate coupled to a 3D acoustic cavity. We expose in this part the details of a finite element discretization of the laminated composite plate with piezoelectric patches. The considered finite element model is based on

an equivalent single layer theory combined with a first order-order shear deformation theory. A nonconforming FE approach is carried out using Lagrange and Hermite interpolations for the mechanical mid-plane displacements and cross-section rotations. For the portion of the plate covered by the piezoelectric patch, only one electrical degree of freedom is used to represent the electrical charge in each patch.

Finally, numerical examples are investigated. They are first analyzed in order (i) to validate and demonstrate the effectiveness of the proposed finite element formulation, (ii) to show that the reduced order model is capable of capturing the main characteristics of the system dynamic behavior, in particular in terms of attenuation. Then, sensitivity analyses concerning the piezoelectric patches (size and position) and the electric circuits (resistance and inductance) are performed in order to highlight the role of each parameter on the performances of the shunt damping techniques.

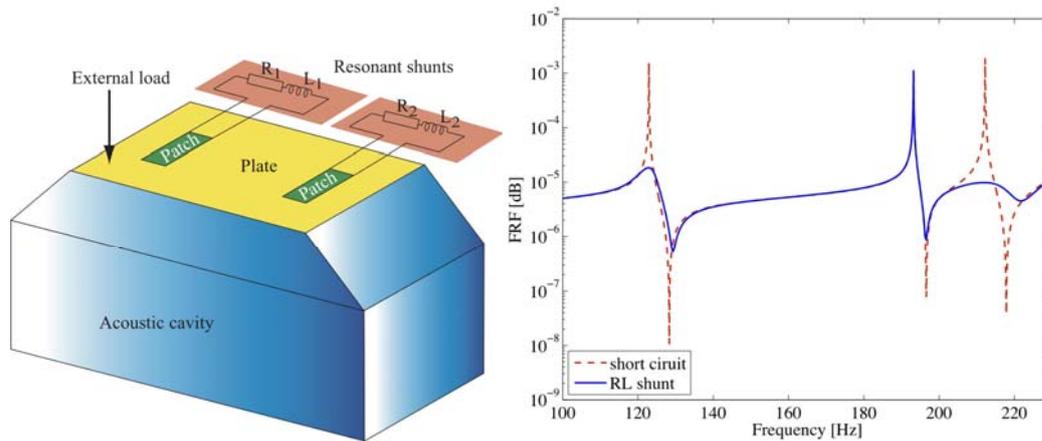


Figure 1: Vibrating composite plate coupled with an acoustic cavity and connected to RL shunt circuit: (a) problem sketch and (b) frequency response function with and without shunt

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