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Hybrid Active-Passive Laminated Structures: Modeling, Optimization and Identification

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In this Lecture, recent developments on modeling, optimization and parameter estimation in sandwich structures with hybrid damping are discussed. A finite element model (Figure 1) has been formulated using a mixed layerwise approach, by considering a higher order shear deformation theory to represent the displacement field of the viscoelastic core (v) and a first order shear deformation theory for the displacement fields of adjacent elastic laminated face layers (e_1) and (e_2), as well as for the sensor/actuator piezoelectric laminae or patches (s) and (a). The layerwise model is based on an eight nodded plate/shell finite element, with 17 mechanical degrees of freedom per node, after imposing inter-layer displacement continuity, and 2 electric degrees of freedom per element. The complex modulus approach is used for the viscoelastic material behavior, and the dynamic problem is solved in the frequency domain, using viscoelastic frequency dependent material data for the core. Active control is applied using proportional displacement and negative velocity feedback control laws, through the exteriorly bonded sensor (s) and actuator (a) layers.

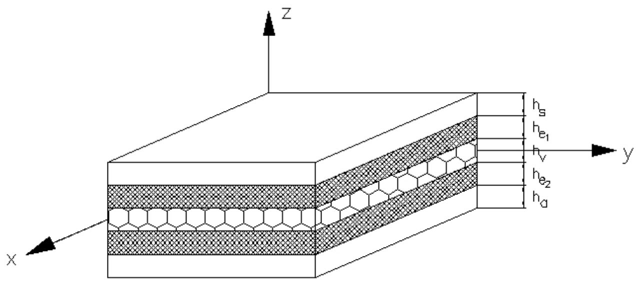

Figure 1: Sandwich plate model

Optimization of passive, active and hybrid damping treatments is conducted, using as design variables the viscoelastic core thickness, the constraining elastic face laminae thicknesses, orientation fiber angles, as well as piezoelectric actuators/sensors locations [1]. The optimization problems are solved using gradient optimization and/or non-gradient algorithms as appropriate. Comparative frequency response functions are presented in Figure 2, regarding a rectangular simply supported sandwich plate with viscoelastic core, carbon fibre laminated elastic face layers, and four pairs of co-located piezoelectric sensors and actuators. The optimization effect on modal damping is clearly depicted from the figure.

Parameter estimation of viscoelastic core material properties is also presented and discussed. The inverse problem is formulated as a constrained optimization problem, by fitting the response of the finite element numerical model to the corresponding experimental response of the viscoelastic sandwich structure, considering specific parametric models for frequency dependent damping material behavior [2].

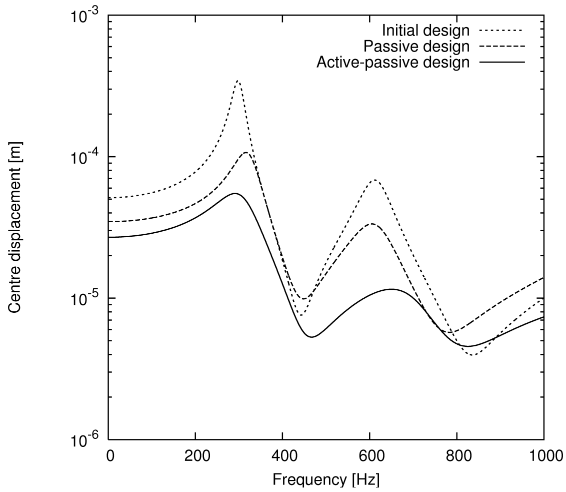

Figure 2: Effect of optimal designs in frequency response of a hybrid active-passive sandwich plate

Constraints are imposed on the design variables, arising from thermodynamic restrictions on isothermal linear viscoelasticity, and gradient based optimization techniques are used to solve the optimization problem [3]. Figure 3 illustrates the outline of the inverse procedure.

Both optimisation and parameter estimation applications will be presented and discussed.

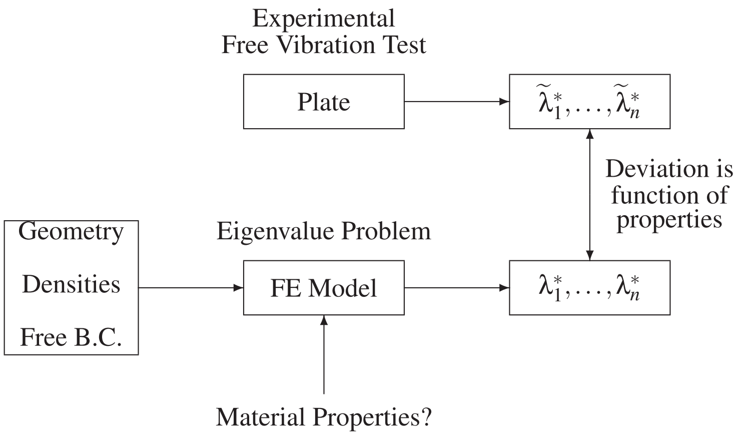

Figure 3: Schematic outline of the inverse problem

References

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