Vibration Suppression of Plates by Optimally Placed and Calibrated Piezoelectric RL Shunt Damping

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ABSTRACT

The present paper concerns vibration suppression of plate structures, characterized by having relatively large stiffness-to-mass ratios and thus dominating natural frequencies, associated with for example acoustics and noise, that are larger than typical for large-scale structures. This makes the use of mechanical damping devices, such as dashpots, springs and auxiliary vibration masses, infeasible for vibration suppression. Instead electromechanical device, with the ability of transforming mechanical energy to electrical energy (and vice versa), have emerged as a favorable alternative. Piezoelectric transducers, patches or laminates can be attached locally on a structure, where they, due to their fairly large force-to-deflection ratios, efficiently dissipate energy at small deformation rates. Regarding plate structures, the relative displacements of a locally attached piezoelectric patch become two-dimensional, making them particularly suitable as supplemental dampers due to their orthogonal material properties [1]. The piezoelectric patch can be designed both as an active actuator, where the patch is controlled by an externally applied voltage, or as a passive device with mechanical to electrical energy conversion governed by the electromechanical coupling effect and a supplemental electrical shunt. The active control is often limited by the requirement of power supply and control instabilities, motivating the use of passive shunt damping.

Resonant piezoelectric damping is introduced by an inductive-resistive (RL) shunt, for which the performance relies on the precise calibration of the shunt frequency. Thus, an important aspect of passive shunt damping of flexible structures like plates is the ability to account for the energy spill-over from the non-resonant modes, which is not taken into account by common calibration procedures. The importance of the non-resonant modes for the optimal calibration increases for patches located indirectly with respect to the deformation pattern of the targeted mode.

The objective of the paper is the suppression of plate vibration by means of piezoelectric RL shunt damping, optimally tuned by the calibration procedure described in [2] for beams, where the spill-over from non-resonant vibration modes is included by a quasi-dynamic modal correction, taking both flexibility and inertia effects from the residual modes into account. The procedure is extended to include the 2D behaviour of a shunted piezoelectric patch, represented in a finite element model with Kirchhoff plate kinematics. The optimum positioning of a piezoelectric patch is determined for particular vibration modes by maximizing the electromechanical coupling coefficient that is also modified by the residual mode correction. Furthermore, the ability to reproduce the desired level of attainable damping is demonstrated for indirect placement of one or more patches. The accuracy of the quasi-dynamic calibration procedure is investigated for a plate structure, in particular with respect to closely spaced modes.

REFERENCES
