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A FEM piezoelectric beam model for damping circuit analysis

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In this work a finite element, developed for straight generally layered smart beam, is used to investigate vibration damping capability of circuit elements. First, the electric state is analytically condensed to kinematical quantities and the mechanical model is then written for shear deformable Timoshenko's beam including the effects of electro-elastic couplings stacking sequence. The contributions of the external electric loads on both the equivalent stiffness properties and the equivalent mechanical boundary conditions are also taken into account. Hermite shape functions, which depend on parameters representative of the staking sequence through the equivalent electro-elastic stiffness coefficients, are then obtained for the beam primary variables. Starting from the weak form of the governing equations and by expressing the kinematical quantities in terms of virtual and actual nodal variables through the obtained shape functions, the definitions of the element mass and stiffness matrices as well as of the equivalent force vector are obtained. It is found that the electro-magnetic boundary conditions are transferred to the FEM representation as work-equivalent axial and bending nodal actions. The State Space representation is then invoked for the assembled smart beam FEM model to favour its implementation using a system conceptual approach. The piezoelectric layers are considered as the electrical current source of the damping circuit which, in turn, controls the amount of difference of electric potential applied on the piezoelectric layers by means of its impedance. Eventually, a cantilever smart piezoelectric-cross ply graphite epoxy laminated beam undergoing a step load at its free end is analyzed. The piezoelectric layers are connected to a resistor R to obtain broadband damping characteristic. Results are reported in figure 1 in terms of beam tip deflection, normalized with respect to the static one, and actuating voltage generated by the smart beam-circuit system.

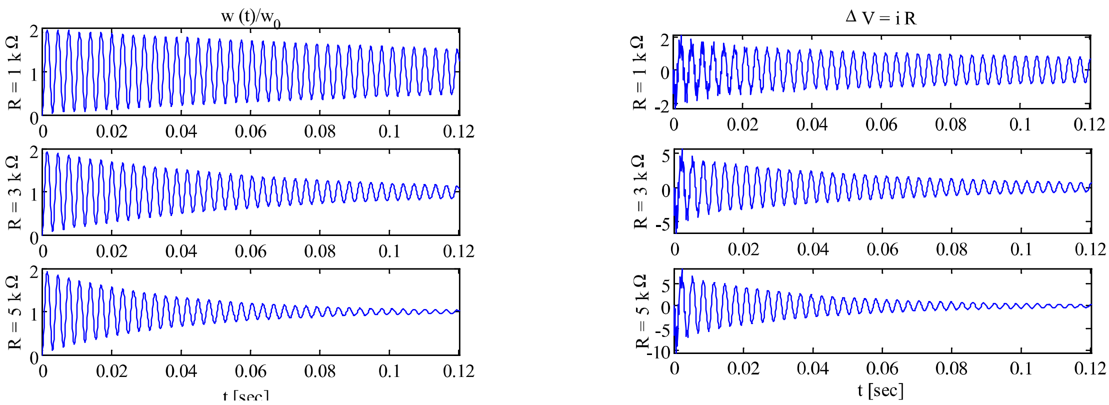

Figure 1. Transient response of [$BaTiO_3$/0/90_2/0/$BaTiO_3$] beam. (left) normalized beam tip deflection; (right) actuating voltage.