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NONLINEAR DYNAMIC DEFORMATION OF A PIEZOELASTIC LAMINATED BEAM WITH FEEDBACK DAMPING MECHANISM

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Piezoelectric materials have been used extensively as sensors and actuators to control structural configuration and to suppress undesired vibration in engineering due to their superior coupling effect between elastic and electric fields. Fiber reinforced plastics (FRPs) such as graphite/epoxy are in demand for lightweight structures because they are lighter than general metals and have high specific strength. The structures composed of laminated FRP and piezoelectric materials are often called piezoelastic laminates and have attracted considerable attention in fields such as aerospace engineering and micro electro mechanical systems. For aerospace applications, structures have to be comparatively large and lightweight. Because of this, they are vulnerable to mechanical disturbances. As a result, the deformations due to the disturbances can be relatively large. Therefore, the large deformations of piezothermoelastic laminates were analyzed by several researchers [1-10].

In this presentation, we treat the control of the vibration with large amplitudes in a piezoelastic laminated beam with a closed-loop control system. The analytical model is a symmetric cross-ply laminated beam composed of fiber-reinforced laminae and two piezoelectric layers. The beam is simply-supported at both edges, and it is subjected mechanical disturbances. The undesired vibration of the laminate is transformed into the electric current by the direct piezoelectric effect in one of piezoelectric layers, which serves as a sensor. Then, in order to suppress the vibration, the electric voltage with magnitude of the current multiplied by a gain is applied to the other piezoelectric layer which is at the opposite side of the sensor and serves as an actuator. Nonlinear large deformation of the beam is analyzed based on the von Kármán strain and classical laminate theory. Equations of motion for the beam are derived using the Galerkin method. As a result, the dynamic deflection of the beam is found to be governed by a Liénard equation, which features the symmetric cubic restoring force and unsymmetric quadratic damping force due to the geometrical nonlinearity. The equation is studied geometrically in order to reveal the essential characteristics of the beam and to investigate how to stabilize the dynamic deformation.

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