Abstract

This dissertation deals with the active control of flexural vibration of annular plates through the design of two new piezoelectric fiber composite (PFC) actuators in the cylindrical coordinates. The first one is an extension mode PFC actuator, and the next one is a shear mode PFC actuator. The extension mode PFC is basically a cylindrically orthotropic short piezoelectric fiber composite (SPFC) in the shape of a thin annular disc. This annular SPFC disc is comprised of unidirectional short piezoelectric fibers embedded in the epoxy matrix. The longitudinally poled short piezoelectric fibers are oriented in the radial direction so that the extension mode piezoelectric actuation appears along the radial direction in response to an externally applied coaxial electric field. The effective electro-elastic properties of this SPFC actuator are estimated by developing a finite element (FE) procedure, and the changes in the properties due to the use of unidirectional short/discontinuous fibers (SPFC) instead of the continuous fibers (CPFC) are demonstrated. A fruitful arrangement of surface-electrodes over the top and bottom surfaces of the annular SPFC/CPFC disc is proposed, and its (SPFC/CPFC) actuation capability is investigated in active control of harmonically excited flexural vibration of an annular substrate plate. The patches of the SPFC/CPFC actuator are attached to the top surface of the substrate plate, and the controlled frequency responses of the smart annular plate are evaluated by developing a closed-loop FE model. These controlled responses of the smart plate reveal indicative control capability of the SPFC actuator, and it (control capability) is compared with that of the CPFC actuator. This comparison is further extended by taking the poling direction of the fibers in the annular CPFC disc either as longitudinal or as thickness direction. For each of these poling directions, the fibers are oriented either in radial or in the circumferential direction so that four kinds of cylindrically orthotropic CPFCs appear. For each of these CPFCs, the arrangement of surface-electrodes is presented, and the optimal size and locations of the actuator-patches over the top surface of the simply-supported/fully clamped annular substrate plate are addressed through the proposition of a new numerical methodology in conjunction with the FE procedure. On the basis of this optimal configuration of actuator-patches for each of the CPFC actuators, their (four CPFCs) capabilities in inducing the active damping in the smart annular plate are quantified, and the best one among the four kinds of CPFC actuators is recommended.

The new shear mode PFC is made in the form of a thin laminated annular disc that is mainly comprised of two or more 2-2 PFC layers. The 2-2 PFC layer is composed of conventional piezoelectric fibers which are oriented in the radial direction and evenly spaced in the circumferential coordinate. The external electric field acts along the transverse direction of the longitudinally poled piezoelectric fibers, and the electrically induced shear force within the annular actuator appears in the transverse plane of radial and axial coordinates. The cylindrically periodic microstructure within this shear mode annular PFC actuator yields its radially varying electro-elastic properties. These varying properties are estimated by dividing the volume of the corresponding representative volume (RV) into a large number of asymptotically homogeneous micro-volumes of different fiber volume fractions. The effective coefficients of these micro-volumes are estimated by deriving the corresponding closed-form expressions and also by developing an FE procedure. An analysis of these varying properties of RV is performed, and two different geometric configurations of the shear mode annular PFC actuator are addressed for having its improved actuation capability. The actuation capability of this shear mode PFC actuator with any of its two different geometric configurations is investigated by means of using its patches at the core of a sandwich annular plate. A fruitful strategy for the arrangement of the actuator-patches at the core is proposed to have the equal attenuation of all the bending modes of vibration of the smart annular sandwich plate. Concurrently, a useful scheme is also presented for efficient utilization of all the patches of the shear mode PFC actuator according to the velocity feedback control law. Based on these strategies in configuring the smart annular sandwich plate, the frequency responses of the overall plate are evaluated by deriving an FE model, and these results reveal indicative control capability of the shear mode annular PFC actuator. This study is further extended by adding the viscoelastic layers at the core of the smart annular sandwich plate for investigating the performance of the shear mode annular PFC actuator in the active constrained layer damping (ACLD) treatment. This study also reveals indicative performance of the shear mode PFC actuator in the ACLD treatment provided that the viscoelastic layer is to be used with an appropriate thickness.