Abstract

Over the past three decades, engineers have developed piezoelectric composite materials that enable them to tailor the effective electromechanical properties for a specific application. These materials are manufactured by combining piezoelectric ceramics with piezoelectrically active/passive polymers in a variety of geometrical configurations. As it happens with any composite material, the properties and behaviour of piezocomposites are highly dependent on the properties of the constituent materials and the local arrangement of the different phases. In particular, the physics of the interface plays an important role in determining the electromechanical coupling in the piezocomposite. In the present thesis, the electromechanical behaviour of the piezocomposite is investigated from both theoretical and numerical stand points followed by the validation of the performance parameters of such piezocomposites with the experimental results.

Theoretical investigations are centered on the development of a micromechanics model for predicting the local fields and effective behaviour in the piezo-composites. Extending the results of the constraint tensors, namely Eshelby tensors obtained earlier for the elastic isotropic inclusion cases; a set of four constraint tensors analogous to the Eshelby tensors are developed for mapping the electromechanical coupled field responses in a piezoelectric composite. The interaction among inclusions or inhomogeneities (in the case of piezocomposites) are approximated through the Mori-Tanaka mean field approach. The final relation to determine effective coefficients of the bulk piezocomposite is then derived with the equivalent inclusion method.

The derived micromechanics model based on electro-elastic Eshelby tensors are used to study various aspects of piezoelectric composites. The derived exact results for

electro-elastic Green's function are plotted to understand how the coupled responses are distributed in the space. The results suggest that the distribution of all the Green's functions are symmetric around the origin in the three-dimensional space, while the order of their magnitude varies significantly. In particular, the electric potential induced as a response to a unit electric charge and a unit force differ by 12 orders of magnitude, while the difference between electric potentials differs by only 2 orders of magnitude.

The formula to predict the effective coefficients of the piezoelectric composites developed earlier are utilized to study the behaviour of these coefficients as a function of aspect ratio and volume fraction of the fiber. From the material system studied, it is observed that the longitudinal elastic coefficients and the piezoelectric constants decrease with increasing fiber aspect ratio; in-plane shear modulus remains independent of the fiber aspect ratio; and the dielectric coefficients uniformly increase with the fiber aspect ratio. It is also noticed that, the predicted value of all the coefficients attains a saturation value at fiber aspect ratio of 10 and beyond this ratio the geometry of the inclusion doesn't have significant effects on these coefficients.

For the case of long fiber composites (1-3), a refined model is presented, namely modified strength of materials (MSM), to study the effects of fiber packing geometry and Poisson's ratio mismatch on the effective coefficients of such composites. With the derived parameters of the MSM model another model is developed based on the conservation of strain energy. The predicted results with these proposed models are then compared with the existing strength of material (SM) model. A finite element analysis (FEA) is also carried to validate the results for the six discrete fiber volume fractions (0.1-0.6). Later, the proposed MSM model is utilized to predict performance parameters (or figures of merit) of the piezoelectric composites.