11th International Conference on Advanced Materials

Rio de Janeiro Brazil
September 20 - 25

ICAM2009

Multi-coating inhomogeneities micromechanical model for the effective thermo-electro-mechanical properties of piezoelectric composite materials

Fabio Biscani(1,2)*, Yao Koutsawa(1)

(1) Centre de Recherche Public Henri Tudor, 29, Avenue John F. Kennedy, L-1855 Luxembourg, Luxembourg, fabio.biscani@tudor.lu, (352) 54 55 80 530
(2) Department of Aerospace Engineering, Politecnico di Torino, Torino, Italy
* Corresponding author.

Abstract – A micromechanical model for the prediction of the effective thermo-electro-elastic properties of piezo-electric composite materials with ellipsoidal multi-coated inclusion is presented. Such functional piezoelectric composite materials have been rapidly developing with increasing applications in ultrasonic imaging devices, sensors and transducers. A finite element analysis based homogenization is also performed for twophase composite materials using ABAQUS finite element software. The results obtained from the multicoated homogenization method show good agreement with the existing experimental results and the finite element results. The effects of the shape of the inclusion, of the poling direction and of the presence of a coating phase are investigated.

This work presents micromechanics-based methods to investigate the effective thermo-electro-mechanical properties of piezoelectric composite materials. The modelling is based on the integral equations and the interfacial operators [1]. The effective thermo-electro-mechanical properties are derived by considering a multi-coated inhomogeneity embedded in a host material in the framework of the generalized self-consistent method (GSCM). Two kinds of piezoelectric composites are considered: (polymer/piezo-ceramics) and (piezo-ceramic/void). In order to improve the results of the GSCM when there is a big contrast between the matrix and the inhomogeneities properties as it is in the case of piezo-ceramics matrix and void inhomogeneity, an incremental scheme of the GSCM is introduced. The two GSCMs differ on the manner of introducing the reinforcements' volume fractions in the host material. In the non-incremental GSCM, the reinforcements' volume fractions are entirely added to the host material of the composite while in the incremental GSCM case, the reinforcements are incrementally put in the host material.

The validation of the micromechanical model is performed with experimental data [2] and with numerical results obtained with a finite element homogenization method for ellipsoidal inhomogeneities based on [3]. Many numerical simulations are performed to get insight to the influence of various parameters such as geometric properties, constituents' material properties and volume fractions, the thickness of the coating, the orientation angle with respect to the polling direction on the effective thermo-electro-mechanical properties of piezoelectric composite materials.

The model proposed has a wide range of applications thanks to its multi-coating capability and thanks to the wide set of properties considered. Moreover it can be easily extended in order to take into account other properties.

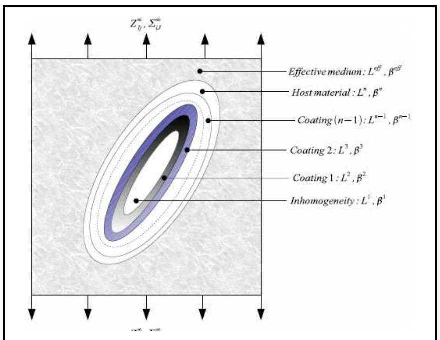

Figure 1: Topology of the multi-coated inhomogeneity problem.

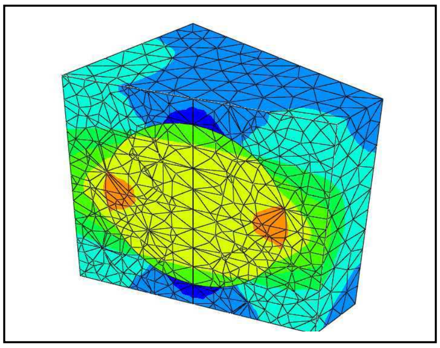

Figure 2: Finite element model of the representative volume element.

References

[1] P. Lipinski, E. Barhdadi, M. Cherkaoui, Micromechanical modeling of an arbitrary ellipsoidal multi-coated inclusion, Philosophical Magazine 86 (10) (2006) 1305-1326.

[2] H.W. Chan, J. Unsworth, Simple model for piezoelectric ceramic/polymer 1-3 composites used in ultrasonic transducer applications, IEEE Trans Ultrason Ferroelectr Freq Control 36 (4) (1989) 434-441.

[3] H. Berger, S. Kari, U. Gabbert, R. Rodríguez-Ramos, J. Bravo-Castillero, R. Guinovart-Díaz, A comprehensive numerical homogenisation technique for calculating effective coefficients of uniaxial piezoelectric fibre composites, Materials Science and Engineering: A 412 (1-2) (2005) 53 - 60.