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Effects of interface contacts on the magneto electro-elastic coupling for fiber reinforced composites

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ABSTRACT

Imperfect bonding between constituents is studied where displacements, electric and magnetic static potentials are considered to have a jump proportional to the normal component of the mechanical traction, electric displacement and magnetic flux. This condition may model various interface damages or the thin glue layer between two adjacent phases. They are termed as the mechanically compliant, dielectrically weakly capacitance and magnetically weakly inductance at the interface. It is shown that while the more imperfect the interface is, the overall properties become weaker, such as longitudinal shear stiffness, out-of-plane piezoelectric coupling, and magnetoelectric coupling. Out-of-plane piezomagnetic coupling, transverse dielectric permittivity and transverse dielectric permeability exhibit no influence by imperfect bonding. The imperfect interface proposed is mimicked by the springs, capacitors and inductances for the mechanical, electric and magnetic interaction between the phases and are highly sensitive to the interphase properties. The results are compared mainly with the self consistent model reported in the literature and good agreements are shown.

1. Introduction

In the last few years, the interest in magnetoelectric effect (ME) (Landau and Lifshitz, 1960) has increased both theoretically and experimentally in an amazing manner (Grossinger et al., 2008; Petrov et al., 2007a,b; Bichurin et al., 2003a,b). A variety of systems exhibit the ME effect, including single phase (de la Vega Reyes et al., 2007; Fuentes et al., 2006). The highest magnetoelectric coefficients are reported for biphasic composites that based their coupling in the mechanical interaction at contact between a piezoelectric and a magnetostrictive phase (Bichurin et al., 2003a; Lin et al., 2005; Petrov and Srinivasan, 2008). That is why many authors have focused their attention on a piezoelectric-piezomagnetic composite (Nie et al., 2009; Srinivas et al., 2009; Singh et al., 2008). Composite materials based on a variety of phase connections can also be found in the literature including layered structures (Cao et al., 2008; Zhang and Wei, 2008), thin films (Delgado et al., 2009; Guyomar et al., 2009) and nanostructures (Hua et al., 2008; Glinchuk et al., 2008).

In previous works (Camacho-Montes et al., 2006, 2009; Bravo-Castillero et al., 2009) determined analytical expressions for the effective properties of magneto-electro-elastic (MEE) fibrous composite where perfect interface conditions were assumed. Perfect bonding invokes that the displacement and the interfacial traction are continuous across the boundary between the constituents. However, experiments show that local or partial debonding at interfaces is a rule rather than the exception in materials such as reinforced metal matrix composites (Llorca and Gonzales, 1997). This leads to strength degradation and the reduction of the effective stiffness.

Furthermore, heterogeneous smart materials might exhibit new properties not existing in any of the constituents due to the coupling of different fields. For example, the most interesting behavior of fibers composites consisting of piezoelectric and piezomagnetic constituents is that the magneto-electric effect, which is only present in composites but absent in constituent phases, is created by the interaction between the constituent phases, a result of the so-called product property (Nan, 1994). The mechanical constitutive response of the active materials can be coupled with the non-mechanical effects as in Camacho-Montes et al. (2009).

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