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Theoretical and experimental investigation of magnetoelectric (ME) effects in tri-layered composites

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ABSTRACT

In recent years, there is a growing interest to understand new functional composites known as magnetoelectric composites. Due to the coupling between magnetic and electrical energy, ME composites finds application in various aspects such as energy harvesters, gyrators, sensors and actuators. ME coupling behaviour can be characterized by obtaining either the ME voltage coefficient (dV/dH) or the ME field coefficient (dE/dH). For a given magnetic field (H), V and E represent the induced voltage and electric field respectively. This coupling behaviour is considered to be a product property of the ME composite. Layered composites with enhanced ME effect have become promising materials from application perspective. In the literature, most of the research work is focused on enhancing the ME effect. Also, several theoretical models have been reported to model the ME effect by considering linear constitutive equations for both the ferroelectric and ferromagnetic materials [1-2]. Meanwhile, experimental observation shows that an enhanced ME effect can be obtained by operating the ME composite at sufficiently large static magnetic fields [3]. A few theoretical models have been reported to capture this nonlinear ME effect by considering non-linear constitutive relations for the ferromagnetic material [4-5]. However, very less attention has been paid to development of theoretical formulation of nonlinear and hysteretic behaviour of ME composites. Hence the present work is motivated with the objective of developing a formulation which can account for both nonlinear and hysteretic effects in ME composites. The present work involves in development of a three dimensional nonlinear constitutive model for a ferromagnetic material by employing the principles of plasticity and thermodynamics. First, an experimental investigation is carried out to capture the nonlinear magneto-mechanical behaviour of ferromagnetic material. Ferromagnetic material strain response between experimental data and proposed constitutive model and the results are in agreement with each other. Also, experimental response of the ME composite is compared with proposed formulation and the results are in agreement with each other. Hence this work involves in proposing a computationally efficient formulation by developing a three dimensional nonlinear and hysteretic constitutive model for the ferromagnetic material.

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