Coupled magnetoelastic and electroelastic effects in rod

Abstract

Over the past several years, there has been a significant increase in the popularity of smart materials. Magneto and electro-elastic polymers are some of the most widely used polymers these days in biomedical engineering (e.g., tissue engineering drug delivery systems), soft matter engineering (e.g., soft robotics), design of smart structures and systems with dynamic properties etc. To further improve the utility of these materials in device design, it is essential to develop mathematical models that can describe their coupled nonlinear characteristics. Many of the works to model slender magneto and electro-elastic structures focus on using classical beam theories such as the Euler-Bernoulli and Timoshenko beam theories. However, these theories are geometrically linear, which can model only small rotation of the beam's cross-section. On the other hand, the theory of rods is nonlinear and geometrically exact allowing large rotation of the cross-section. In turn, this also requires nonlinear constitutive relations when the induced curvature and twist are large enough. In this viva-voce, I present nonlinear magneto/electro-elastic theories for rods and tubes. The first part of the presentation focuses on developing an axisymmetric and axially homogenous variational formulation to model coupled extension-torsion-inflation deformation in compressible magnetoelastic thin tubes with helical magnetic anisotropy in the presence of azimuthal and axial magnetic fields. Here several analytical expressions are shown in terms of the applied magnetic field, preferred magnetization direction and magnetoelastic constants which tell us how these parameters can be tuned to generate unusual coupled deformations such as the negative Poisson's effect. In the second part, a theory for finite and spatial elastic deformation of rods embedded with paramagnetic inclusions and under the influence of arbitrary magnetic fields and boundary conditions is presented. Finally, a one-dimensional electroelastic rod theory also incorporating the free space energy is presented. Here the effect of free space energy on the deformation field inside the electroelastic body is numerically shown to be significant thus highlighting the importance of including the free space energy which is largely neglected in the literature.

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