Magnetostriction of soft-magnetorheological elastomers

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Abstract

Soft-magnetorheological elastomers (s-MREs) are particulate composites made of a non-magnetic elastomeric matrix dispersed with micron-sized particles of a "soft-magnetic" material. The phenomenon of magnetostriction in specimens made from s-MREs is the change in their shape when they are subjected to an external magnetic field. Experiments in the literature show that for circular cylindrical specimens subjected to an axially applied magnetic field the magnetostriction is strongly dependent on their aspect ratio, with specimens with a low ratio of the length to the diameter exhibiting a larger tensile magnetostrictive strain than specimens with a large aspect ratio — the "shape-effect." This response is also hysteretic because of the underlying viscoelasticity of the matrix material. In this talk we report on a large deformation magneto-viscoelasticity theory for s-MREs and its finite element implementation. Using our theory we show that we can model this non-intuitive geometry-dependent magnetostrictive response of cylindrical s-MRE specimens. We show that the effect of the magnetization of the cylinder is to decrease the magnetic field within the cylinder relative to the applied magnetic field outside the cylinder, the well-known demagnetization effect, and that this demagnetization is diminished in more slender cylinders due to magnetic fringing at the boundaries of the cylinder. This is the physical reason behind the macroscopically-observed "shape-effect." Our magneto-viscoelasticity theory is quite broad, and it has many potential applications beyond modeling the magnetostriction of cylindrical specimens. As an example we apply the theory to study the bending actuation response of beams of s-MREs when they are subjected to magnetic fields at different incidence angles to their longitudinal axis.

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