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Modeling and analysis of a magnetoelastic annular membrane placed in an azimuthal magnetic field

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Abstract

This work presents the development of a 2D nonlinear magnetoelastic framework for a thin membrane undergoing large deformations. An asymptotic $O(h)$ theory is obtained, starting from the 3D variational magnetostatic and force balance equations for a weakly magnetizable material. The model is subsequently specialized to axisymmetry and applied to a pre-stretched annular membrane deforming under azimuthal magnetic field and transverse pressure loading. Parametric studies are performed by varying the pre-stretch, magnetic field, and transverse pressure inputs.

Keywords

Magnetoelasticity, annular membrane, magnetorheological elastomer, membrane actuators

1. Introduction

Magnetorheological elastomers (MREs) are a class of smart materials that exhibit nonlinear magnetoelastic coupling and undergo large deformation. They also exhibit change in stiffness in the presence of an external magnetic field. These properties make MREs suitable for a wide range of engineering applications such as vibration isolation [1, 2], artificial muscle actuators [3], soft robotics [4, 5], and design of pressure valves. MREs are soft materials prepared by mixing micro-sized ferromagnetic particles in a non-magnetic polymeric matrix and curing the mixture. Fabrication and characterization of both isotropic and anisotropic MREs were studied in several early works. Isotropic MREs were fabricated using carbonyl iron particles dispersed randomly in the polymeric matrix [6–8]. To obtain anisotropic properties in MREs, the magnetic particles were arranged in a columnar structure [9–11]. These works investigated the dependence of magnetic and structural properties on the applied magnetic field as well as the composition and microstructural arrangement of the MRE [12].

Modeling of MREs requires coupling of continuum mechanics with electrodynamics wherein the magnetomechanical interactions are modeled as electromagnetic body force and body couple. Some of the pioneering

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