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ON 3D FEM FINITE STRAIN FORMULATIONS FOR MAGNETORHEOLOGICAL ELASTOMERS

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Magnetorheological elastomers (MREs) are smart materials composed of an elastomeric matrix filled with magnetic particles. The (visco)elastic response of the matrix combined with the magnetic properties of the particles allow these flexible composites to deform in response to a relatively low externally applied magnetic field in a reversible manner. The rapid response, the large deformations and the possibility to control the material response in general by adjusting the magnetic field make them of special interest in modern engineering. Yet, the characterization of the magneto-mechanical properties at finite strains and high magnetic fields is still far from being optimal. As stated in [3, 2], this task is complicated by the high nonlinearity of the constitutive equations and also a *shape-dependency* that is due to the fact that each MRE sample interacts with the surrounding magnetic field and thus experiences *shape-dependent boundary conditions*. In order to predict this *shape effect* and properly characterize these materials, the use of numerical tools is a necessity.

In this work, we develop a set of finite element codes using all three available and equivalent magnetomechanical formulations. The formulation with independant variables $\mathbf{F}$,$\mathbf{H}$ is the most widely used since it only requires 4 degrees of freedom given the fact that $\mathbf{H}$ can be expressed as the gradient of a scalar potential ϕ (i.e. $\mathbf{H} = -\nabla \cdot \phi$). This formulation can have its own limitations since it relies on a min max formulation. For that purpose, the formulations with independent variables $\mathbf{F}$,$\mathbf{B}$ (and/or $\mathbf{m}$) are also explored since they rely on a min min formulation, but require 6 degrees of freedom since $\mathbf{B}$ is defined as the curl of a vector potential $\mathbf{A}$. Each code is assessed by a simple boundary value problem (ellipsoidal specimen with the magnetic field applied far from it) and is subsequently used to probe the shape effect in our experiments.

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