Stability of magnetorheological elastomers with periodically distributed magnetizable particles

A. Goshkoderia[1], S. Rudykh[1]

[1] *Technion, Haifa, Israel, rudykh@mit.edu*

We study the magneto-mechanical behavior of magnetorheological elastomers (MRE) undergoing large deformations when excited by external magnetic fields. These magnetoactive materials can change their mechanical properties and can develop large deformations when subjected to a magnetic field. We focus on the role of the microstructures in the overall performance and stability of the deformable magneto-active composites. We examine the coupled behavior of the active composites with (i) periodically and (ii) randomly distributed magnetizable particles embedded in soft matrix [3], and (iii) periodic laminate composites and anisotropic structured composites with chain like structures [2]. We identify the key parameters governing the magneto-mechanical couplings. We find that even very similar microstructures, such as periodic composites with hexagonal and rectangular representative volume elements (RVE), exhibit very different behavior both in terms of actuation, and effective properties [3].
Next, we investigate the coupled magneto-elastic instabilities in MREs [1] that may develop at different length-scales. Potentially, these instability induced patterns can be exploited to achieve new functionalities such as tunable band-gaps [4]. Here, we focus on the so called macroscopic or long-wave magneto-mechanical instabilities to obtain estimates of the onset of magnetomechanical instabilities. We explore the role of external magnetic fields, microstructure parameters, and consentient properties on the onset of magneto-mechanical instabilities. To this end, we develop a finite element based code, which allows us to obtain the primary solution for various RVEs subjected to finite deformation and magnetic field ; moreover, the critical condition for the onset of macroscopic instability. By making use of the numerical tool, we identify the unstable domains for MRE composites with periodically distributed circular and elliptical inclusions embedded in a soft matrix. We use the isotropic Langevin model for magnetic behavior, to account for the initial (linear) susceptibility and saturation magnetization of the magnetoactive inclusions. We analyze the influence of the applied magnetic field and finite strains, as well as particle shape and material properties, on the stability of the MRE composites. We find that the stable and unstable domains can be significantly tuned by the applied magnetic field, depending on deformation, microstructure and magnetic properties of the inclusions such as initial susceptibility and saturation magnetization.

Références

[1] Goshkoderia, A. & Rudykh, S. ; Stability of magnetoactive composites with periodic microstructures undergoing finite strains in the presence of a magnetic field. *Composites Part B* ; **128** ; 19-29 (2017)

[2] Rudykh, S. & Bertoldi K. ; Stability of Anisotropic Magnetorheological Elastomers in Finite Deformations : A Micromechanical Approach. *Journal of the Mechanics and Physics of Solids* ; **61** ; 949-967 (2013)

[3] Galipeau, E., Rudykh, S., deBotton. G. & Ponte-Castaneda, P. ; Magnetoactive elastomers with periodic and random microstructures. *International Journal of Solids and Structures* ; **51** ; 3012-3024 (2014)

[4] Galich, P.I. & Rudykh, S. ; Shear wave propagation and band gaps in finitely deformed dielectric elastomer laminates : long wave estimates and exact solution. *Journal of Applied Mechanics* ; **84** ; 091002 (2017)