# Surrogate Modeling of Micro-Structural Instabilities of Magnetorheological Elastomers

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Magnetorheological elastomers (MREs) are composite materials comprised of elastomer matrix and magnetic inclusions. Due to their magneto-mechanical coupling properties, they have immense potential for application as soft actuators showing large mechanical deformation induced remotely by magnetic fields [1, 7]. The magneto-mechanical properties of MREs can be tuned by the design of their microstructure [2]. At the microscopic level, the magneto-mechanical response of MREs is driven by particle-particle and particle-matrix interactions. In periodic structures, these interactions can further be exploited to induce buckling-type structural instabilities that give rise to an abrupt change in their microscopic morphology [5]. Associated pattern transformations result in altered acoustic, phononic and photonic properties of the MRE.

The detection of the related instability points together with the resulting buckling patterns is an elaborate and time-consuming process. It is thus our goal to create a surrogate model that can predict the associated effects in an accelerated manner and with a reduced footprint concerning direct computational resources. We study the microscopic bifurcation behavior of MRE microstructures with different inclusion types [5] as a starting point.

To assess the coupled behavior of MRE microstructures, we will employ a multiscale approach to large strain magneto-elasticity according to [5], which is further utilized to determine microscopic and macroscopic instabilities. The underlying formulation is based on a four-field Hu-Washizu-type variational formulation proposed in [6], implemented in a finite element setting. The microscopic structural stability analysis is based on a Bloch-Floquet wave analysis [3]. This analysis can determine structural microscopic instabilities that result in representative volume elements (RVEs) composed of several unit cells (see Fig. 1).

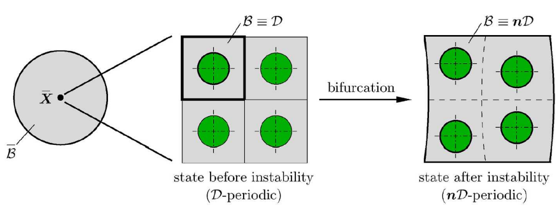


Figure 1: Change of periodicity of a microstructure due to microscopic structural instability [5]

In order to consider various occurring deformation types in a design process, a surrogate model is proposed to obtain a first estimate of the bifurcation of specific microstructures. The surrogate model will be based on a Convolutional Neural Network (CNN), implemented as a forward model using SENet-blocks [4]. Input to the surrogate model is the binarized image of the initial voxelized microstructure and the amplitude of the applied magnetic induction. The output is a voxelized map of deformation in two spatial dimensions. The CNN is trained on a dataset created by using the simulation framework documented in [5]. Emphasis is put on a wide range of different inclusion types and the resulting microstructures by parameterizing the volume fraction as well as the orientation and shape of the inclusions. With this parametrization, the CNN can predict the resulting deformation modes within a parameter-specific periodic RVE for a vast parameter space of inclusion types, volume fractions and magnetic loadings.

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