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HYBRID IGAFEM/IGABEM FOR TWO-DIMENSIONAL MAGNETIC AND MAGNETO-MECHANICAL FIELD PROBLEMS

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Magneto-sensitive elastomers (MSE) feature mechanical moduli that become strongly enhanced by an applied external magnetic field as well as the ability to generate magnetically induced deformations and mechanical actuation stresses. Typically, MSE represent a two-component system, in which micron-sized magnetizable particles are embedded in a cross-linked polymer network. The spatial distribution of magnetic particles in MSE can be either isotropic or anisotropic depending on whether the particles have been aligned by an applied magnetic field before the cross-linking of the polymer. Since the effective coupled magneto-mechanical behavior is of special interest in these applications, an in-depth understanding of the structure-property relations in MSE, suitable theories for computing the effective macroscopic material response as well as efficient simulation procedures for technical components are required.

To this end, a continuum formulation for coupled magneto-mechanical problems suitable for both microscopic and macroscopic scales previously developed by the authors and implemented in the framework of classical and extended Finite Element Methods (FEM) [1, 2, 3] is applied. This approach utilizes a split of the total stress tensor into electromagnetic and mechanical parts. Here, this formulation is discretized using Isogeometric Analysis (IGA) [4]. In addition to the IGAFEM modeling of finite domains which is used in the framework of homogenization to predict the effective behavior of MSE, the coupling of the isogeometric Finite Element and Boundary Element Method (IGAFEM/-BEM) is proposed and applied to two-dimensional stationary magnetic field problems on infinite domains as typically required for the simulation of magnetic components.

In this approach, IGAFEM is used to model magnetizable bodies allowing for heterogeneous structures and non-linear constitutive behaviour, the IGABEM domain accounts for the surrounding free space. Both methods are coupled on the surface of the magnetizable body. Due to this hybrid IGAFEM/-BEM approach, no meshing of free space is necessary and truncation errors are avoided for problems to be solved on open, infinite or semi-infinite domains. Once the solution for the magnetic problem is obtained using the hybrid method, IGAFEM is used to solve a magneto-mechanical field problem with one-sided coupling in a subdomain of the magnetic problem. This one-sided coupling is realized by a magnetic stress tensor computed from the solution of the stationary magnetic field problem. From the comparison of error norms and convergence rates for NURBS and discretisations based on Lagrangian polynomials, smaller errors and similar convergence rates are found for the proposed method for the same polynomial order of the basis functions and a comparable mesh size (Figure 1 (a)).

The example in Figure 1 (b) illustrates the modeling of magnetostriction by the hybrid approach. It considers an elliptic sample which consists of magnetizable circular inclusions embedded in a soft polymeric matrix. A magnetic stimulus is provided by a homogeneous external magnetic field $\bar{\mathbf{B}}$. However, the magnetisation of the particles will induce local variations of the magnetic field which result in interactions between the particles eventually generating the observable magnetostriction of the elliptic sample.

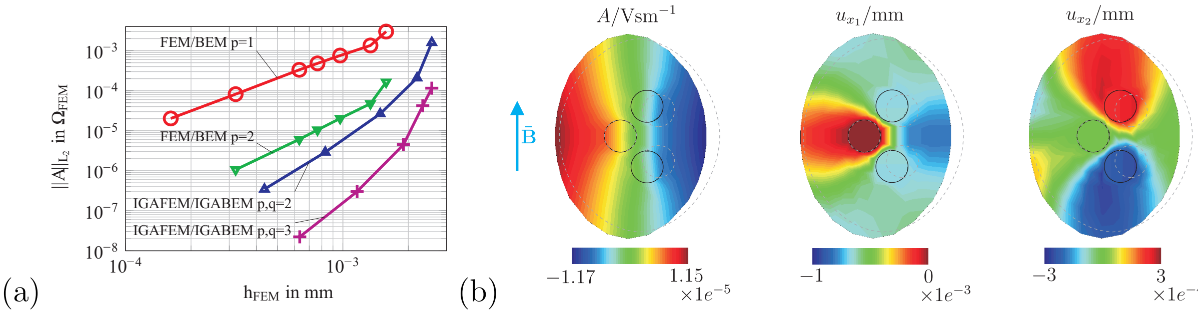

Figure 1: (a) Normalised error norm of the magnetic potential $||A||_{L_2}$ in the domain Ω_{FEM} and (b) local magnetic field resulting from the particle magnetisation and magnetically induced deformation of an elliptic sample for a vertically aligned magnetic field $\bar{\mathbf{B}}$. The dashed grey lines illustrate the original undeformed configuration, while the solid black lines show the position of the particles at the end of the simulation.

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