A hp-Finite Element Formulation for the Simulation of 3D Magneto-Mechanical Problems with Application to MRI Scanners

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ABSTRACT

Magnetic resonance imaging (MRI) has become a tool available in most of major medical centres. Its importance in the medical industry is continuously increasing due to its application to a wide range of medical areas such as tumour detection or neuroimaging. MRI scanners utilise a set of superconducting coils to generate a uniform strong magnetic field, and a set of gradient coils to produce pulsed field gradients in order to generate an image. These gradient fields give rise to eddy currents in conducting components, as well as Lorentz forces leading to vibrations and deformations. These eddy currents and vibrations are undesirable, as they can lead to imaging artefacts, patient discomfort and helium boil-off.

To address this issue we present a new computational methodology [1] to solve the coupled three-dimensional magneto-mechanical problem of interest. Our approach employs a Lagrangian description of the problem [2], an AC-DC splitting of the fields to linearise the problem [3] and a hp-finite element discretisation for accurate solutions. We use H^1 and $\boldsymbol{H}(\text{curl})$-conforming finite elements to discretise the mechanical displacements and magnetic vector potential, respectively. The success of our proposed methodology is demonstrated by applying it to challenging benchmark problems.

To provide further computational efficiencies, we propose a reduced order model based on the proper orthogonal decomposition [4] for the fast computation of outputs of the problem under parameter sweeps. Results demonstrating the success of this approach are also included.

REFERENCES

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