Coupled Electromagnetic-Thermal Model of a Superconducting Motor

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1. Introduction
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Background

- Construction of a fully superconducting motor
- Rotor with magnetised stacks of HTS tape
- Cooling with hydrogen to 20K
- Demagnetisation issues and need for magnetic shielding
- Anisotropic heat transfer properties
Introduction

Goals
- Design of efficient stacks to serve as trapped field magnets in the rotor
- Find the maximum magnetic flux that can be trapped
- Tackle the issue of demagnetisation to prolong the operation time of the motor
- Optimise heat removal to maintain temperature below critical

Methods
- Coupled thermo-electromagnetic model
- Application of A-formulation and H-formulation in a single model to decrease time of computations
- Consideration of material parameters
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Geometry of the model
Coupled Electromagnetic-Thermal Model of a Superconducting Motor

Methods

Mesh
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Methods

Numerical method

H-formulation
\[
\frac{\partial H_x}{\partial t} + \frac{\partial H_y}{\partial t} + \frac{\partial}{\partial x} (E_z(J_z)) - \frac{\partial}{\partial y} (E_z(J_z)) = 0
\]

Electric field
\[
E_z = \begin{cases} 
E_0 \left( \frac{|J_z|}{J_c} \right)^n \frac{J_z}{|J_z|} & \text{when } |J_z| \geq J_c \\
0 & \text{when } |J_z| < J_c
\end{cases}
\]

Current density
\[
J_z = \frac{\partial H_x}{\partial y} - \frac{\partial H_y}{\partial x}
\]

- $H$ - magnetic field
- $J$ - current density
- $J_c$ - critical current density
- $n$ - exponent of power law, assumed as 31 [1]
- $x, y, z$ - geometrical axes
- $E_0$ - electric field threshold

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\footnote{Kvitkovic et al., 2018}
Critical current density
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Results

Magnetisation

Magnetic induction in T and magnetic vector potential in Wb/m

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Results

Current density

Current density in A/m²
Operation

Voltage response of a coil in V
Anisotropic heat transfer in optimised configuration

Temperature and heat transfer direction in a section of a conduction-cooled rotor
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Conclusions

- The shape of stacks is selected and they will be manufactured soon.
- Further thermal analysis will be performed to find optimal mounting method.
- Research on protection against demagnetisation is ongoing.
- The results from the operation of a demonstrator motor will be available in 1Q 2020.
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Conclusions

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- Further thermal analysis will be performed to find optimal mounting method
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