Magneto-Mechanical-Thermal Couplings for the Pulsed Magnetic Technology with Single-Turn Coils

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Abstract

Single turn coils produce AC and transient magnetic fields in pulsed magnetic technologies for which magneto-harmonic and transient magnetic analysis can be primarily performed. We suggest studying one single turn coil example made of a conducting massive coil, an optional conducting field shaper and an internal conducting tube supposed to be deformed. The pulsed high magnetic field created induce eddy currents in both the field-shaper and the tube. The latter interact with the magnetic field to induce a Lorentz force that tends to deform the field-shaper and compress the tube. Meanwhile, the electrical currents inside the coil, the field-shaper or the tube generate heat losses and the temperature might increase during the process. Therefore, couplings between the magnetics and the mechanics on one side and between the magnetics and the thermal effects on the other side are required. The complete electromagnetic and electrical analysis have already been computed and validated with the AC and transient magnetic field mode with COMSOL Multiphysics® in [1]. The aim of this study is to evaluate the feasibility, accuracy and reliability of a 2D axi-symmetrical numerical model by comparing with reference like measurements or 3D calculations in order then to build an approximate but reliable analytical solution that might ease the coupling with electrical, mechanical and thermal physics.

In this work we propose to:
- First introduce the 2D axi-symmetrical geometry and the initial electromagnetic model in COMSOL (sources, materials, limit conditions and mesh)
- Then introduce and perform transient mechanical and magneto-mechanical computations:
  o Definition of the mechanical model (sources, materials, limit conditions and mesh)
  o Governing coupled electromagnetic and mechanical equations
  o Draw the Lorentz force density, stress and deformation profiles
  o Analysis of the relationship between the current, the maximum force, elastic stress and deformation as a function of time
  o Yield stress threshold and deformability analysis
- Finally introduce and perform thermal and magneto-thermal computations:
  o Definition of the thermal model (sources, materials, limit conditions and mesh)
  o Governing coupled electromagnetic and thermal equations
  o Draw the heat source, flux and temperature profiles
  o Extract some needed information on the coil, such as the equivalent heat capacity, thermal resistance and time constant
References


Figures used in the abstract

**Figure 1**: Peak compression Von Mises stress (left) and main strain (right) due to Lorentz force.