Analysis of D-Shaped Toroidal Superconductive Coils for Medium Size Fusion Experiment Facility

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INTRODUCTION: In magnetic confinement nuclear fusion the magnetic fields are utilized to confine an extremely hot gas (plasma) of hydrogen isotopes**.** The most used device is the Tokamak, where three main magnetic systems are present. The Tokamak is a pulsed machine and the fusion reactor projects need to reach quasi-stationary regime through the adoption of superconducting wires. This work deals with the design of the Toroidal System, whose structural requirements are very stringent due to the high E. M. loads.

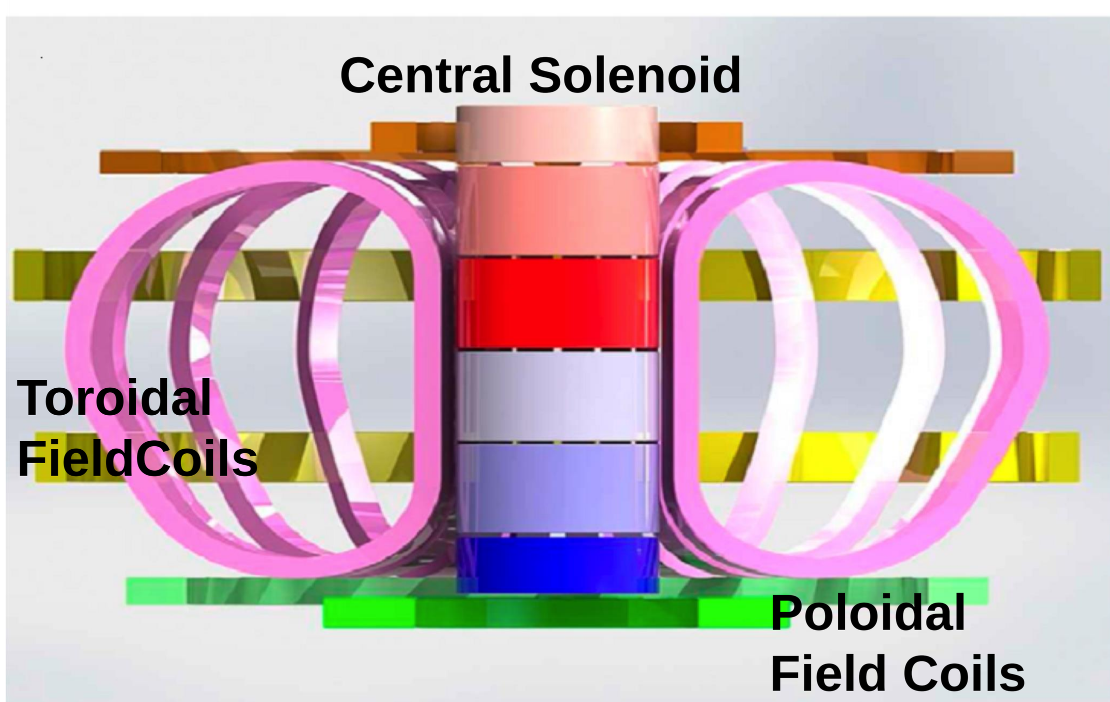

Figure 1. General picture of the magnetic system of a Tokamak

COMPUTATIONAL METHODS: The preliminary design is based on a 3 steps iterative procedure:

-Definition of the global D-shape of the coil, sweeping a geometry parameter, with smeared material properties in a 3D model.

-Determination of the Stress Intensification Factors (SIF's) in the equatorial inner leg section by comparing the stresses of a heterogeneous 2D model with those of a homogeneous one imposing the same displacements.

-Validation of the smeared material properties through a set of virtual test made by controlled displacements and proper constrains of an elementary 3D cell of the coil.

RESULTS:

First Step Results:

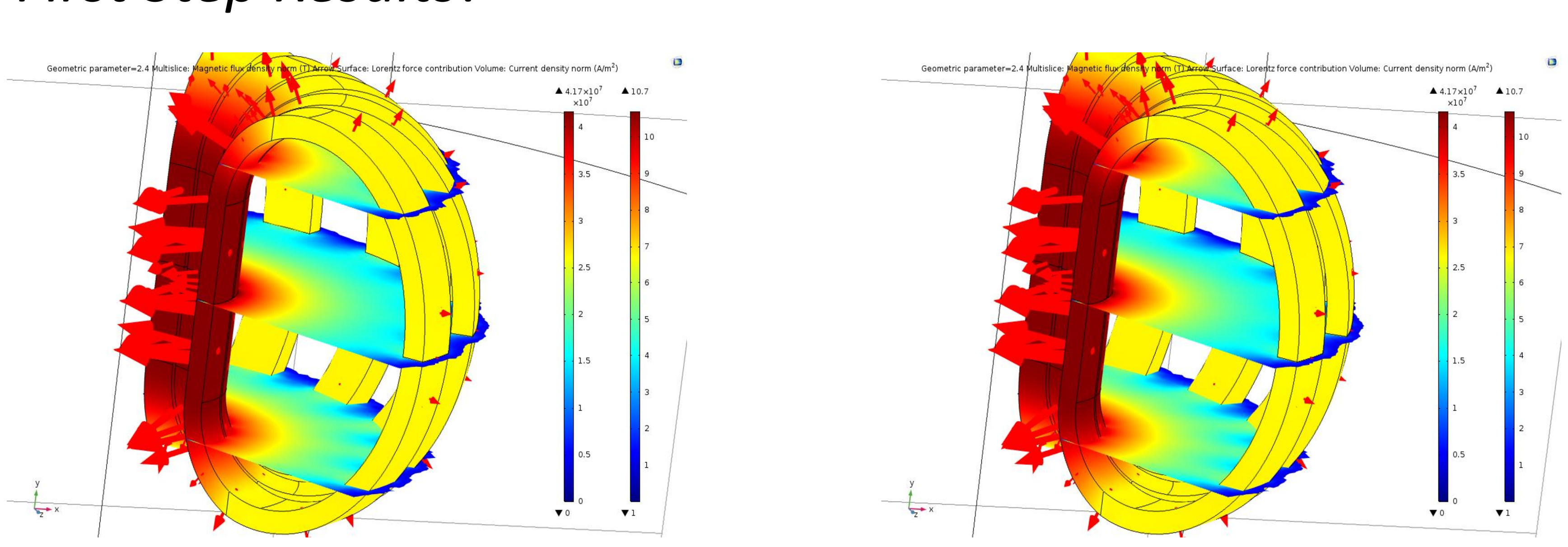

Figure 2. Magnetic field (slice), current density and Lorentz forces (arrows).

The D shape is choose not only on the basis of mechanical reasons but also of magnetic configuration considerations such the Ripple defined as:

$$R_{\%} = 100 \cdot \frac{B_{max} - B_{min}}{B_{max} + B_{min}}$$

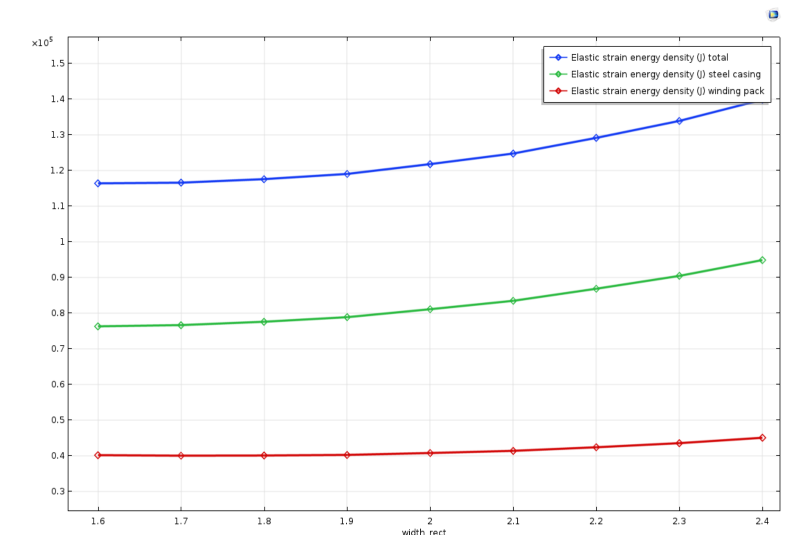

Figure 3. Elastic strain energy density integral.

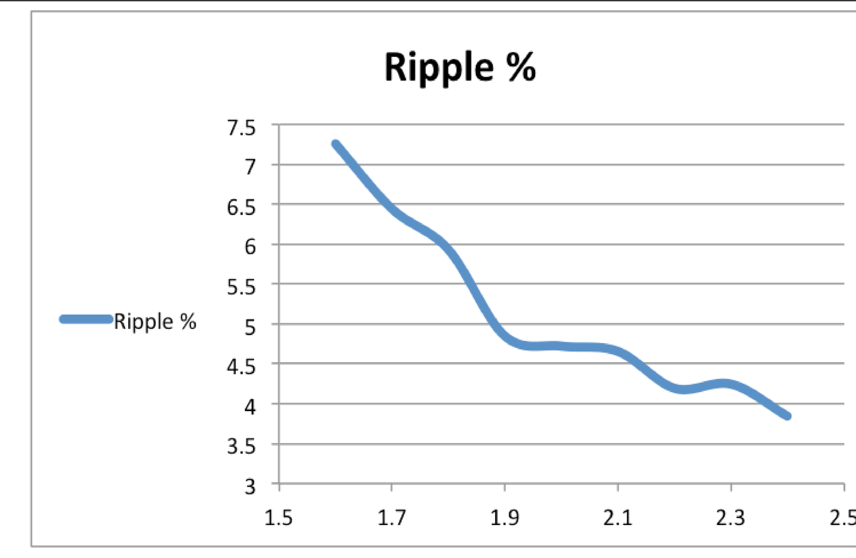

Figure 4. Magnetic field ripple in the upper corner the the poloidal section

Second Step Results: Two 2D models are compared. The first is the real winding pack with the effective properties. The second has the smeared properties, but same mesh.

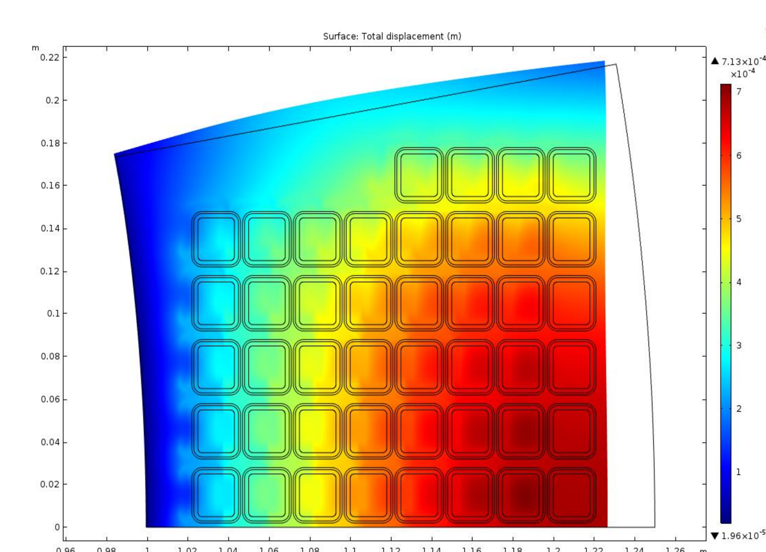

Figure 5. Total displacement in the heterogeneous winding pack

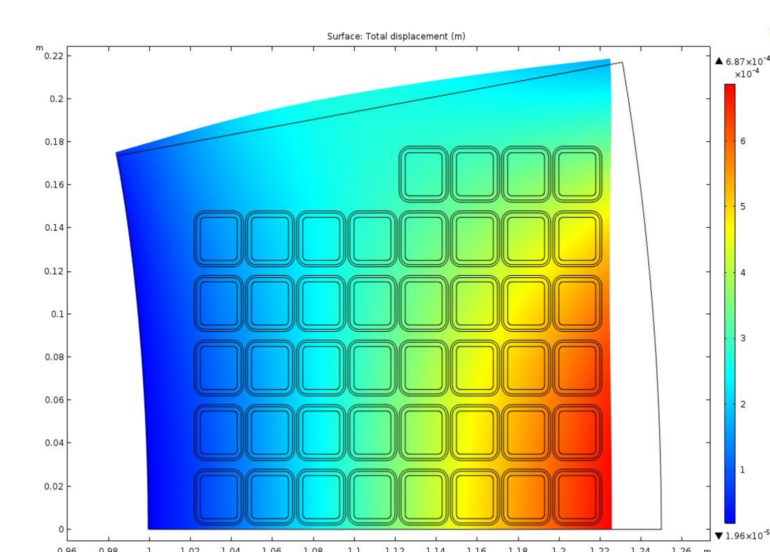

Figure 6. Total displacement in the homogeneous winding pack

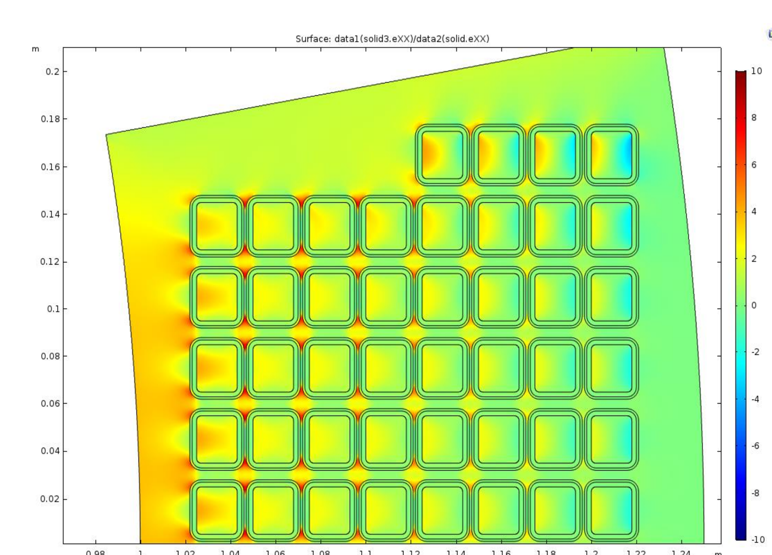

Figure 6. Ratio between strain tensor XX component

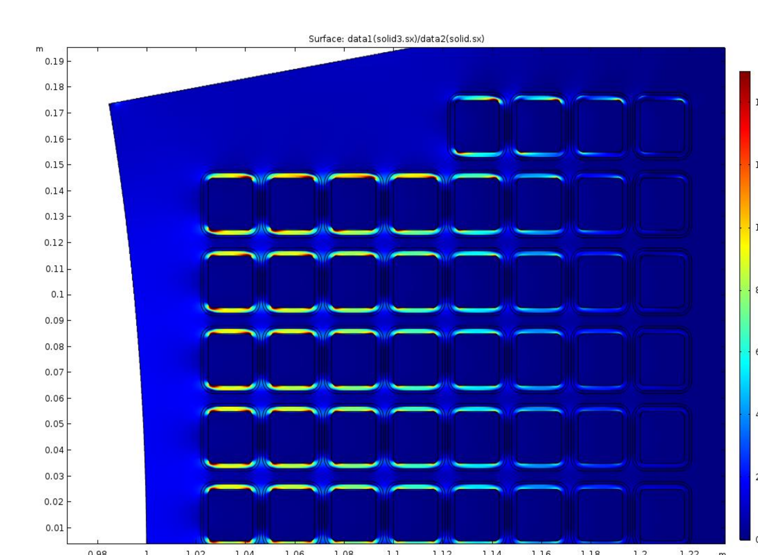

Figure 7. Stress Intensification Factor for stress tensor x component

Third Step Results: Virtual tests on an elementary coil cell to get equivalent smeared material properties.

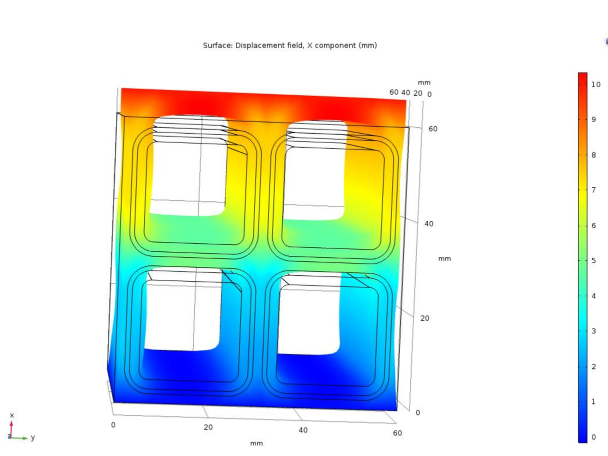

Figure 8. Displacements for E_{xx} determination, face yz fixed.

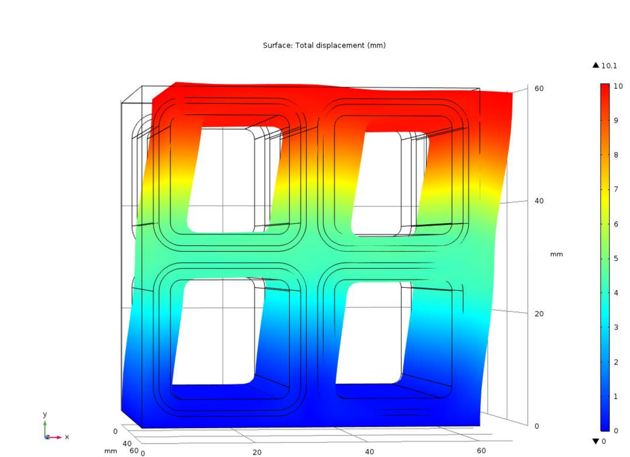

Figure 9. . Displacements for G_{xy} determination, face xz fixed.

CONCLUSIONS: The method proposed has to be validated by tests on real specimens. Its main value is to reduce the specimens number to test.

Figure 10. Specimens for validation tests

REFERENCES:

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2. J. File, R. G. Mills, G. V. Sheffield, Large Superconducting Magnet Designs for Fusion Reactors, *IEEE Transactions of Nuclear Science*, NS-18, pp. 277-282 (1971)