Magneto-structural Analysis of Fusion grade Superconducting Toroidal Field Coils

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Abstract: In this paper, detail magneto-structural analysis of fusion grade superconducting toroidal field coils that are used in 'tokamaks' is presented. The stresses that arise due to Lorentz forces in large size superconducting coils that carry high currents are of catastrophic type in nature. These stresses are expected to influence the integrated performance of the magnet system. In this paper we have analyzed two-toroidal field coils system using COMSOL Multiphysics.

Keywords: Insert Tokamak, Toroidal field Coils, Magneto-structural stresses.

1. Introduction

One of the most promising paths to realize Fusion Power is by magnetic confinement. 'Tokamak' is a 'toroidal magnetic bottle', which magnetically confines plasma to achieve fusion. Institute for Plasma Research is engaged in building such research reactor called SST-1 to study plasma physics and fusion science.
By the very nature of its design, superconducting coils in tokamak are vulnerable to high magneto-structural stresses. These stresses are expected to influence the integrated performance of the magnet system. In this paper we have analyzed two-toroidal field coils system using COMSOL Multiphysics.

2. Description of the Problem

Institute for Plasma Research is engaged in building Steady State Superconducting Tokamak SST-1, which consists 16 D-shaped Toroidal Field Coils, made of NbTi superconducting cable. To validate the coils' performance, a pair of coils is presently under various tests at low temperature. Each coil consists of 108 turns and carry 10 KA DC current in steady state. The problem is modeled as shown in the fig.-1.

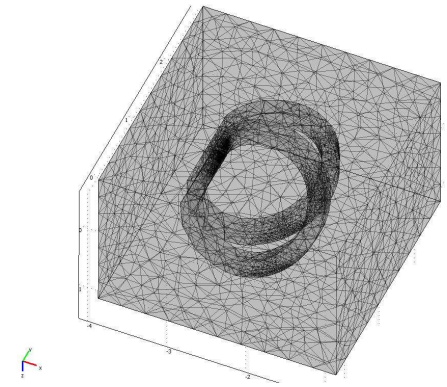

Figure 1. The meshed model of two Toroidal Field Coils system.

Two inter-coil separators support the two coils from each other. In addition to that, the two coils are rigidly fixed at the inner nose side. AC/DC Module and Structural Mechanics modules are used in COMSOL Multiphysics to solve this problem.

3. Results & Discussion

The magnetic flux density profile at the mid-horizontal plane is shown in the fig.-2.

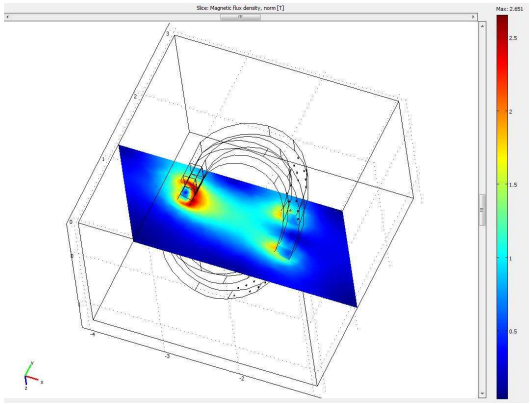

Figure 2. The magnetic flux density profile B at the mid horizontal plane.

The maximum field is about 2.77 T at the inner legs of TF coils. This is in agreement with the analytical calculations.

Similarly the magnetic flux density profile at the mid-vertical plane is shown in the fig.-3.

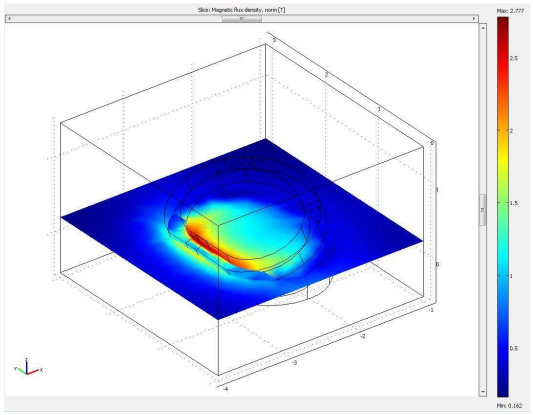

Figure 3. The magnetic flux density profile B at the mid vertical plane.

These fields interacting with the self-carrying current in the coils produce JXB forces, which make the coils vulnerable to high stresses. The profile of these Lorentz forces is shown in the fig.-4. The maximum force is of the order of 84.3MN/m^3 .

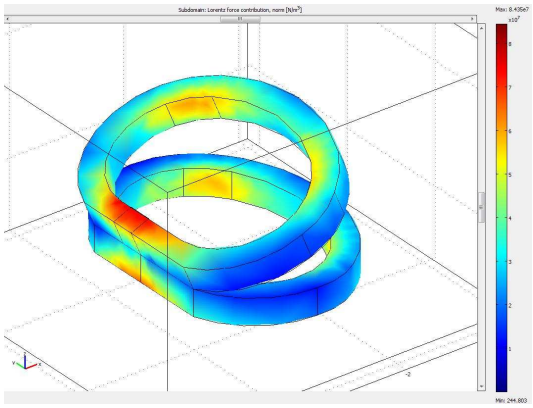

Figure 4. The Lorentz (JXB) force profile on the two TF coils system.

Finally the stresses arise due to these Lorentz forces are calculated as shown in the fig.-5. The maximum stress is around 20 GPa at the inter-coil supports. As this is unacceptably high, we need to consider more number of inter-coil supports to alleviate the problem.

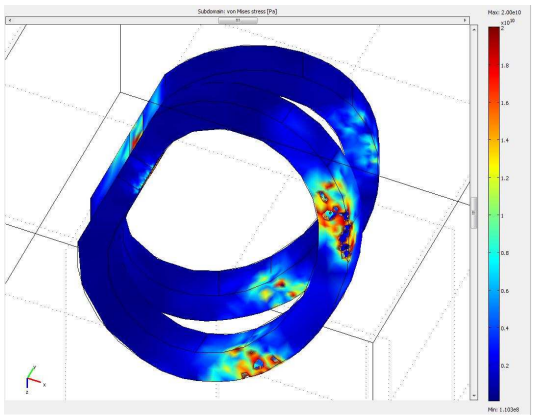

Figure 5. Stresses (von-Mises) in the two TF coil system due to Lorentz forces.

The corresponding deformation plot is shown in the fig.-6.

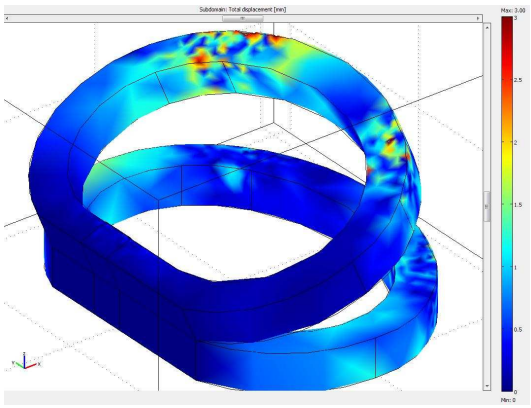

Figure 6. The deformation in the two TF coils system due to Lorentz forces.

7. Conclusions

In this work two TF coil system is analyzed for magneto-structural stresses in detail using COMSOL Multiphysics. Thermo-structural stresses duo to cool-down will be added in the future work.

9. Acknowledgements

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