Prediction of Magnetic Fields, Eddy Currents, and Loads in a Tokamak During a Disruption for Alcator C-Mod's Advanced Outer Divertor

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Abstract

Introduction
In the Alcator C-Mod tokamak, one of the major mechanical design considerations for a new device inside the vessel is that it will survive a disruption. A disruption occurs when the current driven in the plasma, which can be up to 2.5 MA, rapidly decays creating eddy currents in the surrounding metal structure. This in turn results in Lorenz forces due to the high magnetic fields inside the tokamak. A new advanced outer divertor has been designed for C-Mod using the COMSOL Multiphysics® software for FEA. To predict the loading it will see, and then design the required support structures, we must first predict the local fields and currents during a disruption.

Use of COMSOL Multiphysics®
COMSOL has been used to model the rapidly decaying fields during a disruption of the plasma on the Alcator C-Mod tokamak. The fields are created by the current in the plasma and the coils in the vessel. The coil currents are measured during a discharge, so that data can be entered into COMSOL directly. Plasma current, however, is not uniform throughout the volume of the plasma. Its magnitude and direction varies by location, so to simulate the magnetic fields created by the plasma, the plasma is modeled as 24 current carrying filaments in COMSOL using magnetic fields physics. The current in each of these filaments is calculated in a MATLAB® model that solves Maxwell's equations so that the fields and fluxes generated by the 24 filaments match the fields and fluxes due to the plasma measured during a discharge. A force calculation module is used on the divertor to calculate the loads resulting from the induced eddy currents crossing the magnetic fields. These loads are then mapped to a structural model where the stress and displacements are predicted.

Results
These models showed that preliminary designs for the divertor needed reinforcements around local cutouts as well as stronger supports at the attachments to the vessel. The design was modified to meet these requirements, and models of the updated geometry show that stresses and displacements are within allowable limits.

Conclusion

This technique provides greater detail in the model in that it can recreate the spatially varying fields from an actual C-Mod discharge, and allows us to model both the current decay of the plasma as well as any physical translation it may make up or down. Capturing these effects lets the model more accurately reflect the conditions the new divertor will see, more accurately predict the loads and stresses it will need to be designed for, and make changes in the design to reflect these requirements.

Reference

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