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Multiphysics Finite Element Modelling of "close-to-real" coil winding of a Toroidal Field Coil in a Tokamak

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Finite Element Modelling (FEM) is the common practice for the design and performance evaluation of superconducting magnets. Electromagnetic models are combined with structural ones to first compute the forces that are applied to the magnet during its operation and then evaluate the stress distribution that is attained in its subcomponents. Due to the computational size of the global problem, a simplified configuration of the coil winding is usually implemented in the models: the coil is not modelled as a continuous wound cable, but each of its turns is a closed loop positioned in a grid to recreate the section and global geometry of the magnet. This results in a uniform distribution of the current in all the magnet sections and does not account for the electromagnetic effects in correspondence of the winding and layer jumps and of the coil terminations. This paper discusses the FEM procedure that has been developed with Ansys APDL to include these details in the 3-dimensional (3D) electromagnetic and structural model of a Toroidal Field Coil system (TFC) of a Tokamak. We evaluated the effect of implementing a "close-to-real" winding pack and compared the results with those from an ideal model, both in terms of electromagnetic field generated and stress levels in the magnet. In addition, we show how the detailed force distribution computed can be exploited as an input for structural sub-models to evaluate stress conditions in correspondence of the winding and layer jumps and of the coil terminations. This work has been completed as part of the EUROfusion roadmap to fusion energy in the framework of the development of the Divertor Tokamak Test facility (DTT) currently under construction at the ENEA Research Center of Frascati, Italy.

Keywords

TFC, tokamak, winding pack, Nb3Sn, CiCC, FEM

Category

Multi-scale and multi physics design methods

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