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

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Abstract

The research in magnetic confinement fusion is carried out through electromagnetic machines, with a toroidal geometry, where a hot plasma of heavy hydrogen isotopes (deuterium and tritium) is contained in a vacuum vessel. Due to the very high temperatures reached by the plasma, strong magnetic fields are used to prevent the plasma to touch the walls of the vacuum vessel. The toroidal magnetic field coils are the main system aimed to confine the hot plasma while the nuclear fusion reactions take place for a sufficient time such that the plasma temperature can increase, protecting at the same time the wall surrounding it. This toroidal magnetic system is constituted by a number of discrete coils, whose number ranges normally between 16 and 24, and they are shaped in a D form to minimize as far as possible the bending stresses on the coils and to better adapt to host the divertor used to extract the fusion ashes from the plasma, whose shape is also elongated.

Between the different types of electromagnetic machines conceived until now the Tokamak had reached the larger success in the fusion community because its simplicity and easiness of operation. In this kind of machine the plasma is mainly heated through the Joule effect obtained making an electric current flow in the plasma itself by the magnetic induction from a solenoid installed in the hole of the torus. So the Tokamak mode of operation is inherently pulsed. To get longer pulses the use of superconducting coils, either for the toroidal system and for the solenoid and other poloidal systems intended for plasma equilibrium purpose, is mandatory.

It's easy to expect that the complexity in the design of a similar facility increase dramatically. So the design of medium size experimental facility has to rely on a careful balance between the different issues deriving either from the requirements inherent the general arrangement of this type of machine and from the specific constrains imposed by the use of superconducting coils on a hand, and on the other hand the plasma performances that can't be reduced without loosing the experiment relevance. These issues are relevant for all the physical aspects of the device, magnetic, mechanical , thermal and fluidic. So a number of different analysis have to be carried out in the various stages of the project, also in a recursive approach. So the use of a multiphysics software, the COMSOL Multiphysics® software, appears natural and suitable for further improvements regarding the model complexity and the detail grade as the design process proceeds.

So in this work the preliminary analysis relative to the main magnetic feature and the consequent mechanical loads for a medium size Tokamak, intended as accompanying device of the bigger projects such ITER and DEMO, are presented and discussed in the

light of its peculiarity constituted by the reduced geometrical dimensions but full value of the magnetic field proposed.

Figures used in the abstract

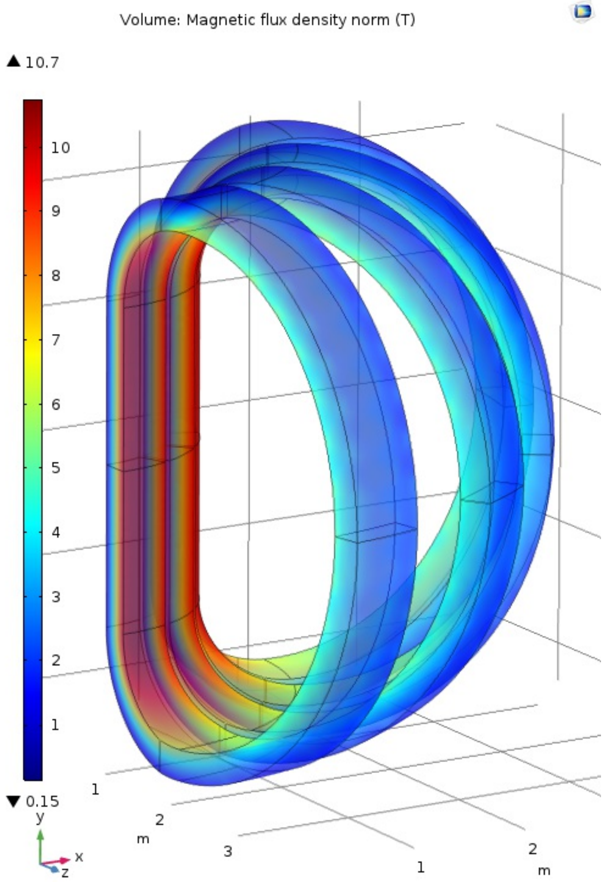

Figure 1: Magnetic flux density norm for a 90 degree sector