Supraconductive Magnets don't like Quench !

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Context: Simulation of the nonlinear behavior of supraconductive magnets.

Objectives: Design and sizing under thermal and mechanical loads when frictional contact conditions between the parts ar etaken into account.

Tools :

Research code : COFAST (COntact and Friction in Assemblies of Structures)

Partners:

Commissariat à l'énergie Atomique (CEA) at Saclay DSM/IRFU :

- Service d'Ingénierie des Systèmes/Laboratoire de Conception et d'Avant-Projets
- François NUNIO, Pierre MANIL / Zhihong SUN

Detailed context:

In particle accelerators, such as LHC in Geneva or next generation accelerators in France or abroad, supraconductive magnets guide particle rays. The supraconductive state (non-resistive state) allows the creation of high intensity magnetic fields. This state is obtained for very low temperature of the coil (less than 2°K!).

The components of the magnets are submitted to very strong loads that are due to the diminution of temperature and to very high magnetic forces (Lorentz forces). Because of the contractions of the parts, some internal gaps can appear. They can allow relative motions that can generate heat by friction. A very small elevation of temperature can have catastrophic effects if the coil leaves the supraconductive state and becomes resistive as it conducts very high currents. This is the behavior that must be avoided: the quench!

In order to reduce the gaps under low temperatures, the components are pre-strained. The aim of the CEA is to establish some simulation tools for magnets under thermal and magnetic loads in order to predict the risks of quench.

Objectives: During the last twenty years, LMT Cachan as developed some numerical tools that are dedicated to the simulation of assemblies of structures with contact and friction (Code COFAST). The objective of the project is to extend these tools to the fit the applications proposed by the CEA.

First Application: Finite Element analysis of the Shear Panel of the structure of the toroidal magnet of Tokamak JT60-SA in Japan.

Within the framework of a project between Europe and Japan on controlled fusion by magnetic confinement, France (CEA) contribute to the definition of the toroidal magnet of Tokamak JT60-SA.

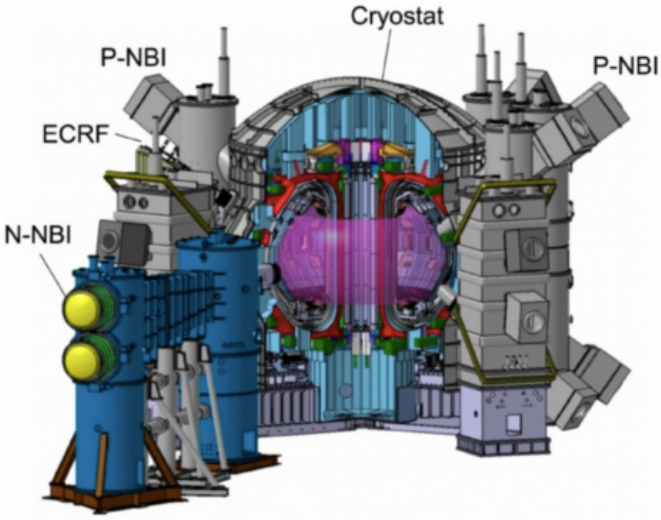

Figure 1 : JT 60 SA

The toroidal is composed of 18 supraconductive coils (temperature 4°K). The structural assembly of the coils is enforced by external belts (OIS : Outer Intercoil Structure) linked by bolted junctions (SP : Shear Panel). The mechanical load is as high as 300 tons during nominal behavior of the magnet.

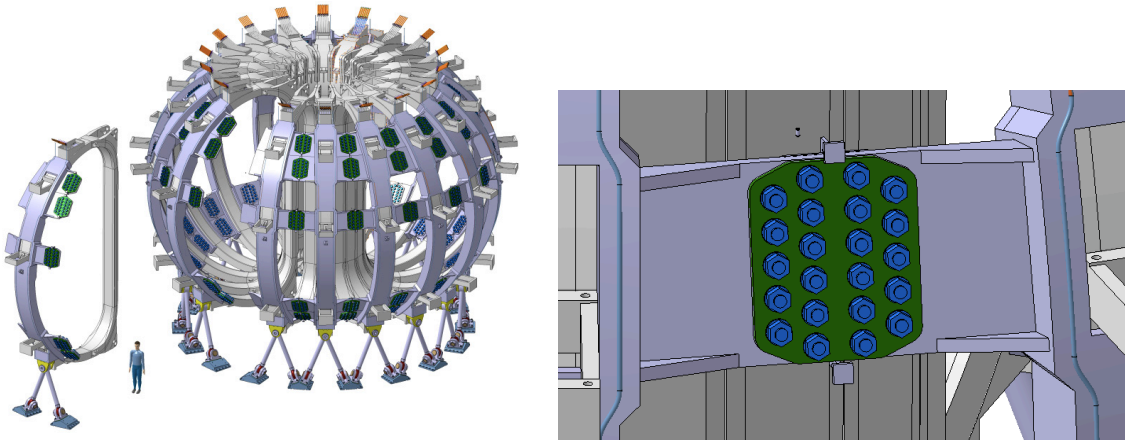
Figure 2: mechanical structure of the toroidal magnet of Tokamak (zoom on SP)

The present work deals with the modelization of the bolted junction of the Shear Panel and with the study of the effects of some parameters: [i] prestrain of the bolts, [ii] type of interface (material, friction) and [iii] mechanical tolerances (gaps).

Work: parameterization of the geometry. definition of a finite element model in COFAST. Sensitivity analysis. The short term objective if to establish the representativity of the test of the shear panel in the cryogenic test set.

Second application: Finite Element analysis (with COFAST) of the behavior of a SMC magnet

Within the framework of the design of high field supraconductive magnet (Nb3Sn), Irfu develops some prototype magnet in order to test the mechanical and magnetic capacities. In the experimental sets the prestrain of the coils (figure 3) can be change in order to evaluate its effects on the quench.

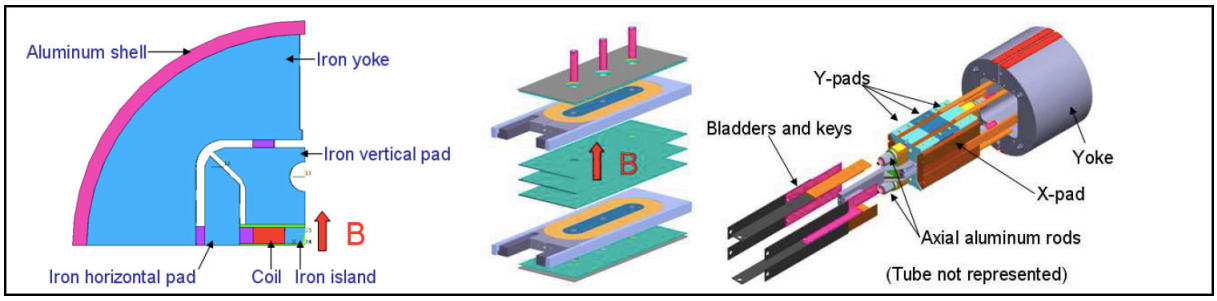

Figure 3 : SMC magnet (SD01 coil)

These mechanical assemblies are submitted to:
- (i) hydraulic prestrain
- (ii) differential thermal contraction (300°K->4°K)
- (iii) Lorentz magnetic forces

The behavior of the prototype magnet is highly influenced by the friction effects and by the gaps between the components. This works deals with the definition of the mechanical model of the assembly with COFAST in order to analyze the capacities of the numerical tools with respect to the treatment of unilateral contact phenomena.

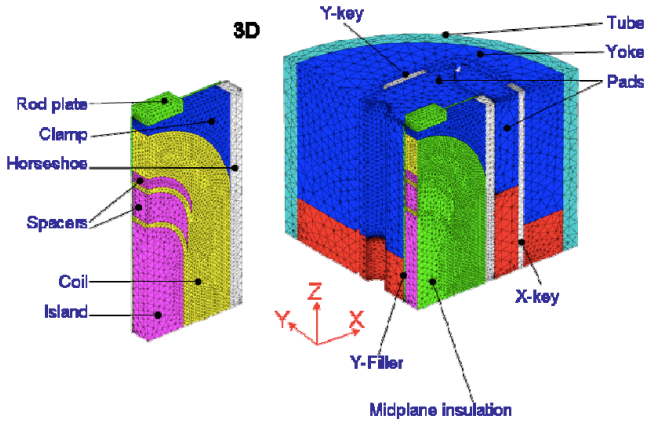

Figure 4 : modèle EF Cast3M d'un prototype SMC

Work: parameterization of the geometry. Definition of a finite element model in COFAST. Sensitivity analysis.