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Electro-mechanical analysis of the European Superconducting Dipole

Pietro Testoni(1), **Francesca Cau(1),** Manuela Di Mauro(1), Alessandra Fanni(1), Alfredo Portone(2), Ettore Salpietro(2), Piergiorgio Sonato(3)

1. University of Cagliari, DIEE Piazza D\\\'armi 09123 Cagliari Italy
2. EFDA CSU-Garching Boltzmannstr. 2 D-85748 Garching bei München Germany
3. Consorzio RFX - Associazione EURATOM -ENEA sulla fusione Corso Stati Uniti 4 I-35127 Padova Italy

The detailed design of a high-field superconducting dipole magnet, coordinated by the European Fusion Development Agreement (EFDA) in collaboration with several European Associations, is being finalized, the aim being to make available a new facility to perform tests of large superconducting conductors in high magnetic fields (B=12.5 T). The main use of the facility shall be to test the ITER conductors during the manufacturing of the ITER magnets in order to implement the quality control program. The dipole magnet consists of a pair of identical saddle-shaped coils of rectangular cross section that are layer wound using a Cable In Conduit Conductor (CICC) made of Nb3Sn strands jacketed inside a high strength, austenitic steel conduit. A circular section iron yoke is used to improve the field quality and intensity over the bore cross-section. An outer steel cylinder made of austenitic steel encloses the whole dipole assembly and provides pre-compression at cryogenic temperature due to the differential contraction. Each coil is made of a High Field (HF) section and a Low Field (LF) section. All conductors carry the same operating current, all turns being in series. The HF grade differs from the LF grade in the outer dimensions of the superconducting strands, resulting in a different current density between HF and LF sections. In view of the relative complexity of the system (shape, size and non linearities) to be designed, 2D and 3D Finite Element Models of the dipole have been built and several electromagnetic and thermo-mechanical analyses have been performed with the ANSYS code, in order to study, optimize and verify the requirements of the system. The analyses have been carried out by first computing the magnetic field distribution and the magnetic stored energy due to the imposed current in the superconducting coils. For this purpose three different numerical formulations have been used and the results compared. The applied loads in the structure have been then computed (the JxB cross product of the current distribution with the static magnetic fields, the magnetic forces in the iron, the thermal strains due to thermal contraction) and stresses and deformations derived. Both EM and structural FEMs share the same mesh, therefore no approximation and/or interpolation is done by transferring loads from one model to the other one. The results obtained have shown the feasibility of the system with respect to the mechanical design criteria adopted.