Engineering and Materials Challenges in ITER Toroidal Magnet System

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Abstract— The ITER Tokamak magnet composed of 4 superconducting coils (toroidal field (TF), poloidal field (PF), central solenoid (CS) and correction coils (CC)) is now well under procurement. Concerning the D-Shape Toroidal Field Coils (TFC), the first windings and structures components are being fabricated by industries through large contracts managed by European Fusion For Energy (F4E) and Japanese Domestic Agency (JADA) since last mid 2010. Those large magnets with unprecedented 41GJ magnetic total stored energy are used to contain plasma and consist of eighteen toroidal field coil windings, utilizing Nb_3Sn Cable in conduit conductor, electrically connected in series and operated with nominal transport current of 68kA, supplied through HTS current leads. The coils are cooled by supercritical helium at about 4.5K, and experience a peak field of 11.4 T.

One of the key challenges of all ITER coils design is the development of high strength class, fatigue-resistant structural 316LN stainless steel material in forging and welded form compatible with high operating stress at liquid helium temperature. Composite materials used in magnet insulation system and the large precompression rings require specific qualifications and manufacture processes to guarantee final properties over lifetime. Some important coil features such as helium supply inlets, electrical joints require dedicated qualification to confirm the design choices and the utilized manufacturing routes. At each stage of manufacture of those components, proper allocation of tolerances to the different manufacture steps of winding, assembled encased coils has been defined in order to guarantee the final mechanical integrity of the assembled coils under operating loads. The resulting position of the magnetic center line datum installed in the cryostat allows to control plasma interactive errors of magnetic fields. This paper will present an overview of the key development on material related to ITER TF fusion magnets and their main challenges on integration engineering.

Keywords – ITER, toroidal field coils, magnets, high voltage, joints, winding, Nb_3Sn CICC, 316LN structures, insulation, composite, tokamak assembly