Contribution ID: **933** Type: **Poster Presentation of 1h45m**

Investigation of Materials and Welds for the Precompression Structure of the ITER Central Solenoid

Wednesday, 30 August 2017 13:15 (1h 45m)

The Central Solenoid (CS) is the backbone of the ITER magnet system. It consists of six independent coils held together by a vertical pre-compression structure that must react tensile loads and provide sufficient preload to maintain coil-to-coil contact during all stages of plasma operation. The CS pre-compression system includes three different types of tie plates, lower and upper key blocks, load distribution plates and tubing that will carry supercritical helium at temperatures as low as 4.5 K. Material selection and specifications applicable to the structural components of the pre-compression structure are particularly demanding. These include large forgings manufactured from a high strength austenitic stainless steel (FXM-19) with a stringent specification in terms of fineness of the grain size, inclusion cleanliness, maximum allowed magnetic permeability and ferrite content. In order to meet these requirements, an adapted steelmaking route including Electroslag Remelting must be followed. The melt chemistry is specially tailored. The re-melted ingots are subject to redundant, multi-directional forging. Ultrasonic examination of 100% of the volume of the forgings is performed in accordance with applicable standards, such as ASTM A745/A745M, with acceptance criteria adapted to the functional requirements of the individual components. Stringent requirements are also imposed on all welded joints. Structural welds, as well as the attachment welds of the cooling pipes to the structure, are subject to challenging restrictions in terms of weld imperfections and geometry. They must induce limited distortion and are subjected to inspections carried out in accordance with the most severe acceptance levels of applicable international and national standards. The results of extensive examinations of different components and welds are reported in this paper, particularly focusing on the quality achieved at microstructural and macrostructural level. The influence of the microstructure on the properties and the inspectability of the material by non-destructive examinations is also discussed.

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Session Classification: Wed-Af-Po3.10

Track Classification: F8 - Structural Materials for Magnets