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## **M2Or1A-04: [Invited] Development of large-scale TF structural XM-19 forgings for SPARC**

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The SPARC tokamak requires large-scale, high-strength cryogenic structures for its toroidal field (TF) coil case. Due to the large electromagnetic forces induced during operation, forged XM-19 was selected as the case material in regions of highest stress. To qualify materials and processes for large forgings, a toroidal field model coil (TFMC) case was produced at relevant SPARC TF scale. A custom alloy chemistry was implemented to maximize strength and fracture toughness properties at cryogenic temperatures and a 20 ton forging with cross section in excess of 350 mm was produced. Heat treatment studies were conducted to determine the effects of solution annealing with air- and water-cooling on precipitate formation and subsequent material properties. Microstructural analysis and tensile testing at 20K found material free of unwanted sigma phase, nitrides, and carbides with yield strengths well over 1200 MPa. Cryogenic fracture toughness testing at 77K was also conducted and K JIC values above 200 MPa.m<sup>1/2</sup> were observed. After the successful testing of the SPARC TFMC case, weld qualification was conducted for the SPARC TF coil. A semi-automated TIG welding process was developed that utilized ER316LMn filler wire and N enhancement in the shielding gas to achieve strengths and fracture toughness comparable to XM-19 base material. The data generated from the extensive TFMC studies, TF weld qualification, and challenges related to the forging size and property coupling at 4K will be presented.

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