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Extrusion process of 316LN L-shape stainless steel and manufacture process of ITER side correction coil box

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ABSTRACT

316 L N L-shape stainless steel is used in ITER Side Correction Coil (SCC) box. Finite Element Method (FEM) simulation is adopted to analyze metal flow characteristics, forecast extrusion force and ascertain extruder tonnage of 316 L N L-shape stainless steel during extrusion process. Based on simulation results, 316 L N round forged billet is used to manufacture L-shape stainless steel by extrusion process. The extrusion process includes circular furnace preheating, induction heating, glass lubrication, mould design and deformation design. 316 L N L-shape stainless steel is manufactured by Φ360 mm circular container and 60 MN horizontal extruder successfully. Mechanical properties and microstructure of 316 L N L-shape stainless steel all accord with the requirements of ITER SCC box. SCC box case is manufactured by bending, machining and welding processes. X-ray, ultrasonic testing (UT) and penetration testing (PT) are used to inspect the welding quality of SCC box case. The SCC box case passes the acceptance of ITER project expert group, this result verifies that the extrusion process and manufacture process are reasonable and feasible.

1. Introduction

The International Thermonuclear Experimental Reactor (ITER) makes use of nuclear fusion reaction of deuterium and tritium, paving the way of a safe, clean and sustainable energy [1]. The ITER magnet system is made up of four main subsystems: Toroidal Field (TF) coils, Central Solenoid (CS) coils, Poloidal Field (PF) coils, and Correction coils (CC). The CC [2] are used for the correction of error fields and include 6 Top Correction Coils (TCC), 6 Side Correction Coils (SCC) and 6 Bottom Correction Coils (BCC), as shown in Fig.1 (a). TCC and BCC are all 60° fan-shaped structures, SCC is a 40°-tile structure. The correction coils mainly consist of internal superconducting winding, middle insulation and external stainless steel coil box. The correction coils system aims to reduce the range of magnetic error fields created by imperfections in the location and geometry of the other coils used to confine, heat, and shape the plasma [3]. In order to reduce the stresses and deformations of these large size coils under electromagnetic load, all have their winding-pack enclosed inside a thick 316 L N stainless steel box.

316 L N L-shape stainless steel elements are used for SCC box, the box is manufactured by welding process of two 316 L N L-shape stainless steel elements [4], as shown in Fig.1 (b). SCC is a 40°-tile structure, which can't be obtained as a whole part, its interior is filled with insulators and superconducting windings. If the top and bottom L-shape half elements are all manufactured by welding and bending process with 316 L N plates, so many welds increase the safety risk of correction coil box. To minimize the amount of welds, the large arc parts of the top and bottom L-shape half elements are produced by extrusion process, the small arc parts of the top and bottom L-shape half elements are produced by welding process and bending process with 316 L N stainless steel plates.

SCC box consists of two 316 L N L-shape stainless steel elements (top L-shape half element and bottom L-shape half element), two elements are seal welded after the superconducting winding and insulator are putted into 316 L N coil box. The final thickness of SCC box is 20 mm, machining accuracy and geometric tolerances are shown in Fig.2, 2 mm steps are machined at welding position (similar to the welding groove). Considering the welding deformation and machining allowance, the thickness of the 316 L N L-shape stainless steel product is 35 mm.

The SCC box is split into 6 parts, as shown in Fig.3. The large arc parts (2 and 5) are manufactured with the bent 316 L N L-shape stainless steel. The small arc parts (1, 3, 4 and 6) are assembled and welded

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