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Manufacturing progress of first delivery sector of ITER vacuum vessel thermal shield

Dong Kwon Kang[a,*], Kwanwoo Nam[a], Kyoung-O Kang[a], Chang Hyun Noh[c], Wooho Chung[a], Hyeon Gon Lee[a], Kijung Jung[a], Kisuk Lim[b], Youngkil Kang[b], Manoj Panchal[c], German Perez Pichel[c], Namil Her[c], Chang Ho Choi[c]

[a] ITER Korea, National Fusion Research Institute, Daejeon, 34133, Republic of Korea
[b] SFA Engineering Corp., Asan-si, Chungcheongnam-do, 336-873, Republic of Korea
[c] ITER Organization, Route de Vinon-sur-Verdon, CS 90 046, 13067 St. Paul Lez Durance Cedex, France

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ABSTRACT

This paper describes the manufacturing progress of ITER Vacuum Vessel Thermal Shield (VVTS) sectors, which are on-going since the start of material buffing in October 2014. Fabrication of VVTS proceeds according to the following main processes: 1) plate cutting, 2) bending and forming, 3) welding, 4) flange final machining, 5) pre-assembly of 40 ° sector, 6) silver coating and 7) final acceptance test. All VVTS shell segments are to be assembled by the flange joints, which are welded to the shells. Two kinds of inspection methods are presented for the cooling pipe welding: endoscope and leak test. A specific endoscope is developed for a long welded cooling pipe. Vacuum leak test is performed in the test vacuum chamber with the helium pressurization of cooling pipe by 3 MPa, which is the same pressure differential with the operating condition of the VVTS. One of the dimensional inspection, 3D laser scanning is also described to see the effect of shape correction for the flange to shell welding. Silver coating jig design has been carried out, focusing on the electrode position. Structural analysis results are shown for the design of pre-assembly jig of 40 ° sector. Finally near term schedule of the manufacturing is summarized.

1. Introduction

Thermal Shield (TS) is one of the components in the ITER tokamak to minimize radiation heat load from vacuum vessel and cryostat to magnet structure that operate at 4.5 K. The TS consists of vacuum vessel TS (VVTS), cryostat TS (CTS) and support TS (STS). Fig. 1 shows the 3D model of VVTS 40 ° sector. The TS are cooled by 80 K pressurized helium gas, which is supplied from the cryoplant via manifold pipes. The cooling pipes are welded on the shell. The surface emissivity of the TS must be maintained under 0.05 by silver coating. ITER TS is being fabricated by the Korean supplier, SFA. The final design was approved in 2012. The manufacturing drawings of VVTS were approved in 2014. The fabrication of all the nine 40 ° VVTS sectors are on-going since the start of material buffing in October 2014.

In this paper, fabrication progress of VVTS is described, focusing on the inspection scheme and the design of fabrication jigs. Cooling pipe inspection methods such as visual inspection and leak test are shown with preliminary results. Dimensional inspection by a 3D laser scanner is performed for a VVTS outboard segment to check the shape correction after welding. Design of 40 ° pre-assembly jig is shown with structural analysis result. Finally, a fabricated silver coating jig prototype of VVTS outboard segment is briefly shown in this paper.

2. Overall status of VVTS fabrication

Fabrication of VVTS consists of the following processes: 1) material buffing (surface polishing) 2) plate cutting, 3) bending and forming, 4) flange to shell welding, 5) 2nd buffing, 6) cooling pipe welding, 7) flange final machining, 8) pre-assembly of 40 ° sector, 9) final buffing, 10) silver coating and 11) final acceptance test. The shell where the cooling tube is attached has 20 mm thickness. Details of the whole manufacturing process except silver coating and FAT are presented in the previous paper about the VVTS 10 ° mock-up fabrication [1]. Currently, material buffing/cutting and bending/forming are completed and the welding is on-going for the whole nine VVTS 40 ° sectors. Fig. 2 shows typical fabricated components of VVTS first delivery sector #6: inboard and outboard segments. Remaining works are cooling pipe welding, final machining, pre-assembly, silver coating and FAT.

* Corresponding author.
E-mail address: dkkang@nfri.re.kr (D.K. Kang).

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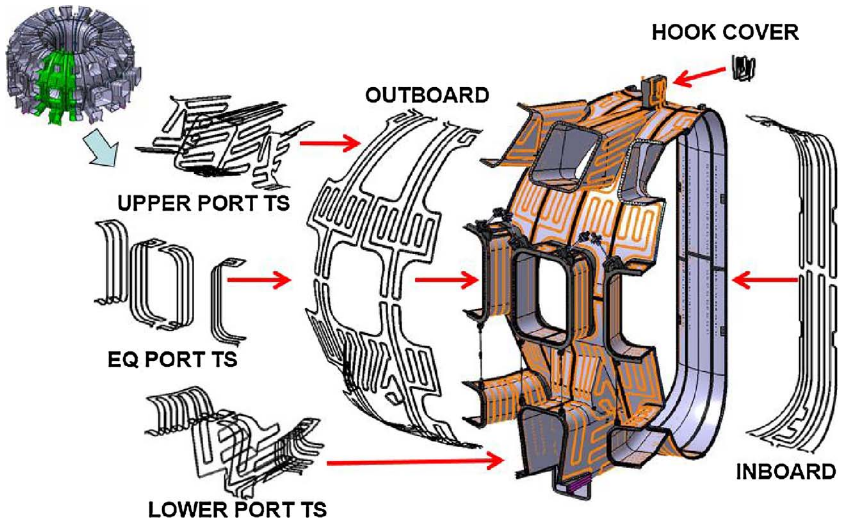

Fig. 1. ITER Vacuum Vessel Thermal Shield (VVTS).

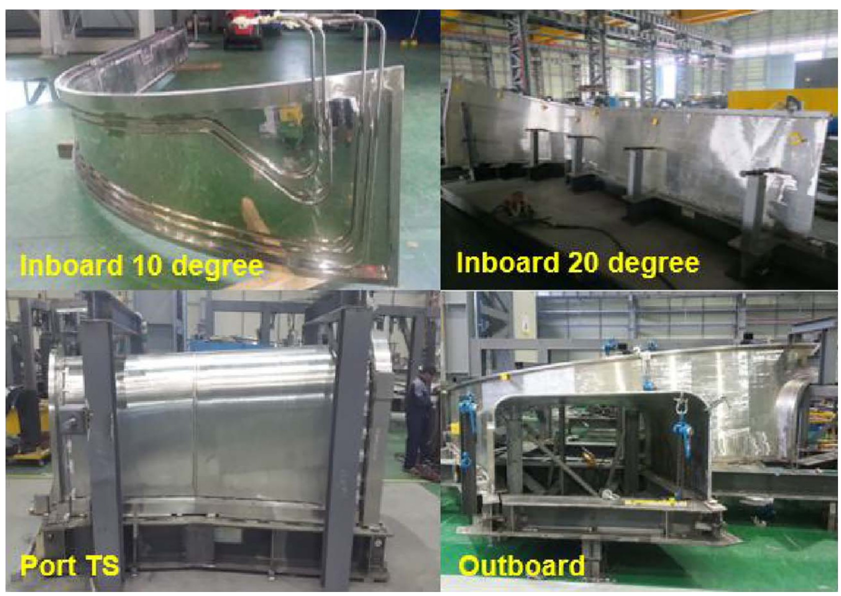

Fig. 2. Fabricated components of first delivery sector #6.

3. Dimensional inspection

Dimension of VVTS outboard upper segment is inspected by a laser scanner after welding as shown in Fig. 3. The 3D scanning is performed to check the effect of shape correction by a hydraulic jack. Scanned dimension of the upper outboard is compared with the dimension before shape correction as shown in Fig. 4. Conventional measurement by plumb bob and theodolite is used before shape correction. Flange lower face of the VVTS upper outboard is fixed at a jig during the inspection. Before shape correction, the ends of the upper flange region and the port TS shell have large deviations compared with the tolerances (flange = ± 2 mm, port shell = ± 6 mm). After applying the shape correction, deviations are reduced within the required tolerances.

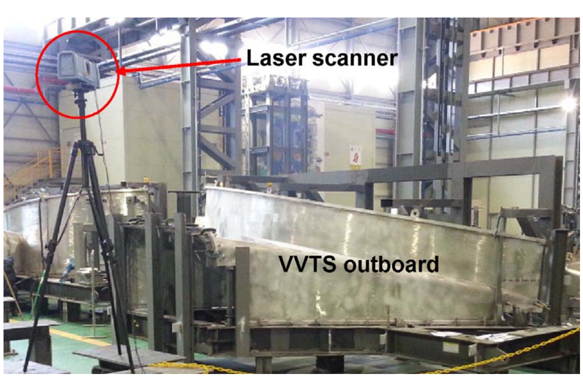

Fig. 3. 3D scanning of VVTS outboard upper segment.

4. Cooling pipe inspection

The cooling pipe is directly welded on the shell by staggered welding method (zigzag pattern) as shown in Fig. 5. The operating pressure of the helium coolant inside the pipe is 1.8 MPa. As most of the cooling pipe welding joints are inaccessible after the completion of tokamak assembly, any helium leak through the welding joints definitely cannot be repaired. Therefore 100% of cooling pipe inner surface must be checked visually by an endoscope. Burned or discolored surface is strictly not acceptable to ensure the leak tightness. Vacuum leak test is also performed after the endoscopic inspection.