Development of Manufacturing Processes for ITER Vacuum Vessel Thermal Shield through Fabrication of Full-size Mock-up for Inboard 10 degree Section

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This paper describes detailed manufacturing processes of Vacuum Vessel Thermal Shield (VVTS) for ITER tokamak through a full-scale mock-up test of inboard 10 degree section.
The VVTS is located in the narrow gap (~ 126 mm) between vacuum vessel and magnet structure in the tokamak. The height of VVTS is about 12 m and its thickness is 20 mm. The minimum tolerance requirement is so tight (~ 2 mm) that the precise manufacturing processes are indispensable. Before manufacturing the entire VVTS, a full-scale mock-up of VVTS inboard section was made in order to develop its manufacturing processes.
VVTS inboard 10 degree section consists of 20 mm panels on which cooling tubes are welded and flange joints that connect adjacent inboard sectors. The whole VVTS inboard is divided into two by bisectional flange joint located at the center. All the manufacturing processes except silver coating were tested and verified in the fabrication of mock-up.
For the forming process, forming jig was prepared and several tests were conducted to get a required 3D curved panel shape by sequentially modifying the jig dimension. Spring back effect data of the panel were obtained during the forming tests. Thickness change of the panel was measured after forming.
The cooling tube welding is critical because high pressure (18 bar) helium gas flows in the tube and the VVTS is surrounded by high vacuum environment. The direct welding of tube on the curved panel was performed after pre-qualification tests of small specimens. The cooling tube has 13.5 mm outer diameter with 2 mm thickness and its continuous length is about 12 m for the inboard 10 degree section. Optimum welding conditions are obtained with the pre-qualification tests. An endoscope was inserted in the cooling tube to examine possible burn-through or discoloration at its internal surface. Panel distortion was measured after the welding of cooling tube. Pressure test and vacuum leak test were then performed to finally check the tube welding.
The flange joint was manufactured by machining and welding. After welding of the flange and the panel, the flange surface was machined precisely in order to meet the final tolerance requirement. Assembly aspect of the mock-up was tested using a custom made assembly jig. A 3D laser scanner was used to measure the final mock-up dimensions. By comparing with the corresponding CAD data, it was found that the final dimensions meet the tolerance requirement.