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Manufacturing completion of the first ITER Vacuum Vessel Sector

Content

Shipping of ITER Vacuum Vessel (VV) Sector #6 was successfully carried out on 26 June 2020 at MIPO port in Korea. Shipping completion means manufacturing completion of the 1st ITER VV Sector for the last 10 years. The interim manufacturing progress was presented via several papers since 2010 [1~5].

Each step of the manufacturing process has been challenging as a First-of-a-Kind (FOAK). There are three main challenges to be overcome that are nuclear safety process as a French nuclear pressure vessel, 100 % volumetric inspections, and tight tolerance requirements.

The first one requires that all applicable documents shall be approved prior to actual application from Korea Domestic Agency (KODA), ITER Organization (IO) and Agreed Notified Body (ANB). It requires several qualifications, demonstrations, and certifications based on essential nuclear safety requirements. Fundamental requirement is maintains traceability for all activities as nuclear pressure vessel. All of manufacturing activities have been officially inspected and recorded with approved formats of documents. One of the most representative quality control is controlled with Manufacturing Inspection Plan (MIP) that describes all manufacturing activities and recorded main sequences with quality control plans. Each of manufacturing step has been inspected by 7 residence inspectors from Vacuum Vessel Project Team (VVPT) and ANB for manufacturing of 4 Sectors. ANB engages to review/approve all nuclear safety related documents and inspect all nuclear safety related manufacturing activities. A total of 45,000 inspection points were performed and 500 manufacturing documents, including reports, have been developed during ITER sector #6.

The second one, 100 % volumetric examination, which promises very reliable quality and simultaneously most technical challenges for this double wall full welded structure with very complicated 3 dimensional geometry that has been achieved eventually. Taking all assembly activities on sector #6 into account, the Hyundai Heavy Industries (HHI) team estimates the total length of full penetration welds at 995 meters. In order to achieve these challenging activities, total 20 welding procedure specifications, and 60 special scanning techniques of phased array ultrasonic test (PAUT) have been developed.

The third one is tight tolerances requirement. Regarding to the tight tolerances, critical manufacturing steps is final assembly. The manufactured each poloidal segment (PS) is assembled all together, and then form the D-shape structure. Final assembly is one of the most challenging work because the precise handling for final assembly is very difficult due to each PS is heavy double walled structure and it has own accumulated deformation during each PS manufacturing stage. In order to satisfy the strict tolerance requirements after final assembly, HHI team in collaboration with the Vacuum Vessel Project Team (VVPT) performed in advance a fitting virtually using actual dimensional inspection data after completion of each segment manufacturing, required dimensions for welding and expected welding deformation during final assembly via engineering analysis. Through this virtual fitting, 3 dimensional target position has been defined for each fiducial post on PS before start of actual final assembly. Fit-up for each PS has been performed on the assemble platform according to defined target position and the final assembly has been completed including upper port stub extension and lower port stub extension. In order to complete these challenging activities, new welding technique was prepared which can perform even 5~21mm wide gap configuration, and special scanning techniques of phased array ultrasonic test (PAUT) have been developed.

The qualification of the VV sector vacuum performance with respect to its safety function is a Protection Important Activities (PIA), thus Helium leak test is a part of Final Acceptance Test (FAT) of the ITER Vacuum Vessel Sector.

In general, 200 °C baking was considered to be essential to achieve the low background leak rate which make the test possible, especially considering probable contamination of the VV Sector. However, there were many risks associated with the baking, and final decision was to perform the leak test without baking. KODA/HHI checked the feasibility of the leak test by pre-pumping the VV interspace, which discovered that the background leak rate as well as the total pressure is low enough to perform the leak test. The leak test procedure which incorporated the result of pre-pumping was developed in a prompt way, and after successful completion of the Pneumatic Pressure Test with 5 bar of Nitrogen gas, which is also a part of the FAT, Helium leak test followed immediately. VV Sector as a test object is enclosed by tracer Helium gas, and the VV interspace is continuously pumped and evacuated gas is monitored by a mass spectrometer. If leak paths are present, Helium would penetrate through the paths and the mass spectrometer senses the change of the amount of Helium in the evacuated gas. Test was performed on 5 April, 2020, and the result was successful. The calculated leak rate (6.08x10-9 Pa·m3·s-1) satisfied the acceptance criteria, which is 1x10-8 Pa·m3·s-1. It is a criterion for the clean, unbaked stainless steel.

The Sector #6 was packed with double hermetically sealed using special sealing material after dimensional inspection.

ITER VV Sector #6 transportation activities are also classified as PIA according to French nuclear order. Therefore, transportation plan including quality plan and inspection plan were prepared and approved from VVPT and ANB before implementation. Inspection by VVPT and ANB inspectors was performed for the major operations based on approved documents.

After long sea transport, the Sector #6 was unloaded on 22 July 2020 at FOS in France and delivered to ITER site on 7 August 2020. Unpacking and site acceptance test including Helium leak test are going on without major issue at IO Site Assembly Hall according to the site assembly schedule.

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Figure 1: Final assembly of First sector at HHI on Aug. 2019

Figure 2: First sector completion at HHI on Apr. 2020

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