Progress on the Design of the ITER Tokamak Assembly Tools

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Abstract. Korea supplies the purpose-built tools to assemble the ITER tokamak which includes the cryostat and the components contained therein. The ITER tokamak assembly is mainly composed of lower cryostat activities, sector sub-assembly, sector assembly, ex-vessel activities and in-vessel activities. The conceptual design of the main tools for lower cryostat activities, sector sub-assembly and sector assembly has been developed to satisfy the ITER basic assembly concept. Also, a structural analysis has been performed on the assembly tools using ANSYS for the situation of an applied load with the same dead weight multiplied by 4/3 in order to take uncertainty into consideration. The results of the structural analyses for the assembly tools were compared with ASME Sec.VIII Div.2.

1. Introduction

The ITER procurement allocation among the seven parties, CN, EU, JA, IN, KO, RF and US was decided in Dec. 2005. The set of the ITER tokamak assembly tools is one of the procurement packages allocated to Korea for the construction of the ITER. The ITER tokamak assembly tools are purpose-built tools to assemble the ITER tokamak which includes the cryostat and the components contained therein. Based on the design description document by the ITER Organization, Korea has carried out the conceptual design of assembly tools. [1]

The ITER assembly tools are classified into 5 groups according to assembly procedures such as lower cryostat activities, sector sub-assembly, sector assembly, ex-vessel activities and in-vessel activities. The conceptual design of the main tools for lower cryostat activities, sector sub-assembly, sector assembly and ex-vessel activities has been developed to satisfy the ITER basic assembly concept [1]. The upending tool, the sector sub-assembly tool, the sector lifting tool and the vacuum vessel support and bracing tool for the sector sub-assembly procedures have been developed and are described herein. Also, the sector in-pit tool for sector assembly procedure has been designed and described herein. [4]

The ITER tokamak is assembled from nine toroidal field coils(TFC)/vacuum vessel(VV)/ vacuum vessel thermal shields(VVTS) 40° sectors. Each TF/VV/VVTS 40° sector is made up of 40° VV, two 20° TFCs and associated VVTS sector. The TF/VV/VVTS 40° sector components are delivered to the ITER tokamak assembly site and sub-assembled into a sector in the ITER assembly hall. Before the sectors are installed, components which cannot be installed after the final sector assembly such as the lower poloidal field coils, the lower correction coils, the lower and side correction coil feeders and the lower pre-compression rings(PCR) should be placed in their proper places on the cryostat base. After the final sector has been installed, the VVs are welded toroidally, aligned with the TFC and placed onto its permanent supports. The lower PCRs are then installed and the preload is applied to each of the TFCs. [1]

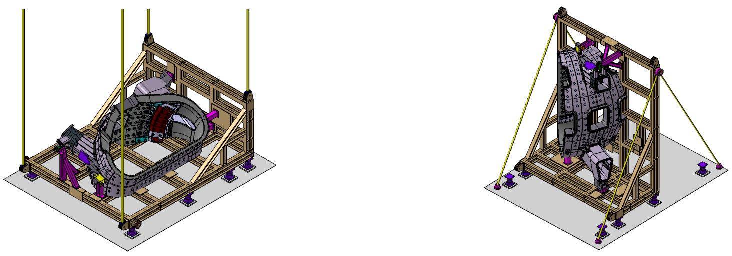
The ITER tokamak assembly tools for the sector sub-assembly are mainly utilized to integrate the VV, VVTS and TFC into the sector. The conceptual design of the upending tool, the sector lifting tool, the sector sub-assembly tool and the VV support & bracing tool for sector sub-assembly have been developed. The sector in-pit tool for sector assembly is to complete the 9 sectors into the 360° torus structure and has been designed. Also, the structural analysis of assembly tools has been performed using ANSYS for the situation of an applied load with the same dead weight multiplied by 4/3 in order to take uncertainty into consideration. The results of the structural analyses for the assembly tools were compared with ASME Sec.VIII Div.2. [4]

2. Design Progress

The function of the upending tool is to raise 40° VV sector, TFC and VVTS sectors from their horizontal position and deliver them to the assembly hall in their vertical position, which is required for the subsequent sector sub-assembly operations. The basic structure of the upending tool has been developed with the assumption that lifting will be performed with a crane which will be installed in the tokamak building. This crane will have four synchronized 375 ton hoists and perform the lifting of sector components. The upending tool is located on the floor of the ITER tokamak assembly hall, and the overall configuration is shown in figure 1. The upending tool is mainly composed of a rotating platform, a crane lug, a clamping unit, safety supporters and sling ropes. [1]

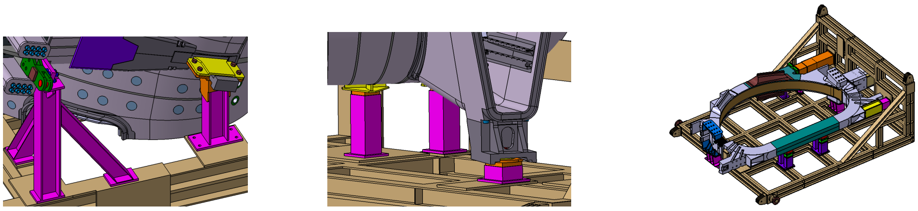
The rotating platform, size of which is 12×15×7m, is made of 430×410×20 mm square pipes, and forms a grid-type structure of transverse and longitudinal beams. The safety supporters are placed at four end-sides of the rotating platform for the horizontal safety, and prevent a possible vertical overthrow as shown in figure 1. Also, 4 sling ropes maintain the vertical position of the rotating frame before 40° VV sector, TFC and VVTS sectors are assembled with the sector lifting tool. The clamping devices fix the VV and TFC onto the rotating platform tightly, as shown in figure 2.

The structural analysis of the upending tool is to be performed using ANSYS under the applied load of dead weight multiplied by 4/3 and the results will be compared with ASME Sec.VIII div.2. For each VV and TFC, 3 cases of the rotating platform tilting angle, 0°, 45° and 90° will be analyzed.



(a) Horizontal Position *(b) Vertical Position*

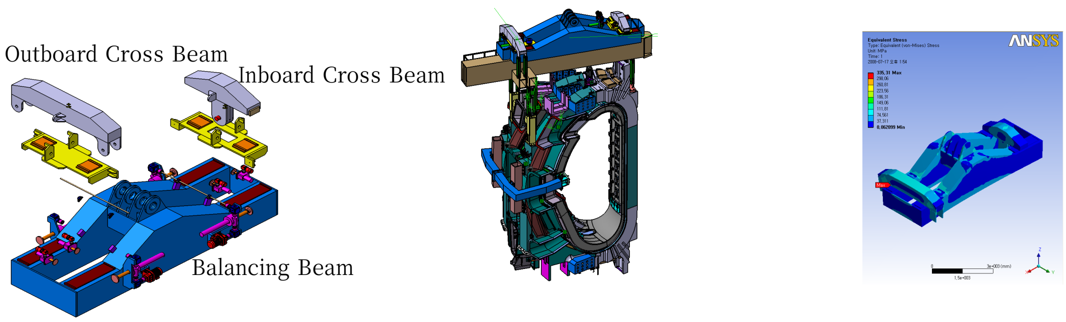
FIG 1.Upending Tool



(a) VV Inboard & Outboard Clamping *(b) TFC Clamping*

FIG 2.Clamping Device of Upending Tool

The function of the sector lifting tool, as shown in Figure 3, is to transfer sector components and the completely assembled TF/VV/VVTS 40° sector from the laydown area in tokamak building to the upending tool, and from the upending tool to the sector sub-assembly tool, and from the sector sub-assembly tool to the cryostat base installed in the tokamak pit. This tool is to be compatible with dual crane heavy lifting beam of the tokamak building crane so that it is able to accommodate the dead weight of each sector (about 1,200 tons) and install each sector in a particular direction within the tokamak pit. This tool is designed to adjust the position of a sector to minimize the difference between the center of the crane installed in tokamak building and the center of gravity of the sector. Outboard cross beam and inboard cross beam hanged with the sector feed the sector by screw jacks and electrical motors to match the center of balancing beam and that of the sector. The structural analysis of the sector lifting tool assembled with sector was carried out under an applied load of the dead weight multiplied by 4/3 using ANSYS. For the applied load, the maximum combined stress was 335MPa at the outboard cross beam and is below the allowable stress as shown in Fig. 3. [4]



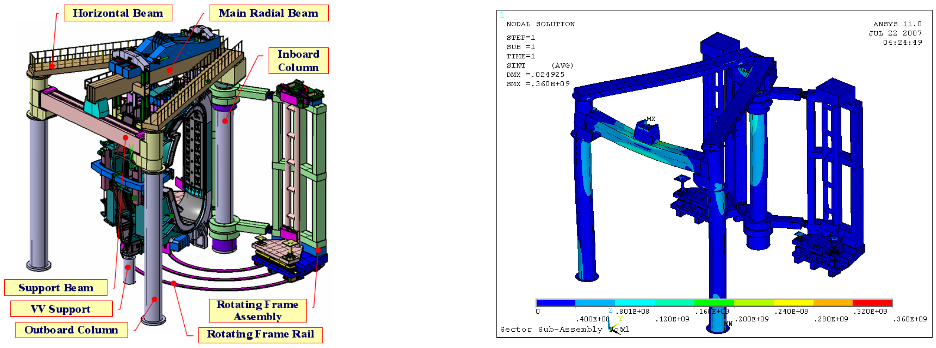
(a) Configuration *(b) Combined Stress Distribution*

FIG 3. Sector Lifting Tool

The sector sub-assembly tool on which the in-pit sector assembly procedures of the tokamak are based, integrates the VV sector, the VVTS sector, the VVTS port shrouds and TFCs into the 40° sector. The overall configuration is shown in figure 4. This tool is composed of a main structure, a rotating frame assembly, VV lower supports and aligning components to meet the required fine position control with 6 degrees of freedom. [2]

The main structure of this tool comprises 1 inboard column and 2 outboard columns which are connected with horizontal beams and the support beam. The axis of the inboard column, which is parallel to the machine center, is the reference for aligning the components in this tool. The VVTS sectors and TFCs rotate along the axis of inboard column, so that they can be assembled with the VV sector. The assembly with the two rotating frames, with which the

TFC and VVTS sectors are fixed, rotates around the VV sector to assemble the sector. The rotational precision is within ±2 mm to satisfy the tight clearances between the sector components. The assembly with the rotating frames is connected to the inboard columns and driven by the reducers and electrical motors. The base of the rotating frame assembly is equipped with the commercially available rollers, and moves along the circular rails. The assembly with rotating frames can precisely control the position with 6 degrees of freedom in order to align the TFC accurately to the VV, as shown in figure 4. The structural analysis of the sector sub-assembly tool was carried out under an applied load of the dead weight multiplied by 4/3 using ANSYS. For the applied load, the maximum combined stress was 360MPa at the slide block on the out board column and is below the allowable stress as shown in figure 4.

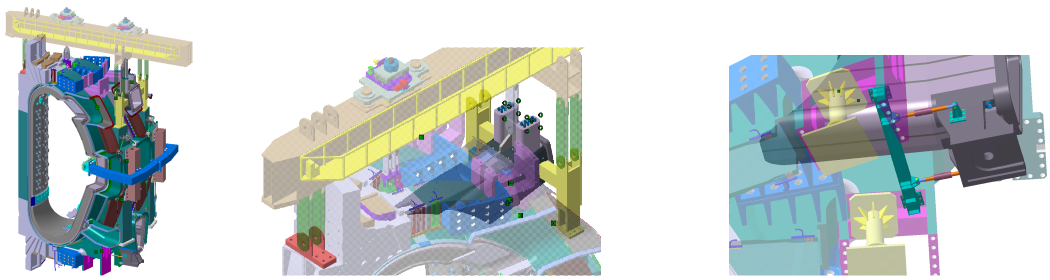


(a) Configuration *(b) Combined Stress Distribution*

FIG 4. Sector Sub-Assembly Tool

The VV support and bracing tool is to support the weight of a 40° VV sector to maintain the gap between the TFCs and the VV sector against dynamic loads before the 9 sectors are assembled into the complete torus structure. The tool comprises of the following sub-systems: the vertical support assembly, the mid-plane brace assembly and the diverter level stabilizer. The overall configuration is shown in figure 5.

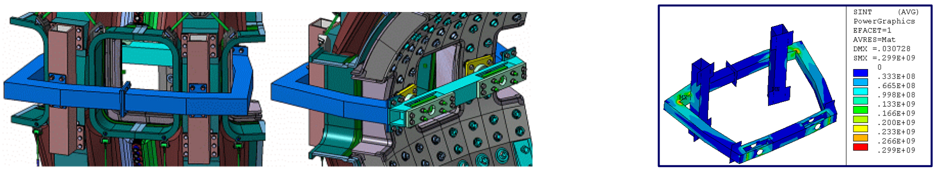
The vertical support assembly connects the radial beam with a hook at the inboard and with a link at the outboard. The outboard frame supports the end of the radial beam, and transmits the associated load to the TFC. It prevents the toroidal components from moving under the dynamic loads. The diverter level stabilizer is located below the VV diverter port, and connects the VV gravity support to the TFC. [4]



(a) Configuration *(b) Vertical Support* *(c) Diverter Level Stabilizer*

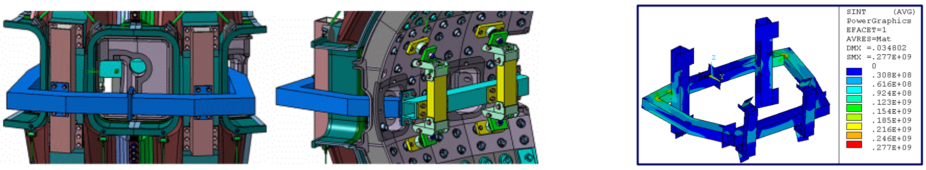
FIG 5. VV Support and Bracing Tool

The mid-plane brace assembly is the horizontal C-shaped frame which connects the outboard side of the TFC and the VV outboard inner wall. The function of the mid-plane brace assembly is to maintain the positions of radial components against dynamic loads. The mid-plane braces are classified into 4 types (A, B, C, D-type) according to the shapes of equatorial ports. Figure 6, 7 show type A, B of mid-plane brace. The structural analysis of the mid-plane brace was carried out under an applied load of the dead weight multiplied by 4/3 using ANSYS. For the applied load, the maximum combined stress distributions of type A, B of mid-plane brace are 299MPa, 277MPa respectively and are below the allowable stress. [4]



(a) Configuration *(b) Combined Stress Distribution*

FIG 6. Mid-Plane Brace of VV Support and Bracing Tool (Type A)



(a) Configuration *(b) Combined Stress Distribution*

FIG 7. Mid-Plane Brace of VV Support and Bracing Tool (Type B)

The sector in-pit tool is to support, align, and stabilize the sub-assembled 40° sectors during tokamak in-pit assembly. The configuration of this tool is shown in figure 8, where the first 40° VV/VVTS/TF sector is under installation. This tool comprises one central column and nine radial beams. Central column supports about half weights of VV sectors and TFCs, and precisely aligns TFCs. A pair of VV sector adjusting units, installed on each radial beam, hangs the 40° VV sector and aligns VV sectors to their position with TFC as points of reference. The bottom of the central column is based onto the floor of the tokamak pit and the radial beams are supported from the central column and the bio-shield. In order to evaluate the basic structural safety of the sector in-pit assembly tool, 4 cases of analysis according to the combination of assembled sectors are now ongoing. [3]

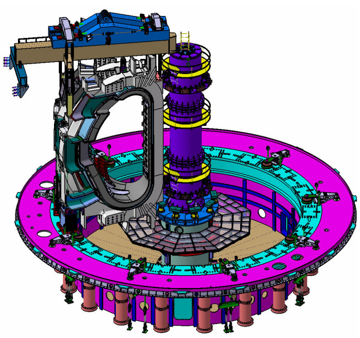


FIG 8. Sector In-Pit Tool

3. Summary

Conceptual designs of the ITER tokamak assembly tools have been developed for the upending tool, the sector sub-assembly tool, the sector lifting tool, the VV support and bracing tool and the sector in-pit tool which are based on the design concept suggested by the ITER Organization. The structural stabilities of assembly tools have been studied using ANSYS with an applied load that is 4/3 times the dead weight and the results of structural analyses for these tools are well within allowable limits.

Works continues to develop the conceptual design of the ITER assembly tools for ex-vessel and in-vessel activities by November 2008.

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