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# Design of the ITER Tokamak Assembly Tools

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## 1. Introduction

ITER (International Thermonuclear Experimental Reactor) Procurement allocation among the seven Parties, EU, JA, CN, IN , KO, RF and US had been decided in Dec. 2005. ITER Tokamak assembly tools is one of the nine components allocated to Korea for the construction of the ITER. Assembly tools except measurement and common tools are supplied to assemble the ITER Tokamak and classified into 9 groups according to components to be assembled [1].

Among the 9 groups of assembly tools, large-sized Sector Sub-assembly Tools and Sector Assembly Tools are used at the first stage of ITER Tokamak construction and need to be designed faster than seven other assembly tools. ITER IT (International Team) proposed Korea to accomplish ITA (ITER Transitional Arrangements) Task on detailed design, manufacturing feasibility and contract specification of specific, large-sized tools such as Upending Tool, Lifting Tool, Sector Sub-assembly Tool and Sector Assembly Tool in Oct. 2004. Based on the concept design by ITER IT, Korea carried out ITA Task on detailed design of large-sized and specific Sector Sub-assembly and Sector Assembly Tools until Mar. 2006 [2,3].

The Sector Sub-assembly Tools mainly consist of the Upending, Lifting, Vacuum Vessel Support and Bracing, and Sector Sub-assembly Tool, among which the design of three tools are herein. The Sector Assembly Tools mainly consist of the Toroidal Field (TF) Gravity Support Assembly, Sector In-pit Assembly, TF Coil Assembly, Vacuum Vessel (VV) Welding and Vacuum Vessel Thermal Shield (TS) Assembly Tool, among which the design of Sector In-pit Assembly Tool is described herein [2,3].

## 2. Design and Structural Analysis

The function of the Upending Tool is to upend major components (VV 40° sector, TF coil, VVTS sectors), from the horizontal orientation, in which they are delivered to the assembly hall, to the vertical orientation, in which they are required for completion of the sub-assembly and all subsequent operations. This tool is located on the floor of the assembly hall, and its overall configuration is shown in Figure 1. To evaluate the structural stability of the upending tool under dead weight and seismic loadings, 5 cases of upending tool configuration for tilting angles 0/30/45/60/89 degrees, with VV mounted, were considered. Also 2 cases of tilting angle 0 and 89 degrees were analyzed, for TFC (TF Coil) upending under dead weight. The seismic loading used in these analyses is from Cadarache in France where ITER will be constructed. For dead weight analyses of VV upending, the maximum resultant displacement was found to be 24 mm with tilting angle 0 degree. Also, the stresses were below the allowable values in dead weight case, for primary membrane and primary local stress bases except local peak stresses in the rotating platform which can be easily reduced by the local structural reinforcement. This is true for TFC upending, even though only 2 configurations of 0 and 89 degrees were analyzed. For TFC upending under dead weight load, the maximum resultant displacement was 19.6 mm for tilting angle 0 degree. For VV upending under seismic loading, the maximum resultant displacement was calculated to be 41.6 mm for tilting angle 89 degrees. The location was found to be at the rotating platform [2].

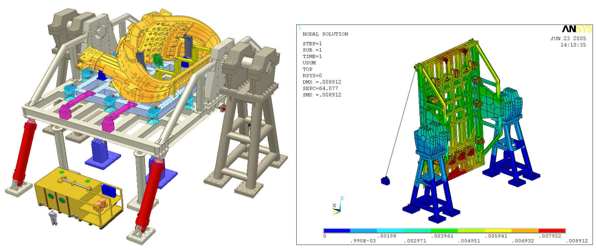

Figure 1. Upending Tool design and resultant displacement distribution (tilting angle 89 degrees).

The function of the Sector Lifting Tool, shown in Figure 2, is to transfer the completely assembled TF/VV/TS 40° sector from the Sector Sub-assembly Tool to the cryostat base installed in the Tokamak pit. This tool shall be compatible with the DCHLB (Dual Crane Heavy Lifting Beam) so that it is able to accommodate the dead weight of the assembly components (about 1,300 ton), rotate the sector at a TF/VV/TS 40° sector assembly azimuth (E-W) and install the sector with a special azimuth at the Tokamak pit. To evaluate the structural stability of the Sector Lifting Tool with VV and 2 TFCs subject to 1.6g of static load, which is equivalent to dead weight and dynamic load (seismic and handling), the finite element code ANSYS was used in this analysis. The maximum resultant displacement was calculated as 17.6 mm and it is located at the divertor level stabilizer, which is connected to the VV gravity support. Also, the maximum in membrane stress over the model was calculated as 248 MPa at the inboard region of the vertical support, whereas the maximum combined stress over the model was found to be 342 MPa at the divertor level stabilizer. It is concluded that the relevant stress types are all below the criterion adopted in this analysis, so that the Sector Lifting Tool is structurally safe against the 1.6g of static load [2].

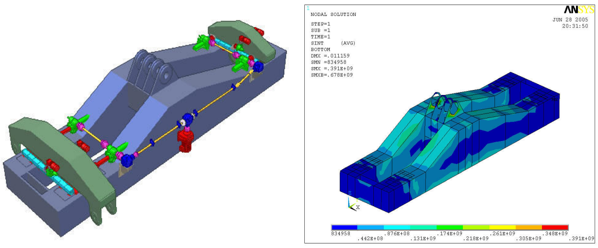

Figure 2. Lifting Tool design and combined stress distribution in the main plates.

The Sector Sub-assembly Tool, shown in Figure 3, is the device in which the VV sector, VVTS sectors, VVTS port shrouds, and TFCs are integrated to form the assembly unit (40° sector), on which the in-pit assembly procedures of the Tokamak is based. Design of Sector Sub-assembly Tool was improved to simplify assembly procedures and reduce the size by ITER IT in Oct. 2005. The width and length of the tool were reduced by approximately 1.5 m, and height by 0.7 m, respectively. Structural analysis for the improved design has not yet finished whereas it had been carried out for the previous design with dead weight [2].

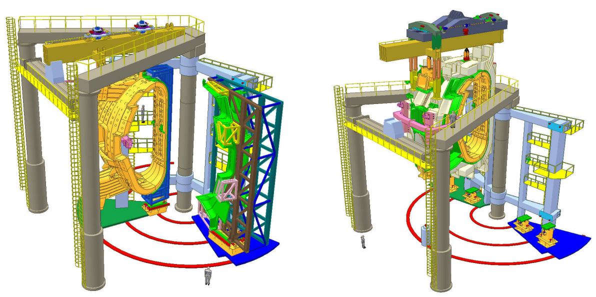

Figure 3. Sector Sub-Assembly design.

The function of the Sector In-pit Tool is to support, align, and stabilize the sub-assembled 40° sectors during Tokamak in-pit assembly. The layout of this tool is shown in Figure 4, where the first 40 degree VV/VVTS/TF sector is under installation. This tool comprises one central column and nine radial beams. Central column supports the half weights of VV sectors and TF coils and precisely aligns TF coil. A pair of VV sector adjusting units, installed on each radial beam, hangs the 40 degree VV sector and aligns VV sector position against TF coil. Optional radial brace connects the outboard region of TFC and bioshield. Bottom of the central column is supported from the floor of the Tokamak–pit. Radial beam is supported from central column and bioshield. In order to evaluate the basic structural safety of the in-pit assembly tool, a lot of analysis works have been done with 3G.author and ANSYS. To develop the upper part of central column and radial beam, a series of 3G.author runs were made. The eventual design, double-walled central column, each skin 50 mm thick and nine radial ribs of 50 mm thick, gave maximum radial bending of only 0.27 mm at four VV sectors loading. The maximum vertical bending of the radial beam, with a pair of 50 mm thick flanges and four 25 mm thick webs, was 11.7 mm at five VV sectors loading and the maximum combined stress was 227 MPa at four VV sectors loading, which was below the allowable stress. The 3G.author result was benchmarked with ANSYS run. Both results were well agreed. The development of the lower part of the central column was led by ITER IT and a series of ANSYS runs were made. The maximum displacement was 1 mm level and stresses were within the allowable values. Thus, basic safety of the central column and radial beam was confirmed [3].

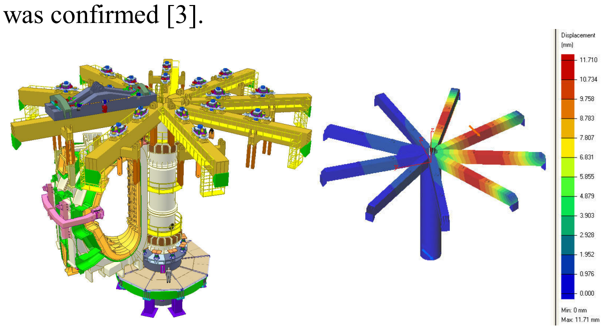

Figure 4. Sector In-pit Assembly Tool design and vertical displacement distribution (Case of four VV sectors loading).

### 3. Conclusion

Based on the concept design supplied by ITER IT, detailed design works and structural analysis on the Lifting, Upending, Sector Sub-assembly and Sector Assembly Tool were accomplished. Future work is design optimization of the Lifting, Upending, Sector Sub-assembly and Sector Assembly Tool to reduce fabrication cost and preparation of technical specification for engineering design. More detailed design and associated structural analysis of the Sector Sub-assembly and Sector Assembly Tool should be continued. Also, design and structural analysis of the other seven ITER assembly tools will be finished until Aug. 2008.

### REFERENCES


[1] ITER Council, Final Report of the ITER Engineering Design Activities, 2001.

[2] K. H. Im, et al., "The Structural Design of ITER Tokamak Sub-assembly Tools", APFA 2005, Ramada Plaza Hotel, Jeju-city, Korea, August 29-31, 2005.

[3] K. H. Im, et al., "The Structural Design of ITER Tokamak In-pit Assembly Tools", APFA 2005, Ramada Plaza Hotel, Jeju-city, Korea, August 29-31, 2005.