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# The Conceptual Design of the 40° Sector Sub-assembly Process and Tools

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## 1. Introduction

The ITER tokamak assembly tools are purpose-built tools to complete the ITER tokamak machine which includes the cryostat and the components contained therein. Based on the design description document prepared by the ITER organization [1,2], Korea has carried out the conceptual design of assembly tools [3,4]. Basically, the ITER assembly tools are classified into 5 groups according to machine 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 [5]. 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 in this paper.

## 2. Sector Sub-assembly Process and Tools

In this section, the 40° sector sub-assembly process and required tools are described. The sector sub-assembly tools include upending tool, sub-assembly tool, lifting tool and VV support and bracing tool.

### *2.1 Sector Sub-assembly Process*

Basically, the ITER tokamak machine is assembled from nine toroidal field coils (TFCs) / vacuum vessel (VV) / vacuum vessel thermal shields (VVTS) 40° sectors. Each TFCs/VV/VVTS 40° sector is made up of 40° VV, two 20° TFCs and associated VVTS sector. The TFCs/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 (PCRs) should be placed in their proper places on the cryostat base. The sub-assembled 40° sectors in assembly hall are transported to tokamak hall by lifting tool in sequential. After the final sector has been installed, the VVs are welded toroidally, aligned with the TFCs and placed onto its permanent supports. The lower PCRs are then installed and the preload is applied to each of the TFCs.

### *2.2 Upending Tool*

The function of the upending tool is to upend major components from their horizontal delivery orientation, into their vertical orientation for assembly tasks. Components that shall need upending include VV 40° sectors, TF coils and VVTS. The tool comprises of: upending frame, component interfaces (clamps, supports, component touching surfaces), man-access interfaces, and mechanical lock. Indicative representations of the upending tool orientated horizontally shown in below.

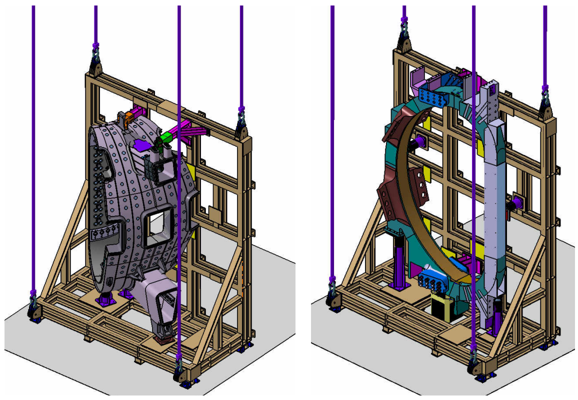

Fig. 1. The Overall Configuration of the Upending Tool

### *2.3 Sector Sub-assembly Tool*

The sub-assembly of the 40° sectors is carried out in the assembly hall, with the components in their final, vertical orientation. 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 fig. 2. 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. 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 base of the rotating frame assembly is equipped with the commercially available rollers, and moves along the circular rails.

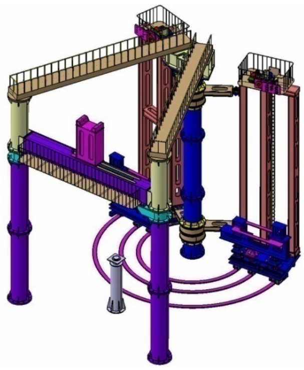

Fig. 2. The Overall Configuration of the Sector Sub-assembly Tool.

*2.4 Sector Lifting Tool*

The function of the sector lifting tool, as shown in fig. 3., is to transfer sector components and the completely assembled TFCs/VV/VVTS 40° sector from the lay-down 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 (DCHLB) 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.

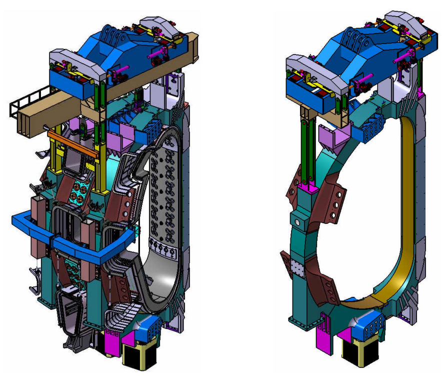

Fig. 3. The Configuration of the Lifting Tool.

*2.5 VV Support and Bracing Tools*

The function of VV support & bracing tool is to support the VV 40° sector in order to keep the gap between TF coils and VV 40° sector against dynamic loads during the handling and transportation. The tool comprises the following sub-systems: the vertical support assembly, the mid-plane brace assembly and the divertor level stabilizer. The vertical support assembly connects the radial beam with a hook at inboard while with a link-type connection at outboard. The outboard frame supports the outboard end of the radial beam, transmits the associated load to the TF coil and prevents the toroidal components from movement under the dynamic loads. The divertor level stabilizer is located below the VV diverter port and connects the VV gravity support to the TF coil. The mid-plane brace assembly is the large horizontal C-shaped frame which is bolted into the outboard side of the TF coil and VV outboard inner wall. The function of the mid-plane brace assembly is to keep the radial components against dynamic loads. The mid-plane braces are classified into 4 types because shapes of the equatorial ports differ from each other.

## 3. Conclusions

The 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 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 preliminary and detailed design of the ITER assembly tools for satisfying ITER assembly schedule and procedure.

## REFERENCES

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