Status of Preliminary Design on the Assembly Tools for ITER Tokamak Machine

Nam Kyoungo [a*], Park Hyunki [a], Kim Dongjin [a], Jaehwan Moon[b], Kim Byungseok [b], Lee Jaehyuk[b], Robert Shaw [c]
[a] *ITER Korea, National Fusion Research Institute, Gwahangno 169-148, Yuseong-gu, Daejeon, 305-806, Korea*
[b] *SFA Engineering Corp., 166 Sinhang-ri, Dunpo-myeon, Asan-si, Chungcheongnam-do, 336-873, Korea*
[c] *ITER Organization, CS 90 046, 13067 St Paul lez Durance Cedex, France*
[*] *Corresponding author: namko@nfri.re.kr*

1. Introduction

The ITER Tokamak device is principally composed of nine 40° sectors. Each 40° sector is made up of one 40° vacuum vessel (VV), two 20° toroidal filed coils (TFC) and associated vacuum vessel thermal shield (VVTS) segments which consist of one inboard and two outboard vacuum vessel thermal shields. Based on the design description document and final report prepared by the ITER organization (IO) [1,2] and conceptual design, Korea has carried out the preliminary design of these assembly tools [3-8]. The assembly strategy and relevant tools for the 40° sector sub-assembly and sector assembly at in-pit should be developed to satisfy the basic assembly requirements of the ITER Tokamak machine. Assembly strategy, preliminary design of the sector sub-assembly and assembly tools are described in this paper.

2. Assembly of ITER Tokamak machine and Tools

2.1 Assembly of the ITER Tokamak Machine

Basically, the ITER tokamak machine is assembled from nine VV/TFC/VVTS 40° sectors. Each VV/TFC/VVTS 40° sector is made up of one 40° VV sector, two 20° TFCs and associated VVTS segments. The components of VV/TFC/VVTS 40° sector are respectively delivered to ITER site and sub-assembled into a 40° sector in the ITER assembly building. The VV, TFC and VVTS are upended using the upending tool operated by tokamak main crane (maximum capacity: 1500 tonne). The components upended in vertical position are transferred to the sector sub-assembly tool using the lifting tool and associated lifting attachments. The sector sub-assembly tool is capable to integrate sector components into VV/TFC/VVTS 40° sector. Before transfer the 40° sector to in-pit, the VV support and bracing tool are assembled to keep the gap between TFC and VV against dynamic loads during the handling and transportation. The completed VV/TFC/VVTS 40° sector with VV support and bracing tool is transferred using the lifting tool into tokamak in-pit and positioned. VV/TFC/VVTS 40° sectors transferred with radial beam are placed on central column and radial beam supports. The inboard end of radial beam is supported on the upper plate of central column and the outboard end of radial beam is supported on the radial beam support which is connected with support brackets installed to bio-shield wall via anchor bolt. The simple sector sub-assembly and sector assembly scheme are as shown in Fig. 1.

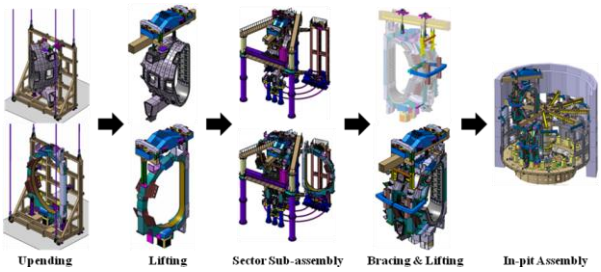

Fig. 1. Assembly sequence of the VV/TFC/VVTS 40° sectors and overall configuration of the sector sub-assembly and sector assembly tools.

2.2 Sector Sub-assembly Tools

The 40° sector is assembled at the sector sub-assembly tool which has the 6 degrees of freedom (DOF) system for fine alignment of each component. The sub-assembly of the 40° sectors is carried out in the assembly building, 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. This tool as shown in Fig. 2 is composed of main structure such as one inboard column and two outboard columns, two rotating frames, lower components supports and aligning units. Overall size of this tool is 17.7 m(L) x 19.1 m(W) x 20.9 m(H) and its weight is about 465 tonnes. To assemble the TFCs and VVTS sectors around the VV sector necessitates their rotation about an axis corresponding to the center of the Tokamak assembly. This kinematic motion must be precise due to the tight clearances between the components. Aligning system with 6 DOF motion should be applied to this tool for accurate assembly with 3 mm assembly resolution. These frames are attached to the inboard column, around which they are constrained to rotate via a pair of slewing bearings. The base of the frame is provided with roller units, driven by hydraulic moving system, to facilitate movement of the load along floor mounted, circular rails. As a key system of sector sub-assembly tool, 6 DOF system has been checked and verified by 1/5 scaled mock-up manufacturing and test.

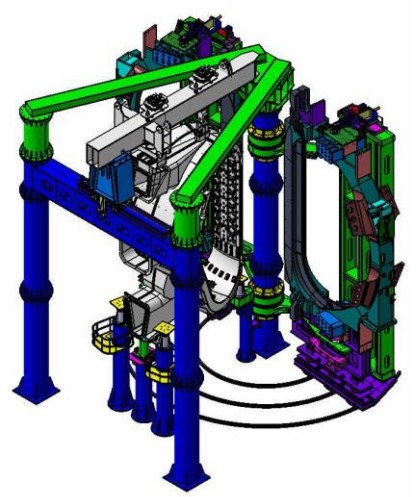

Fig. 1. Configuration of the sector sub-assembly tool.

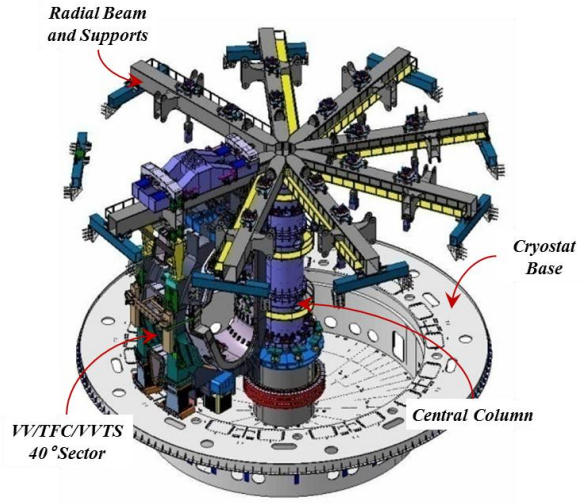

Fig. 2. Configuration of the sector assembly tools.

2.3 Sector Assembly Tools

The ITER sector assembly tools have functions to support, align, and stabilize the sub-assembled 40° sectors during final assembly and integration at tokamak in-pit. The other function of these tools as shown in Fig. 3 is to support temporarily during sector assembly and to assemble PF5 and 6 coils. These tools mainly comprise one central column, TF inner supports, nine radial beams and their supports, and PF assembly tools installed on cryostat base.

The central column with bottom cylinder was designed to endure approximately half of the dead weight of the nine VV sectors (One 40° sector is about 410 tonne in regular type.), nine VVTS sectors (One VVTS 40° sector is about 40 tonne.) and 18 TF coils (One TF coil is about 310 tonne.). TF inner adjustment devices installed in upper and lower cylinder of central column were designed to align precisely TF coil inboard. The bottom cylinder of the central column was also designed to be anchored to floor of Tokamak in-pit.

In final assembly at Tokamak in-pit, exact and accurate positioning of TF and poloidal field (PF) coils is very important to ensure that ITER Tokamak machine has high performance in operation. PF installation tools are furnished with synchronized lifting facilities to lift safely PF5 or 6 coil to each PF seats of TF at lower cryostat assembly phase.

As key alignment systems of these sector assembly tools, hydraulic operation and synchronized systems to achieve fine adjustment of TF and PF coils have been developed. Displacement control system using linear scale sensors is adopted to synchronize the system of alignment unit with solenoid valves. For verification of sector assembly tools and their functions, 1/5 scaled mock-ups have been fabricated and tested.

3. Conclusions

Based on the final report prepared by the ITER organization and conceptual design, Korea domestic agency (KODA) has carried out the preliminary designs of customized assembly tools to satisfy ITER assembly procedure, technical and functional requirements. Also, scale-down mock-ups of sector sub-assembly and sector assembly tools including VV and TFC dummies were manufactured and tested to verify their designs and their fine alignment system. The final design of these tools will be completed by the end of 2012.

REFERENCES

[1] ITER Organization, Final Report of the ITER Engineering Design Activities, 2001.
[2] ITER Organization, Design Description Document; Assembly Tooling (DDD 22), 2004.
[3] K.H. Im, et al., The Structural Design of ITER Tokamak In-pit Assembly Tools, APFA 2005, Jeju-city, Korea, August 29-31, 2005.
[4] H.K. Park, et al., Design of the ITER Tokamak Assembly Tools, Fusion Engineering and Design, Vol. 83, pp. 1583-1587, 2008.
[5] H.K. Park, et al., Progress on the Design of the ITER Tokamak Assembly Tools, 22nd IAEA Fusion Energy Conference, Geneva, Switzerland, October 13-18, 2008.
[6] K.O. Nam, et al., The Conceptual Design of Assembly Tools for the 40° Sector Assembly and Sub-assembly Process, SOFE 2009, San Diego, USA, May 31-June 5, 2009.
[7] K.O. Nam, et al., Conceptual Design and Structural Stabilities of In-pit Assembly Tools for the Completion of Final Sector Assembly at Tokamak Hall, Fusion Engineering and Design, Vol. 85, pp. 1716-1719, 2010.
[8] K.H. Im, et al., The Design of the Assembly Tools for the ITER Tokamak, SOFT 2010, Porto, Portugal, September 27-October 1, 2010.