Development of Sector Sub-assembly Tool and Mock-up Test

Nam Kyoungo [a*], Park Hyunki [a], Kim Dongjin [a], Kim Byungseok [b], Kim Kyungkyu [b], Im Kihak [c], 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 (TFCs) and associated vacuum vessel thermal shield (VVTS) segments which consist of one inboard and two outboard vacuum vessel thermal shields. The VV/TFCs/VVTS 40° sectors are sub-assembled at assembly building respectively and then nine 40° sectors are finally assembled at the Tokamak in-pit. As a fundamental assembly unit for ITER Tokamak device, the assembly strategy and relevant tools for the 40° sector sub-assembly should be developed to satisfy the basic assembly requirements of the ITER Tokamak device. Each 40° sector is assembled at the sector sub-assembly tool which has the 6 degrees of freedom system for fine alignment of components. As a key system of sector sub-assembly tool, 6 degrees of freedom system has been checked and verified by mock-up manufacturing and test.

Based on the final report and design description document prepared by the ITER organization, Korea has carried out the conceptual and preliminary designs of custom assembly tools [1]-[6]. The development of sector sub-assembly tool is described in this paper. The development of the scale-down mock-up to verify fine alignment system in sector sub-assembly tool is described also.

2. Tool Design and Mock-up

2.1 Sector Sub-assembly Tool

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. 1, 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.

The inboard and two outboard columns are connected via a pair of horizontal beams at their upper end. Two outboard columns are connected via a support beam. The support beam is located at the lower elevations of horizontal beams to allow the removal of the completed 40° sector with the limited building height. The installation of the VV sector and the removal of the completed 40° sector require the use of the overhead cranes.

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 degrees of freedom (DOF) motion should be applied to this tool for accurate assembly with 3 mm assembly resolution. The components are supported, and assembled by utilizing two rotating frames. These frames are attached to the inboard column, around which they are constrained to rotate via a pair of slewing bearings as shown the left of Fig. 2. The base of the frame is provided with roller units, driven by electrical motors, to facilitate movement of the load along floor mounted, circular rails.

In 6 degrees of freedom motion system as shown right of Fig. 2, 3 axial rotations are realized by the 3 upper hydraulic cylinders on the upper and lower spherical bearing which is providing the center of all rotations. And 3 directional movements are realized by the linear movements of the lower hydraulic cylinder operation along linear motion guide and rails which are anchored on floor of the assembly building.

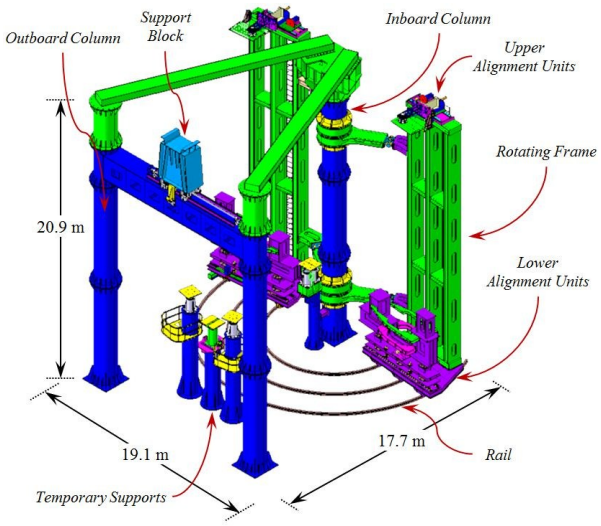

Fig. 1. Configuration of sector sub-assembly tool.

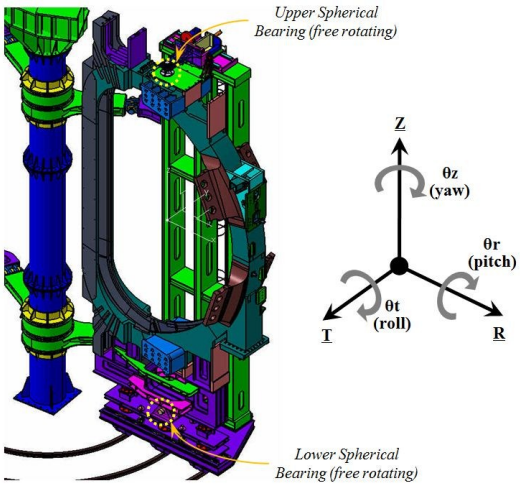

Fig. 2. Configuration of rotating frame and its 6 DOF coordinate.

2.2 Mock-up Manufacturing

The scale-down mock-up, as shown Fig. 3, of sector sub-assembly tool was manufactured for verifying 6 DOF motions system driven by hydraulic cylinders and electric motor. VV and TFC dummy were manufactured also for operation test. Mock-ups of sector sub-assembly tools including VV and TFC dummy were manufactured in the ratio of 5 to 1.

Hydraulic cylinders and electric motors as driving power source were designed to be controlled by solenoid valves and servo motors respectively. 6 DOF motions were monitored by linear scale sensors applied to appropriate positions in the system. Overall dimensions of the mock-ups is 3.5 m(L) x 3.5 m(W) x 4.5 m(H), weighing approximately 5.2 tonnes.

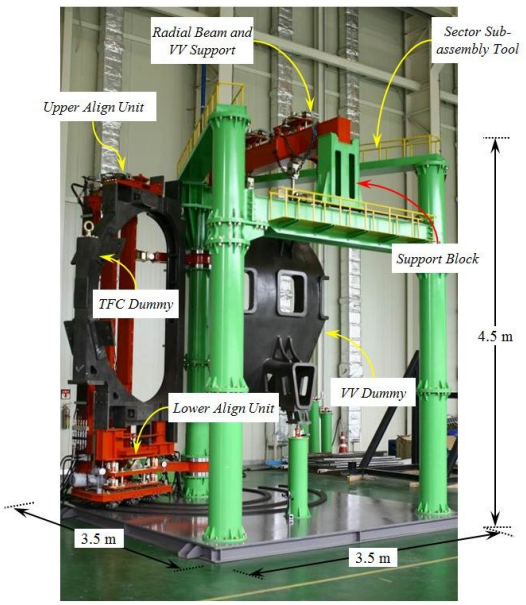

Fig. 3. Mock-up of sector sub-assembly tool and dummies of VV and TFC.

2.3 Mock-up Test

In this test, values between linear scale sensor and real measurement using dial gauge are compared for reliability of tools. All position values were measured and recorded. This result, as shown Table I, indicates that it is verified feasibility of the 6 DOF motions system for fine alignment of ITER components at sector sub-assembly phase. Also, result of mock-up test shows that deviation of each direction in test result is below 3 mm of ITER assembly resolution

Table I: Results of Mock-up Test

Direction	Input [mm] (Cylinder motion)	Output [mm] (TFC dummy motion)
Linear-R	4.94	5.16
Vertical-Z	10.65	12.50
θr	5.00	7.13
θz	5.00	5.77
θt	4.96	5.28

3. Conclusions

Based on the conceptual design suggested by the IO, the preliminary design of the sector sub-assembly tool have been developed to satisfy ITER assembly process, technical and functional requirements by KODA. Also, scale-down mock-ups of sector sub-assembly tool including dummies were manufactured and tested to verify its fine alignment system. Sector sub-assembly tool is the most important and critical tool at sector sub-assembly phase. KODA has designed the 6 DOF motions system, installed in rotating frame, for fine alignment. And this motion system was verified through mock-up test.

Preliminary design of the sector sub-assembly tools has been finished and KODA will finish the detail design by March 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 Sub-assembly Tools, APFA 2005, Korea, Aug.29-31, 2005.
[4] H. K. Park, eta al., A Conceptual Design of Assembly Strategy and Dedicated Tools for Assembly of 40° Sector, 23rd SOFE, USA, Oct.11-16, 2009.
[5] ITER Organization, Project Integration Document, 2007.
[6] H. K. Park, et al., "A Conceptual Design of Assembly Strategy and Dedicated Tools for Assembly of 40° Sector", ISFNT-9, Dalian, China, October 11-16, 2009.