# A Conceptual Design and Structural Analysis for ITER Mid-plane Brace Tools

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## 1. Introduction

The ITER, International Thermonuclear Experimental Reactor, Tokamak machine is mainly composed of 9 vacuum vessel (VV)/toroidal field coils (TFCs)/vacuum vessel thermal shields (VVTS) 40° sectors. Each VV/TFCs/VVTS 40° sector is made up of one 40° VV, two 20° TFCs and associated VVTS segments. The ITER Tokamak assembly tools are purpose-built tools to assemble the ITER Tokamak machine which includes the cryostat and the components contained therein. Based on the design description document prepared by the IO (ITER international organization) [1,2], Korea has carried out the conceptual design of assembly tools with IO cooperation [3,4]. The 40° sector assemblies attached mid-plane brace tools sub-assembled at assembly hall are transferred to Tokamak hall using the lifting tool operated by Tokamak main cranes. The sector sub-assembly tools are composed of the upending tool, the sector sub-assembly tool, the sector lifting tool and the vacuum vessel support and mid-plane brace tools. The mid-plane brace tool is assembled to inner surface of VV and TFCs in phase of sector sub-assembly after completion of all sector components. VV, TFC and VVTS are separated fully before completion of 9 sectors at Tokamak in-pit.

In this paper the mid-plane brace tools is introduced about function, structure and status of research and development are also described.

## 2. Model and Analysis

In this section the technical specifications of the mid-plane brace tools are described. Also classification and analysis result of these tools are introduced.

### *2.1 Tool Function*

The function of the mid-plane brace tool, as shown Fig 1, is to prevent the radial and toroidal clash of components due to dynamic loads (seismic and handling load) in the region of the mid-plane port.

The mid-plane brace tool is linked to inner surface of VV and outboard of each TFC. These tools are surely necessary because each component that is VV, TFC and VVTS are separated fully during transportation and handling. This system may lead to clash each component owing to relative motion of components during transportation and handling.

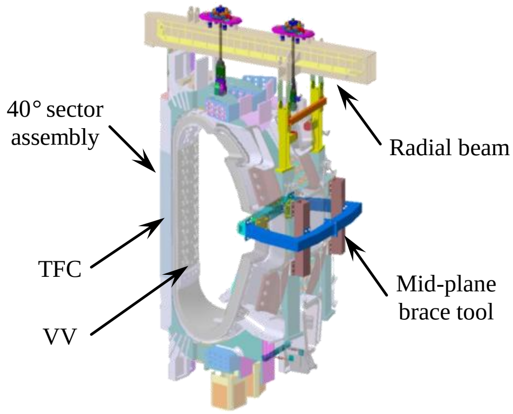



Fig. 1. Configuration of 40° sector assembly and the mid-plane brace tool.

### *2.2 Tool Structure*

The main structural components of the tool, as shown Fig. 2, are a large, horizontal, C-shaped frame that spans the 40° sector, and penetrates the lateral, equatorial level ports, and a toroidally directed, inner beam, located close to the outboard wall of the VV interior. The C-shaped frame is split at the toroidal mid-plane of the sector, and the two halves are connected via a bolted flange pair. The frame is connected to the PF3/PF4 attachment plates, via a pair of brackets.

In the port region the available space is restricted, because of the need to access the upper and lower walls of the port stub, to weld the poloidal field joint of the VV, and to access the rear side of TF IOISs (Intermediate Outer Intercoil Structures). The C-frame, thus, has a heavy, compact section. A view of the tool installed on the sector is shown in Fig. 1.

The region of the outboard VV inner wall where the inner beam attaches is highly congested, so the design concept of tool is to use a number of the sockets by which the blanket modules are subsequently attached, to connect the tool. The connection to the wall is made via 2 groups of 4, "solid" stub connectors that screw into the blanket module sockets, and engage in the bore of the socket. To these bushes, a handed pair of rectangular brackets are engaged, and bolted. The inner beam is connected to the rectangular bracket via a spherical bearing to enable the angular adjustment between blanket module sockets and inner beam. Size of A-type brace tool is 7.1 m(L) x 4.8 m(W) and dead weight is about 27 tonne.

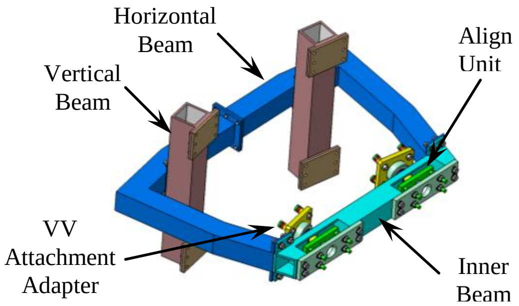
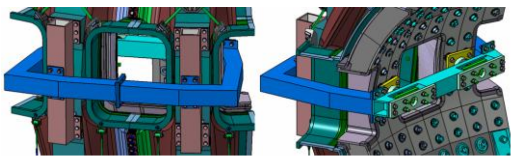



Fig. 2. Configuration of mid-plane brace tool.

### *2.3 Tool Classification*

The mid-plane brace tools are large horizontal C-shaped frames which have four different shapes, as shown Fig. 3, to be compatible with the four kinds of different shapes for the equatorial ports of vacuum vessel. A-type could be applicable that right and left equatorial port are opened perfectly. B-type could be applicable that middle and left port are opened irregularly and narrowly. C-type could be applicable that middle port is opened irregularly and narrowly, right and left port are closed perfectly. And D-type could be applicable that middle and right port are opened perfectly, left port is closed perfectly.



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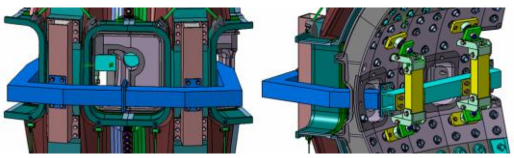

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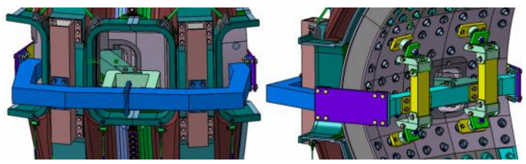

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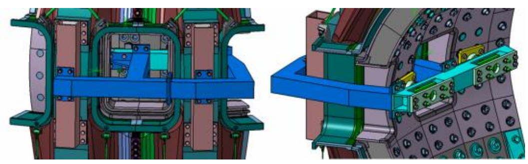
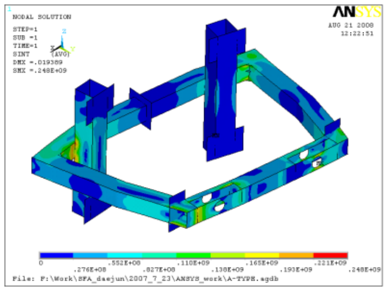


(d)

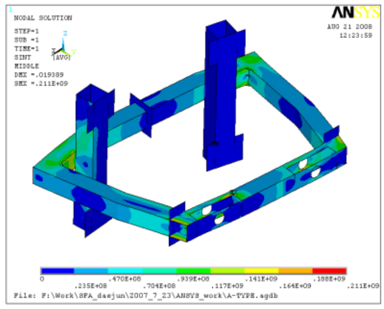
Fig. 3. Classification of the brace tool; (a) A-type, (b) B-type, (c) C-type and (d) D-type .

### *2.4 Structural Analysis*

The structural stabilities for the mid-plane brace tools have been studied and verified using ANSYS code with an applied load that is 4/3 times the dead weight and the results of structural analyses for these tools are within allowable limits. Stress intensity results of A-type mid-plane brace tool are shown in Fig. 4. Shell elements are used in this analysis.



(a)



(b)

Fig. 4. Stress intensity of ANSYS analysis; (a) Pl+Pb (b) Pm

## 3. Conclusions

The conceptual designs of mid-plane brace tools have been developed. The design of these tools developed by ITER Korea satisfied ITER assembly plan and technical requirements for 40° sector. Also it was verified that the structural stabilities maintain sufficiently to secure assembly tolerance, structural strength and geometrical requirements requested by IO. Work continues to develop the detail design of the ITER assembly tools by May 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.