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Structural analysis for final design of ITER sector sub-assembly tool

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HIGHLIGHTS

- The structural analyses of the load combinations are performed for the SSAT.
- The use of single point mass for the major component is validated by the comparative study.
- The results of stresses are confirmed to meet the design criteria.

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ABSTRACT

The Sector Sub-assembly Tool is a special tool for assembly of ITER Tokamak and is used to sub-assemble the 40° Tokamak sector which consists of vacuum vessel sector, vacuum vessel thermal shield sector and two toroidal field coils. The sector assembled in the assembly building is a basic and fundamental unit for the construction of the ITER Tokamak. The functions of the Sector Sub-assembly Tool are to support and handle heavy components which weigh up to 1200 t. The Sector Sub-assembly Tool is one of the most important tools to perform the assembly of ITER. To assess the design and structural integrity of the Sector Sub-assembly tool, the structural analyses have been performed under the load combinations according to load specifications. The results of the structural analyses show that the stresses of the Sector Sub-assembly Tool are below the allowable stress. This paper provides briefly the result of structural analysis for the Sector Sub-assembly Tool.

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1. Introduction

ITER Tokamak assembly is mainly composed of lower cryostat activities, sector sub-assembly, sector assembly, in-vessel activities and ex-vessel activities [1]. The Sector Sub-assembly Tool, the Upending Tool, Sector Lifting Tool, Vacuum Vessel Support and Bracing Tools are required to implement sector sub-assembly procedures. Sector sub-assembly is to integrate 40° Tokamak sector which consists of vacuum vessel sector (VV), vacuum vessel thermal shield sector (VVTS) and two toroidal field coils (TFC). The 40° sector assembled in the assembly building is a basic and fundamental unit for the construction of the ITER Tokamak. Therefore, the Sector Sub-assembly Tool (SSAT) is one of the most important tools to complete the assembly of ITER Tokamak. The structural analyses have been performed including deadweight, payload and horizontal loads according to the load specification [2] and relevant EN standards [3,4] in order to assess the structural stress of the Sector Sub-assembly Tool. For the structural analysis, the main components are considered by the point mass element. In order to validate the use of point mass method, the comparative study has been performed. This paper provides briefly the results of the structural analyses for the SSAT.

2. Design description

The SSAT is composed of main structure, two rotating frames, and lower component supports including rail system and aligning units. Overall size of this tool is 16.7 m (L) × 16.5 m (W) × 22.6 m (H) and weight is about 820 t, respectively. The configuration of the SSAT is shown in Fig. 1. The main structure of the SSAT comprises three columns, two horizontal beams and support beam. The function of the main structure is to support the main components (VV, VVTS, TFCs) including the radial beam. Two rotating frames have an alignment function with the hydraulic pressure system to assemble the two TFCs and the VVTS segments [5]. In order to align the TFCs and VVTS segments in their final position, 6-DOF (three translation

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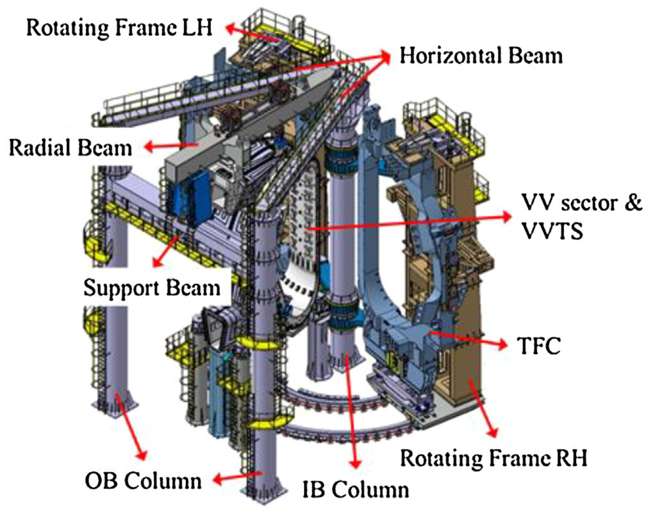

Fig. 1. Configuration of the Sector Sub-assembly Tool.

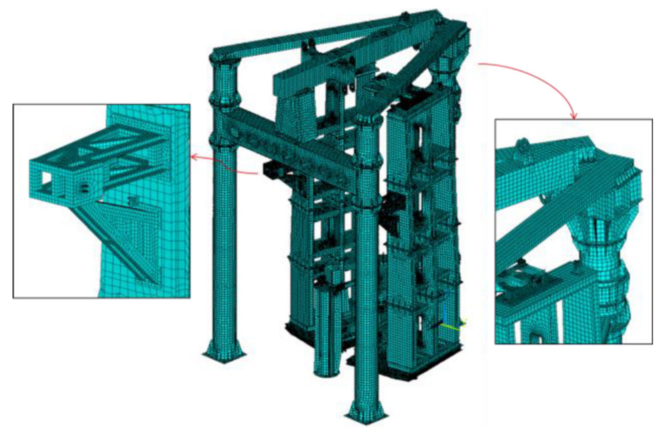

Fig. 2. FE model of the Sector Sub-assembly Tool.

DOF: radial, toroidal, vertical direction, three rotational DOF: θr, θt, θv direction) alignment system is required. Therefore, the rotating frame has three alignment units which are the upper align unit, the middle align unit and the lower align unit including the spherical bearings. The upper align unit has θr align cylinder and θt align cylinder. The middle align unit has θv align cylinder. The lower align unit has vertical align cylinder and radial align cylinder. The roller units under the bottom of the rotating frames are installed with Hilman rollers and a hydraulic skidding system to move the frame from initial position to the final position in toroidal direction [6].

The VV including the radial beam is installed on the main structure. Then, VVTS inboard and outboard segments are assembled with temporary support by the rotating frames. Two TFCs are assembled by the rotating frames. Then, inter-coil structures are installed and the VV-VVTS-TFCs are braced by the bracing tools. After completion of sub-assembly, the sector is transferred to the TOKAMAK pit.

3. Finite element model

The structural analyses for SSAT are carried out using the commercial ANSYS code which is based on the Finite Element Method (FEM). Most of SSAT structures consist of thin plate. Thus, most of SSAT structures are modelled using the shell elements. All shell surfaces are offset to the middle surface of the geometry. For some parts such as Rail, Radial Beam IB Pin, VV vertical Rod and etc. that could not be generated the finite element (FE) model using shell element, the solid and the beam elements are used. And also, contact/target elements and joint elements are used in order to distribute or transfer forces of displacements between unconnected parts. The mass element is used for the payload (VV, VVTS and TFCs) with their mass and rotational inertias. FE model of the SSAT is shown in Fig. 2.SM490 YB of KSD 3515 [7] is considered for the main structure and rotating frames. SCM440 of KSD 3867 [8] is applied to the pin, shaft in SSAT. The equivalent materials are S355 of EN 10025-2 and 42CrMo4 of EN 10083-3, respectively. The material properties used in this analysis are summarized in Table 1.

Table 1
Material property for SSAT.

Material	Density [kg/m^3]	Elastic modulus [GPa]	Poisson's ratio	Yield strength [MPa]
SM490 YB	7850	206	0.3	355
SCM440	7850	206	0.3	500

Table 2
Load combinations for SSAT.

Part	Classification	Load Combinations		Allowable Stress
Main Structure	Steel Structure	LC1	DW + PL	0.91xF$_y$
		LC2	PF$_G$·DW + PF$_{Q1}$·(DF$_S$)·PL + PF$_{Q2}$·HL$_S$	
		LC3	DW + PL + SL-1	
Rotating Frame	Lifting Table	LC1	DW + PL	0.66xF$_y$
		LC2	PF$_G$ ·DW + DF$_T$·PL + HL$_T$	
	Steel Structure	LC3	DW + PL + SL-1	0.91xF$_y$

DW: Dead weight of SSAT.
PL: Payload (mass of VV: 450 t, VVTS: 30 t, TFCs: 2 × 311 t).
DF$_S$: Dynamic factor for steel structure, equal to 1.15 [3].
DF$_T$: Dynamic factor for lifting table, equal to 1.4 [4].
HL$_S$: Horizontal load for steel structure, 0.05 g [3].
HL$_T$: Horizontal load for lifting table, 0.1 g [4].
PF$_G$: Partial factor for dead weight, equal to 1.35 [3].
PF$_{Q1}$, PF$_{Q2}$: Partial factor for variable load, equal to 1.35 [3].

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