Fusion Engineering and Design xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Fusion Engineering and Design

journal homepage: www.elsevier.com/locate/fusengdes

Final design and mock-up of an ITER sector sub-assembly tool

Kyoungo Nam [a,*], Min-Su Ha [a], Jinho Bae [a], Soun Pil Kwon [a], Jaewhan Moon [b], Jihye Park [c], Jihoon Noh [b], Chanhyung Park [d]

[a] National Fusion Research Institute (NFRI), 169-148 Gwahak-ro, Yuseong-gu, Daejeon 34133, Republic of Korea
[b] SFA, 262 Yunposun-ro, Dunpo-myeon, Asan-si, Chungnam 31421, Republic of Korea
[c] TSNE, 27 Seongsui-ro 7-gil, Seongsu-dong, Seongdong-gu, Seoul 04780, Republic of Korea
[d] MOROO Inc., 52-8 Oecheoncheoksan-gil, Nami-myeon, Cheongju-si, Chungcheongbuk-do 28182, Republic of Korea

ARTICLE INFO

Article history:
Received 9 December 2015
Received in revised form 15 February 2016
Accepted 19 February 2016
Available online xxx

Keywords:
ITER
Tokamak
Sector
Sub-assembly tool
ANSYS
Mock-up

ABSTRACT

The assembly and installation tools for the ITER Tokamak machine are special tools which are used to assemble and install ITER Tokamak machine components such as magnets, vessels and thermal shields. The sector sub-assembly tool, requiring six adjustable motions capable of movements in three directions and three-axis rotations for fine and precise alignments of the components of these tools, is a major and very large assembly tool with which to assemble vacuum vessels, thermal shields and two toroidal field coils in a 40° sector that forms the basic unit for the ITER Tokamak machine. To complete the 40° sector, the tool must maintain a sufficient degree of stiffness to support and handle heavy components which weigh up to 1200 tonnes. To meet the tooling requirements, the feasibility of the alignment system with regard to component adjustments in the sector sub-assembly tool was reviewed and verified in a mock-up test. In addition, a structural analysis using ANSYS to verify the structural stability levels under various analysis conditions was also carried out considering the safety factors and seismic load conditions according to the load specifications and codes. The sector sub-assembly sequence and the final design considering the results of the mock-up test and the structural analysis are presented.

1. Introduction

Based on designs by the ITER organization [1], the Korea Domestic Agency (KODA) has implemented the conceptual design of specific assembly tools as defined in the ITER Tokamak assembly procedure [2]. The final design of the sector sub-assembly tool (SSAT), an important tool necessary to complete the sector sub-assembly procedure, and the related sequence were approved through a design review in 2014. Essentially, the ITER purpose-built assembly tools provided by KODA are classified into five sub-assembly groups according to the ITER assembly plan. These are the lower cryostat assembly, the sector sub-assembly of nine sectors at the assembly building, the sector assembly at the in-pit for integration into a complete torus machine, the ex-vessel assembly after all sectors are completed, and the in-vessel assembly for blankets. Conceptual designs of major tools such as upending, lifting and heavy handling tools for the ITER Tokamak machine have been developed to realize the ITER basic assembly concept [3,4].

An ITER Tokamak machine with a torus configuration is fundamentally composed of nine units of 40° sectors. Therefore, the sector assembled in the assembly building is a basic and fundamental unit for the construction of the ITER Tokamak machine. The SSAT of various tools to complete the sector sub-assembly procedure is an important component in which the vacuum vessel (VV) sector, VV thermal shield (VVTS) segments, VVTS port shrouds, and toroidal field coils (TFC) as well as various intercoil structures are integrated to complete the basic assembly unit (that is, the 40° sector), as shown in Fig. 1, on which the in-pit assembly of the Tokamak is based. To assemble the components into a complete 40° sector, the SSAT should be designed to meet the following functions: support the full assembly of the sector, operate and handle the component with six degree-of-freedom (DOF) motions for an accurate installation and assembly, and support of the VV and TFC temporarily. The VVTS and its segments are temporarily supported on the VV and finally the TFC with their temporary supports before the lifting procedure.

This paper describes the final design, including the function and structure of the SSAT. The final design of the tool covers the structural analysis by ANSYS considering the safety factor and the seismic load condition. The fabrication and a test of the mock-up

* Corresponding author.
E-mail address: namko@nfri.re.kr (K. Nam).

http://dx.doi.org/10.1016/j.fusengdes.2016.02.066
0920-3796/

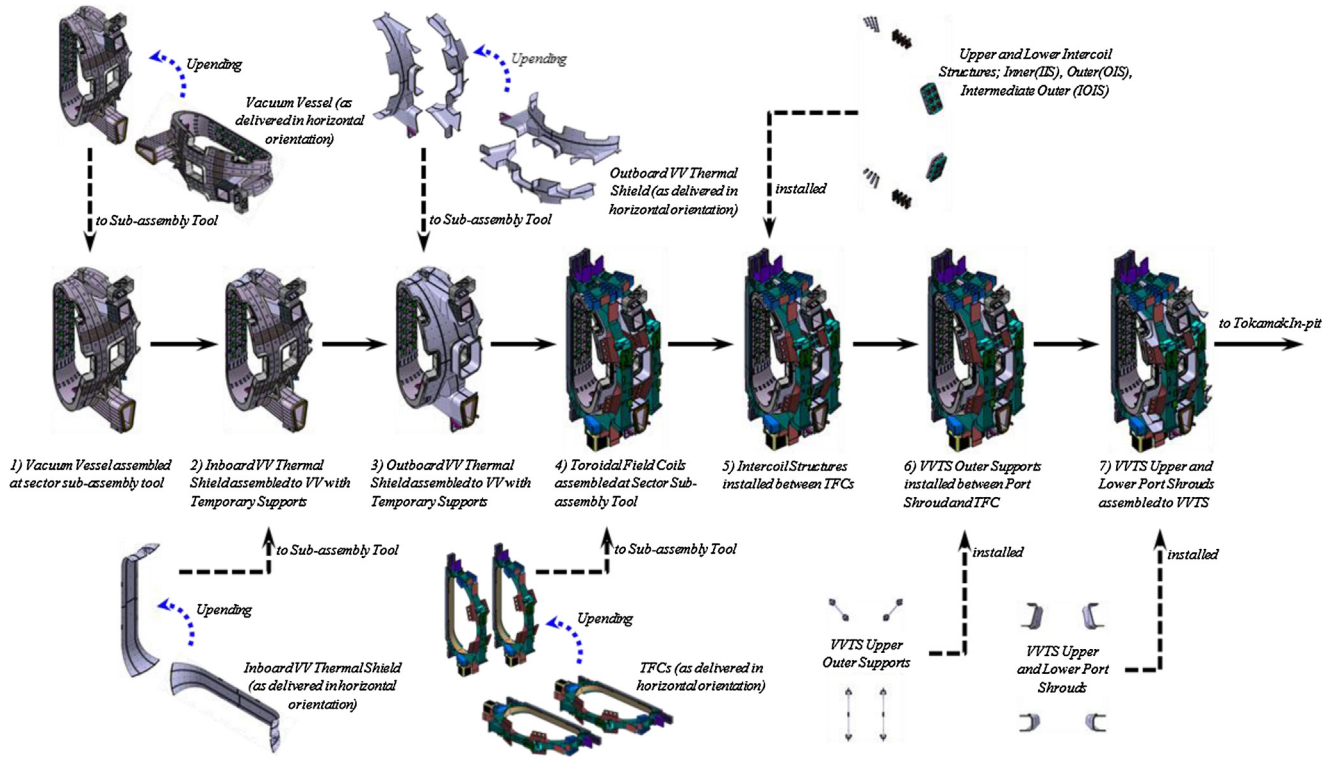

Fig. 1. Overall sequence and procedure for the sector sub-assembly with the VV, VVTS segments, VVTS port shrouds and the two TFCs, including their intercoil structures.

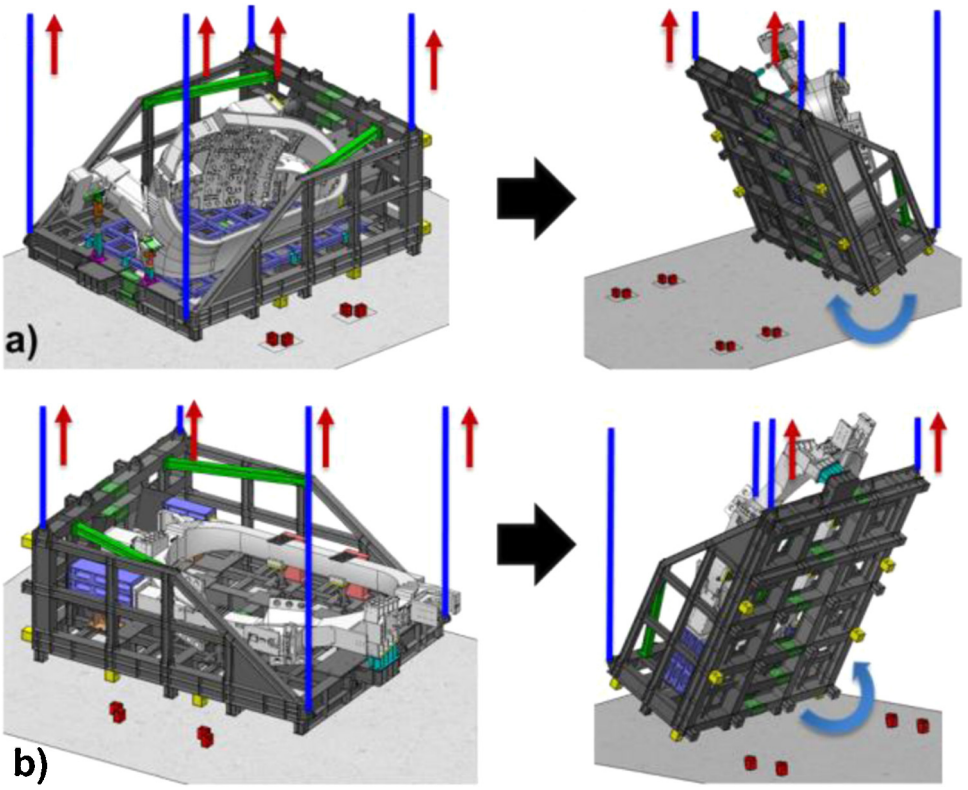

Fig. 2. Upending procedure for (a) VV and (b) TFC using upending tool operated by cranes.

fabricated here to verify the fine and precise alignment accuracy of the six degrees of freedom in the SSAT are described as well.

2. Sector sub-assembly tool

The sub-assembly sequence and procedure to complete the 40° sectors in the assembly building are implemented in the SSAT

Please cite this article in press as: K. Nam, et al., Final design and mock-up of an ITER sector sub-assembly tool, Fusion Eng. Des. (2016), http://dx.doi.org/10.1016/j.fusengdes.2016.02.066