The Overview on the Assembly Process and the Conceptual Design of the Major Assembly Tools for the ITER Tokamak Assembly

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1. Introduction

As a Korea Domestic Agency (KO-DA) of the International Thermonuclear Experimental Reactor (ITER) project which is a joint international research and development project that aims to demonstrate the scientific and technical feasibility of fusion power, National Fusion Research Institute (NFRI) has a responsibility of the 10 in-kind procurements for the ITER project. The set of the ITER tokamak assembly tools is one of the procurement packages allocated to Korea for the construction of the ITER. The ITER tokamak assembly tools are purpose-built tools to assemble the ITER tokamak which includes the cryostat and the components contained therein. This paper describes the assembly process and the conceptual design of the tokamak assembly tools which is developed with ITER Organization (IO) [1,2].

2. Assembly Process and Tools

In this section, ITER tokamak machine, assembly process and tools to meet the requirements of machine assembly are described each article. The assembly tools include lower cryostat activities tools, sector sub-assembly tools, sector assembly tools, ex-vessel and in-vessel activities tools.

2.1 ITER Tokamak Machine

The ITER tokamak machine is assembled from nine toroidal field coils (TFCs) / vacuum vessel (VV) / vacuum vessel thermal shields (VVTS) 40° sectors. Each TFCs/VV/VVTS 40° sector is made up of 40° VV, two 20° TFCs and associated VVTS sector which consists of one inboard (IB) and two outboard (OB) thermal shields. The ITER tokamak machine, also, includes cryostat, central solenoid (CS), ports, correction coils (CC), poloidal field coils (PFCs) and associated feeder and piping.

The major components of the tokamak are the superconducting toroidal and poloidal field coils which magnetically confine, shape and control the plasma inside a toroidal vacuum vessel. The magnet system comprises toroidal field coils, a central solenoid, external poloidal field coils, and correction coils. The centering force acting on the D-shaped toroidal magnets is reacted by these coils by wedging in the vault formed by their straight sections. The TF coil windings are enclosed in strong cases used also to support the external PF coils. The vacuum vessel is a double-walled structure also supported on the toroidal field coils. The magnet system together with the vacuum vessel and internals are supported by gravity supports, one beneath each TF coil. The sets of superconducting coils generate the magnetic configuration to confine and control the plasma in vacuum vessel of the machine. Fusion power is produced by fusion reactions taking place in the plasma. The section view of the ITER tokamak machine is shown as below figure.

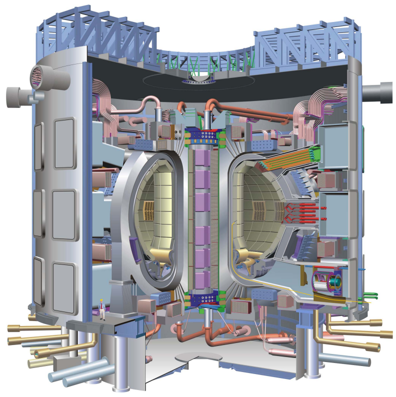

Fig. 1. The Section View of the ITER Tokamak Machine.

2.2 Assembly Process

The tokamak is assembled from 9 sectors, each with a toroidal angle of 40°, and comprising a sector of VV, two TF coils, the associated VV thermal shield, and two VV gravity supports, which provide both the vertical support and lateral stabilization to the VV in the completed tokamak. The components are delivered to the site individually, and sub-assembled into sectors using purpose built jigs and fixtures in the assembly hall. Prior to installing the sectors in the tokamak pit, the tokamak gravity supports, lower cryostat sections, and the components which cannot be installed following final assembly of the sectors, principally the lower PF coils, lower correction coils, the lower CC feeders, and the lower pre-tensioning rings, are installed, or placed in the pit. The sectors are transferred to the pit sequentially. The TF coils and VVTS sectors are connected in the same sequence, whereas the VV sectors are joined (welded) according to a plan which aims to minimize deformations, and the associated technical risk. Following installation of the final sector, the TF coil pre-tensioning rings are installed, and the preload applied to each of the coils. A detailed dimensional survey at this stage provides the geometrical estimate of the magnetic datum for the as-built TF magnet, and these are used as reference for all subsequent installation operations. The VV is closed toroidally, with the welding of near-diametrically opposite joints. Clean conditions are then established inside the vessel, and the installation of the in-vessel systems is completed. The completion of the installation of the ex-vessel components proceeds in parallel. The overall assembly process of the tokamak machine is shown as below figure.

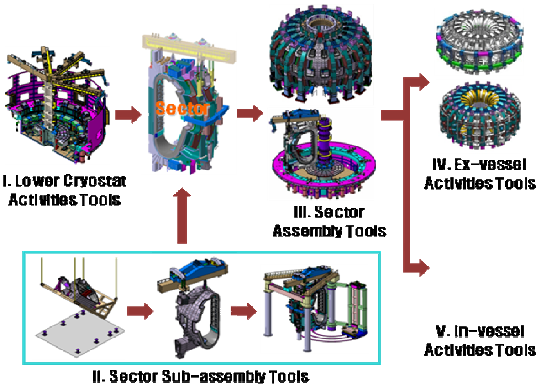

Fig. 2. The Overall Assembly Process and Classification of the ITER Tokamak Machine.

2.3 Assembly Tools

To complete the assembly, both specially designed, purpose-built tools, and standard, commercially available equipment will be required. To support the assembly process, a number of services; metrology, metallurgy, beryllium control, health physics and occupational safety, will either be established, and provided at the site, or furnished via contract to a specialist, off-site, supplier. Additionally, a number of major site facilities will be made available for the duration of the assembly operations. In these items, the KO-DA should procure all purpose-built tools to ITER site. The ITER assembly tools are classified into 5 groups according to assembly process such as lower cryostat activities, sector sub-assembly, sector assembly, ex-vessel activities and in-vessel activities. Based on the design description document by the ITER organization, Korea has carried out the conceptual design of assembly tools [3,4]. The conceptual design of the main tools for lower cryostat activities, sector sub-assembly, sector assembly and ex-vessel activities has been developed to satisfy the ITER basic assembly concept [5]. The in-vessel staging design of tools for in-vessel activities has been merely studied so far. The tool list for the ITER machine assembly is shown as table I. The purpose-built tools which are supplied by the KO-DA are classified into 9 groups according to tokamak components. These tools should be supplied in appropriate time to ITER site through test and inspection by the KO-DA.

Table I: The Tool List for the ITER Machine Assembly

No.	Assembly Tool
1	Sector Sub-assembly Tools
2	Sector Assembly Tools
3	Cryostat Assembly Tools
4	CTS Assembly Tools
5	PF Coil Assembly Tools
6	Port and Piping Assembly Tools
7	CS Assembly Tools
8	CC and Feeder Assembly Tools
9	In-vessel Assembly Tools

3. Conclusions

The conceptual design of the major tools is well advanced; the scope of the design activities now needs to be extended to include the minor tools; the design of all the tools must be reviewed site selection, when the applicable codes and standards will be defined, and may be incorporated into the design of the tools; the preliminary and detailed design for the assembly tools are carried out sequentially.

REFERENCES

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