24P108-P

Study of JT-60SA tokamak assembly
JT−60SA トカマク本体の組立検討

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The JT-60SA tokamak, which is a large superconducting tokamak, needs to be assembled consistently with high precision; assembly of the JT-60SA tokamak has been studied. The absolute coordinate system for the assembly is defined on the basis of the coordinate system of the JT-60 torus hall. The origin ((x, y, z) = (0, 0, 0)) of the absolute coordinate system is defined to be the center of the VV in the plasma operation. A consistent global scenario of the assembly is studied. Assembly procedures and tools for major components such as the TFCs are studies.

1. Introduction

The JT-60SA project is a combined project of Japan-EU satellite tokamak program under the Broader Approach agreement and Japan domestic program. In the JT-60SA project, the JT-60U tokamak is replaced with a full superconducting tokamak. Substantial major components of the JT-60SA tokamak, such as the cryostat base, vacuum vessel (VV), equilibrium field coils (EFCs), and so on, have already been in the process of manufacture. We have been studying the JT-60SA tokamak assembly toward commencement of the assembly, which is planned around the end of 2012 [1]. This paper presents study of the absolute coordinate system and metrology for the assembly, global assembly scenario, and assembly procedures and tools of major components.

2. Absolute Coordinate System and Metrology

From requirements of physical experiment and operation, the JT-60SA tokamak needs to be assembled with very high precision. For assembly of such a large complex system with high precision, it is an important key to define a solid absolute coordinate system and measure the precise positions of the components consistently.

The absolute coordinate system of JT-60SA is defined on the basis of the coordinate system of the JT-60 torus hall, as shown in Fig.1. The origin ((x, y, z) = (0, 0, 0)) of the absolute coordinate system is defined to be the center of the VV in the plasma operation, which is 8000 mm above the floor of the JT-60 torus hall. The VV temperature is 323K in the operation, since borated water at a temperature of 323K is circulated between the double walls of the VV for neutron shielding. In consideration of the thermal expansion in the operation, the VV midplane is leveled at z = -2 mm in the assembly.

As the original reference points for metrology, four points on the floor are used to define the x and y axes and a point on a wall is used to define the level, as shown in Fig.1. The z axis is defined by the direction of the gravitation force. From the original reference points, additional reference points are marked on the building walls, cryostat base, and so on.

Assembly tolerance of the coils is around ± 2 mm in the consideration of the error fields. Using laser trackers, we can measure positions with an accuracy of ~ (0.015 + 0.006 d) (mm) at a distance of d (m). We have been conducting detailed study of metrology procedures for major components.

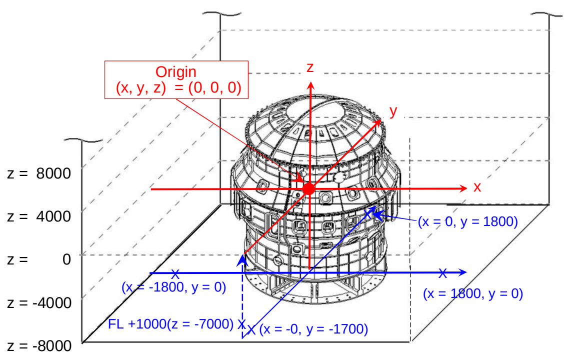

Fig. 1 Absolute coordinate system of JT-60SA and reference points for metrology. The reference points are indicated by blue crosses.

3. Global Assembly Scenario

Since the JT-60SA tokamak is a very complex system, a consistent assembly scenario is required.

In Fig. 2, scenes of the assembly are illustrated in order. After installation of the cryostat base and temporary placement of the lower EFCs (EF 4-6), the VV is installed (Fig. 2 (a)). The VV is composed of seven 40-degree, two 30-degree, and one 20-degree sectors; the two 30-degree sectors are set next to the 20-degree sector. The sectors except the 20-degree sector are welded up to 340 degrees. Next the vacuum vessel thermal shield (VVTS), which is divided into inboard and outboard segments of 20-degree sectors, is assembled over the VV, except for the 20-degree opening sector. Each segment of the VVTS is lifted down into the 20-degree opening of the VV, turned around the VV toroidally, and assembled at the prescribed poloidal section. Then the TFCs except the last TFC are also lifted down into the 20-degree opening, turned around toroidally, and installed. The last TFC, VV sector, and VVTS sector are installed together (Fig. 2 (b), see Section 4). Then, the temporally placed lower EFCs (EF 4-6) are installed under the TFCs, and the upper EFCs (EF 1-3) are installed on the TFCs (Fig. 2 (c)). After the port thermal shield, the lower and middle parts of the cryostat thermal shield (CTS), and the central solenoids are installed, the cryostat body is assembled (Fig. 2 (d)). After assembly of other components in the cryostat, the cryostat lid is installed.

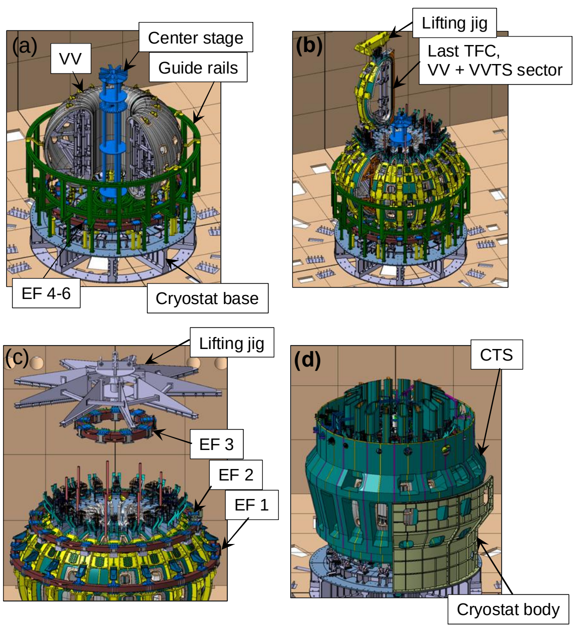

Fig.2 Scenes of the JT-60SA tokamak assembly. Assembly of (a) the VV, (b) the last TFC, VV sector and VVTS sector, (c) EF 3, and (d) the cryostat body. In (a) and (b), the guide rails and center stage for the assembly are also shown. In (b) and (c), the lifting jigs for the assembly are shown.

The assembly scenario will be presented in detail using a movie at this conference.

4. TFC Assembly

Assembly of TFCs is one of the most critical issues for tokamak assembly. Except for the last TFC, the TFCs are lifted down into the 20-degree opening of the VV and toroidally turned around the VV to the prescribed poloidal section using a rotary crane and guild rails of the assembly frame, which surrounds the tokamak. The assembly frame supports the TFCs until all of the TFCs are completely installed. The assembly of the last TFC is especially complicated, since the last TFC is inserted into the narrow opening. The insertion of the last TFC must be done simultaneously with the last sectors of the VV and VVTS, as shown in Fig. 2 (b). Pre-assembly of the last TFC, VV sector, and VVTS sector is illustrated in Fig.3. The VVTS sector is temporarily fixed around the VV sector supported with a pre-assembly jig (Fig. 3 (a)). The TFC lifted using a lifting beam is combined with the VV + VVTS sector by changing the supports of the pre-assembly jig (Fig. 3 (a) and (b)). The TFC and the VV + VVTS sector are individually lifted using the lifting beam (Fig. 3 (c)), and inserted into the opening of the VV (Fig. 2 (b)).

Assembly of other major components such as VV will also be discussed at this conference.

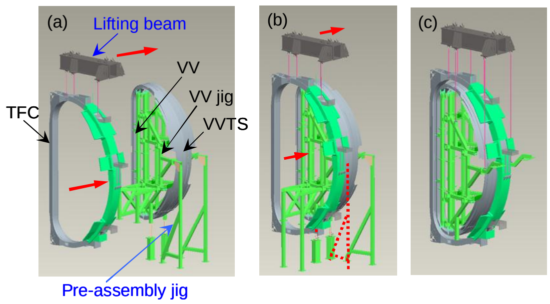

Fig. 3 Pre-assembly of the last TFC, VV sector, and VVTS sector. In (b), the red broken lines indicate the supports removed for the TFC assembly.

Reference

[1] K. Shibanuma, et al., J. Plasma Fusion Res. SERIES, 9 (2010) 276.