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A study on assembly technology of the CFETR 1/32 Vacuum Vessel

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ABSTRACT

Chinese Fusion Engineering Testing Reactor (CFETR) is a superconducting magnet Tokamak, which has the equivalent scale with complementary function to International Thermonuclear Experimental Reactor (ITER). The vacuum vessel (VV) which has a double-layer structure, Cooling water circulating through the double-layer structure will remove the heat generated during operation. The VV will provide a high-vacuum environment for the plasma, improve radiation shielding and plasma stability and provide support for in-vessel components. The CFETR VV is composed of 16 sectors, the angle of each sector is 22.5°. The Research and Development (R&D) of the key technologies to the VV manufacture have been carried out a few years ago by Institute of Plasma Physics Chinese Academy of Science (ASIPP), including Narrow-Gap welding, cutting and non-destructive testing, Poloidal Segment (PS) and sector assembly technologies, etc. ASIPP is constructing a 1/8 sector real size VV mock-up now. The manufacture of the PS for first 1/32 sector VV mock-up has been completed in 2015, the PS will be assembled into a whole this year. This paper will describe the study of the assembly technology for the CFETR 1/32 Vacuum Vessel mock-up.

1. Introduction

Chinese Fusion Engineering Testing Reactor(CFETR) is a superconducting magnet Tokamak, which has the equivalent scale with complementary function to ITER [1]. The vacuum vessel (VV) is the core component in CFETR which has completed the conceptual design. In accordance with the current design, The CFETR VV is composed of 16 sectors, the angle of each sector is 22.5°. The vacuum vessel has 8 upper, 8 equatorial and 8 lower ports which will be used for remote handling operations, diagnostic systems, neutral beam injections and vacuum pumping. As shown in Fig. 1.

The Research and Development (R&D) of the key technologies to the VV manufacture has been carried out a few years ago. The Institute of Plasma Physics Chinese Academy of Science(ASIPP) is constructing a 1/8 sector real size VV mock-up to development Narrow-Gap welding, cutting and non-destructive testing (NDT), Poloidal Segment(PS) and sector assembly technologies, etc. This paper will describe the state of the 1/8 VV mock-up and the study of the assembly technology for the CFETR 1/32 Vacuum Vessel mock-up.

2. Design of the 1/8 VV mock-up

According to the current design, CFETR vacuum chamber has a double-shell structure with torus-shape, the inner and outer shells thickness of 50 mm; stiffening ribs are horizontally and vertically distributed between the inner and outer shells with thickness of 40 mm. The torus outside diameter of the vacuum vessel is 19.5 m, and the inner diameter of the vacuum vessel is 5.74 m, the overall torus height of vacuum vessel is 17.4 m, the thickness of the vacuum vessel inboard side is 280 mm, the outboard side is 380 mm [3]. The main parameters of the 1/8 vacuum vessel mock-up are shown in Table 1.

1/8 vacuum vessel mock-up is composed of four 1/32 sectors in 11.25°. Each 1/32 sector consists of 4 PSs, namely inner Segment (PS1), Upper Segment (PS2), Equatorial Segment (PS3)and Lower Segment (PS4), as shown in Fig. 2. Each PS is composed of inner and outer shells, T-shape ribs, vertical and horizontal ribs by welding, and the whole fabrication process is as follows: inner and outer shells cutting, T-shape rib cutting, joint surface fabrication, welding and heat-treatment. In accordance with the current design, PS1 and PS3 are respectively composed of two different diameters inner and outer shells and inner

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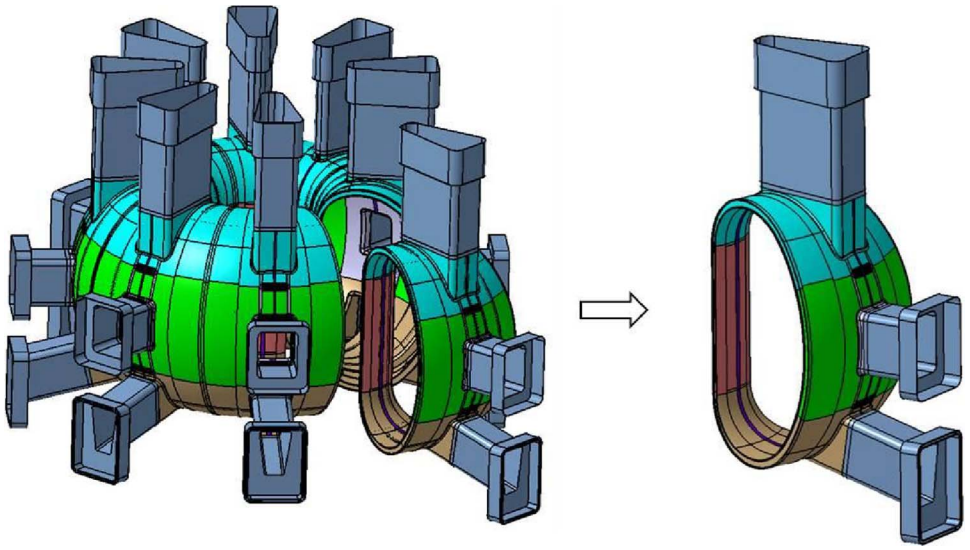

Fig. 1. CFETR vacuum vessel and 1/8 section concept model.

Table 1
Main parameters of the VV mock-up sector.

Parameter	Values
Toroidal extent of mock-up sector	45° (11.25° × 4)
Torus outside diameter	19.5 m
Torus inner diameter	5.74 m
Torus height	17.4 m
Shell thickness	50 mm
Rib thickness	40 mm
Main vessel body weight	~300 ton

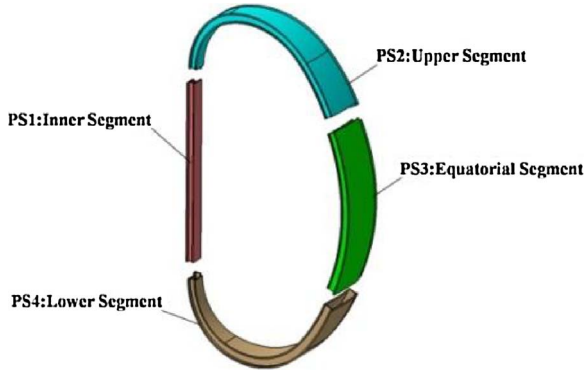

Fig. 2. Vacuum vessel 1/32 sector structure.

and outer shells of PS2 and PS4 are composed of three different diameters arc. Therefore, each torus-shape sector has a total number of 16 segments.

1/8 VV mock-up consists of four 1/32 sectors, 8 upper, 8 equatorial and 8 lower ports by welding. Firstly, assemble and weld the four 1/32 sectors in pairs into two 1/16 sectors in 22.5°. Secondly, the two 1/16 sector will be assembled and welded into 1/8 VV in 45°. Finally, the upper, equatorial and lower ports will be assembled and welded with 1/8 VV sector. Narrow-gap TIG welding will be performed to the 1/8 VV, all structural weld joints within the VV are to be of the full-penetration type and detected with 100% non-destructive testing. The assembly process as shown in Fig. 3.

3. Assembly of 1/32 VV sector

The assembly process of 1/32 VV includes the following operation: the 4 PSs pre-assembly and measurement, PS groove processing, PS assembly, Narrow-gap TIG welding to the 4 PSs, non-destructive testing (NDT) to weld joints, and overall measurement, etc. The welds on the inner and outer shells involving in the 4 PSs are in the number of 8, which are all performed with automatic Narrow-gap TIG welding method. The NDT inspection of the welds between PSs will adopt industrial robot with ultrasonic phased array [6].

3.1. Assembly of 1/32 VV PS

According to the design requirements, the fabricated PSs in 1/32 VV should be reserved about 50 mm allowance for welding area in length direction. Before processing narrow gap grooves on the PS ends, it is required to pre-assemble and measure the 4 PSs, adjust the allowance according to the measurement results to confirm the processing position of the welding groove and ensure the overall assembly dimensions of the VV. In the process of the PS assembly, the 4 PSs levelness should be adjusted to be along the central axis direction on the tooling respectively, and aligned with the mounting surface and then fix them. Through accurately measuring the target stations on the inner and outer shells with laser tracker, the outline dimensions of the VV will come out, and base on the dimensions, to determine processing allowance of each PS end. Due to PS2 and PS4 are composed of three different diameters arc, the ends of PS2 and PS4 need to be processed first after the