24P100-P

Design and Manufacturing Status of JT-60SA Vacuum Vessel and Cryostat
JT-60SA真空容器とクライオスタットの設計、製作の現状

Yusuke K. Shibama, Kei Masaki, Shigetoshi Nakamura, Atsushi Kaminaga, Yasuhiko Miyo, Sinji Sakurai, Kiyoshi Shibanuma and Akira Sakasai
芝間祐介, 正木　圭, 中村誠俊, 神永敦嗣, 三代康彦, 櫻井真治, 柴沼　清, 逆井　章

Japan Atomic Energy Agency
801-1, Mukoyama, Naka-shi, Ibaraki-ken　319-0193, Japan
日本原子力研究開発機構 〒319-0193　茨城県那珂市向山801-1

JT-60SA is a fully superconducting coil tokamak upgraded from the JT-60U. This paper focuses on the vacuum vessel (VV, 150 tons) and cryostat (610 tons), whose structural concepts are developed from the ASME BPVC Section VIII Division 2. The VV is a stainless steel torus double-walled, which achieves high electrical resistivity in the toroidal and high stiffness in the light structure. The cryostat is large size vacuum thermal insulation vessel. The present status of both vessels is reported.

1. Introduction
JT-60SA is a combined Japan (JA) - the European Union (EU) satellite tokamak program, aiming at the ITER program supports and the supplements toward the DEMO, under both broader approach agreement and the JA domestic program [1]. This machine is upgraded to a large volume vacuum space for core plasma and a fully superconducting coil magnet system. These results in larger size of vacuum vessel (VV) construction by JA, and cryostat as an extensive thermal insulation structure by the EU, especially, in Spain. The entire tokamak system of JT-60SA is as shown in figure 1. Recent design and its manufacturing status of the each component are discussed in the following sections.

2. Design
The VV and cryostat are basically designed by the ASME BPVC Section VIII division 2, and some unique design descriptions to the fusion machine are explained. The each component is split in pieces of parts limited by the JA domestic transport and assembled in the JA Naka-site [2].

2.1 *Vacuum Vessel*
The VV is a vessel to ensure sufficient ultrahigh vacuum and one turn toroidal electrical resistance for plasma breakdown. The VV torus is outside diameter of 10 m and its height of 6.6 m, and consists of 18 sectors with 73 port penetrations.

A double wall structure is selected to secure the vessel's higher stiffness, to resist the operational loads and also to support various in-vessel components such as divertor [3] and plasma control coils [4]. The space between these walls is utilized for the neutron shielding by 323 K boron water circulation, and for baking at 473 K by nitrogen gas flow to achieve the vacuum less than 10^{-5} Pa. The total weight amounts to 400 tons which includes the VV of 150 tons, the in-vessel component of 195 tons, and the shielding water of 55 tons. The dead weight is supported from the bottom of every odd number sector, and these 9 support legs have radial leaf-springs to absorb the thermal displacement. The material is selected as type 316L stainless steel (SS316L) additionally restricted in the cobalt contents less than 0.05wt%.

The VV electromagnetic (EM) response is characterized by the toroidal one turn resistance of 15 μΩ and the toroidal eddy current decay time constant of 110 ms [5]. The seismic event is designed by the design response spectrum (DRS), which is based on the geological survey for previous JT-60 construction, and for the ITER design activity [6]. The mechanical response is

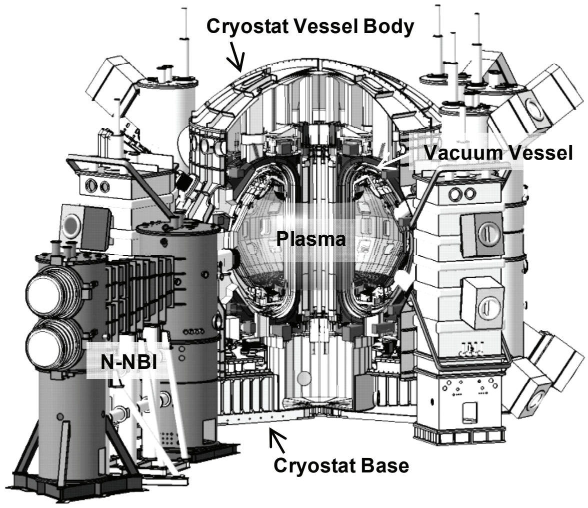

Fig. 1 Tokamak Machine of JT-60SA

Fig. 2 First two sectors (40 deg.) of Vacuum Vessel was in the final inspection, and completed in May 2011 (left).

characterized by the horizontal stiffness of 6.46 x 10^2 MN/m and the design damping ratio of 5.0% at the plasma operational state. The welding technical elements are selected to validate its weldability and mechanical performance before product VV fabrication [7]. The product VV manufacturing is validated by these fundamental surveillance and several mock-up trials [5, 8].

2.2 *Cryostat*

Cryostat [9] is also a vessel to provide the vacuum thermal insulation for cryogenic device, and a base to support tokamak machine dead weight. The vessel is of 14 m diameter and of 16 m height, and the structural material type 304 is selected as same cobalt restriction as the VV. This component is split in mainly two; the upper part as the cryostat-vessel-body (CVB) and the other lower part as the cryostat-base (CB). The CVB structural design condition is substantially governed by difference in pressure; the operational negative pressure of 10^{-3} Pa inside, with various operational loads, as discussed in the VV. The CB is designed by those reaction loads from the tokamak devices. The EM force is very small because the cryostat is located away from core plasma. Toroidal one turn resistance is higher than 25 μΩ, and the decay time of toroidal currents is over 250 ms [10].

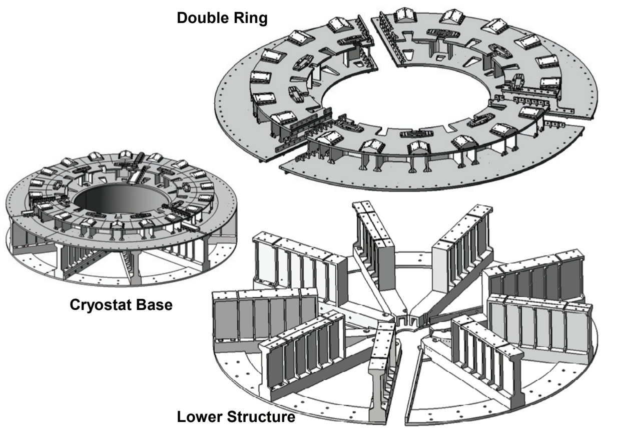

Fig. 3 CB consists of double ring and lower structure [9], whose radial beam is a first part fabricated .

The CVB consists of two major part; lateral part and top lid. The CVB is made of 34 mm thick single-walled with poloidal rib reinforcement. The lateral part has the corresponding port bores to the VV and supports the dead weight of diagnostics port plugs and the other ports for various in-cryostat systems [2]. Bellows are attached between them to absorb difference in operational movements, and rupture disks are also prepared for overpressure protection.

The CB is designed to bear the load of the entire tokamak machine and to transfer the loads to the floor and lower pillars of the tokamak torus hall. The CB is designed as bolt fastened structure, which forms double ring and lower structure as shown in figure 3 [9]. Both structures consist of major three parts split and are assembled as one ring support base. The fabrication of the CB has been started in August.

The each part of the cryostat is connected by bolts and vacuum-sealed by inside conventional welding. Major surrounding facilities in the torus hall; such as the Neutral Beam Injector (NBI), Electron Cyclotron Resonance Heating (ECRH) are connected after assembly. Auxiliary systems such as 80K thermal shield and vacuum exhaust are included as its component.

3. Manufacturing Status and Conclusions

The first 40 degree part of the VV (2 sectors) is completed in May 2011, as shown in figure 2. Other sectors and related ports and gravity supports are under constructions.

The CB has been fabricated since August 2011 (Fig. 3). The CVB and its design in detail are under constructions.

References

[1] S.Ishida et al., Fusion Eng. Des. 85, 2070 (2010).
[2] K.Shibanuma et al, J. Plasma Fusion Res. SERIES, Vol. 9 276 (2010)
[3] S.Sakurai et al., Proceeding of the 23rd IAEA Fusion Energy Conference, Daejeon Korea (2010).
[4] M.Takechi et al., ibid.
[5] Y.K.Shibama et al., Proceeding of 2011 ASME PVP Conference, Baltimore, Maryland (2011).
[6] S.Tado et al., Seismic, Shock, and Vibration Isolation -1998, ASME 1998 PVP-Vol.379, 197 (1998).
[7] S.Asano et al, Fusion Eng. Des. 86 1816 (2011)
[8] K.Masaki et al, Fusion Eng. Des. 86 1872 (2011)
[9] E.Rincóna et al., Fusion Eng. Des. 86 623 (2011)
[10] Y.K.Shibama et al., Fusion Eng. Des. 83 1605 (2008)