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Progress of ITER vacuum vessel

K. Ioki[a,*], A. Bayon[b], C.H. Choi[a], E. Daly[a], S. Dani[a], J. Davis[a], B. Giraud[a], Y. Gribov[a], C. Hamlyn-Harris[a], C. Jun[a], B. Levesy[a], B.C. Kim[c], E. Kuzmin[d], R. Le Barbier[a], J.-M. Martinez[a], H. Pathak[e], J. Preble[a], J.W. Sa[c], A. Terasawa[a], Yu. Utin[a], X. Wang[a]

[a] ITER Organization, Route de Vinon sur Verdon, 13115 St Paul-lez-Durance, France
[b] F4E, c/ Josep Pla, No. 2, Torres Diagonal Litoral, Edificio B3, E-08019 Barcelona, Spain
[c] NFRI, 52 Yeoeundong Yuseonggu, Daejeon 305-333, Republic of Korea
[d] NTC "Sintez", Efremov Inst., 189631 Metallostroy, St. Petersburg, Russia
[e] ITER-India, A-29, GIDC Electronic Estate, Sector 25, Gandhinagar 382025, India

HIGHLIGHTS

- This covers the overall status and progress of the ITER vacuum vessel activities.
- It includes design, R&D, manufacturing and approval process of the regulators.
- The baseline design was completed and now manufacturing designs are on-going.
- R&D includes ISI, dynamic test of keys and lip-seal welding/cutting technology.
- The VV suppliers produced full-scale mock-ups and started VV manufacturing.

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ABSTRACT

Design modifications were implemented in the vacuum vessel (VV) baseline design in 2011–2012 for finalization. The modifications are mostly due to interface components, such as support rails and feedthroughs for the in-vessel coils (IVC). Manufacturing designs are being developed at the domestic agencies (DAs) based on the baseline design. The VV support design was also finalized and tests on scale mock-ups are under preparation. Design of the in-wall shielding (IWS) has progressed, considering the assembly methods and the required tolerances. Further modifications are required to be consistent with the DAs' manufacturing designs. Dynamic tests on the inter-modular and stub keys to support the blanket modules are being performed to measure the dynamic amplification factor (DAF). An in-service inspection (ISI) plan has been developed and R&D was launched for ISI. Conceptual design of the VV instrumentation has been developed. The VV baseline design was approved by the agreed notified body (ANB) in accordance with the French Nuclear Pressure Equipment Order procedure.

1. Introduction

The VV is one of important components in the ITER facility. There are many interfaces with other components including in-vessel components. This paper explains the status of the VV design and R&D, and preparation for its construction.

2. VV design and related activities

2.1. Completion of VV design

The basic design of the VV remains the same. It has a double-walled torus-shaped structure consisted of inner and outer shells, poloidal and toroidal ribs and in-wall shielding [1]. Keys and flexible support housings (FSHs) are welded to the vessel shells (see Fig. 1) [2], and the blanket modules are directly supported by the VV. Electron beam (EB) welding will be used as much as possible for joints between the inner shell and these structures to minimize welding deformation. The layout of welds on the inner and outer shells is very tight considering non-destructive examination

* Corresponding author. Tel.: +33 44217 6967; fax: +33 44225 7261.
E-mail address: Kimihiro.Ioki@iter.org (K. Ioki).

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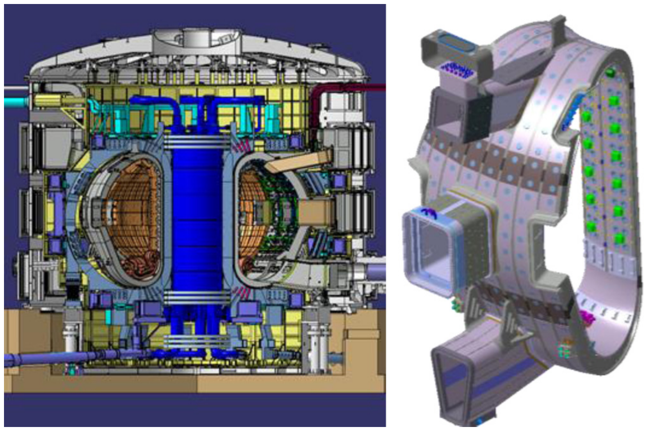

Fig. 1. ITER machine and vacuum vessel (one of nine 40° sectors).

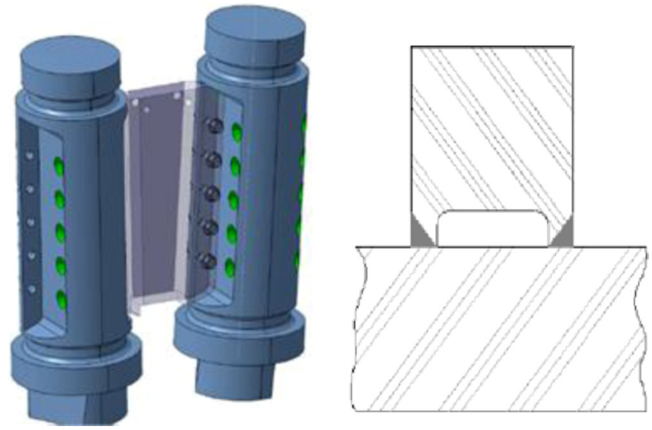

Fig. 3. Manufacturing designs in DAs: bolted IWS support rib (left) and bridge design of IVC support rail (right).

requirements defined in the design code. The baseline design (3D CAD models) was distributed to the DAs and their suppliers for their development of the manufacturing design.

In 2011–12, several design modifications/optimizations were made for the VV, as explained below (a)–(f) (also see Fig. 2). The designs of interfacing components drove most of these changes.

(a) Increased size and/or modified shape of blanket supporting keys and adjustments of the flange sizes and layout of the welded joints
(b) IWS supporting platform design improvement
(c) Adjustments of locations of cooling holes in toroidal and poloidal ribs
(d) Design simplification of the triangular support
(e) Further design progress on the IVC support rails and feedthroughs
(f) Other local design changes and corrections

Manufacturing designs of the main vessel in European and Korean DAs have progressed. They include "bolted IWS support rib design" (EU) and "bridge design of IVC support rail" (see Fig. 3).

The nine VV sectors are transported to the ITER site and they are welded together in the pit of the Tokamak building. Preparatory work has started together with industry. It is required to complete all-position welding within predicted deformations and to satisfy code requirements for non-destructive examination.

2.2. Other design activities, analysis and R&D

2.2.1. In-wall shielding design and analysis

IWS plates are mainly made of an austenitic stainless steel 304 containing boron for effective neutron shielding performance. A ferritic stainless steel, type 430, is used under the TF coils in the outboard area to reduce the toroidal field ripple in the plasma region. The toroidal field ripple calculation was completed and the maximum ripple in the plasma region was reduced from 1.16% to 0.30% (in the nominal toroidal field) and minus 0.67% (overcompensation in half of the nominal toroidal field) by the ferromagnetic inserts in the regular sector regions. Electromagnetic (EM) loads on IWS blocks due to the magnetization effect have been analyzed using a 3D solid model. The maximum per IWS block is 200 kN (toroidal direction), 45 kN (poloidal direction) and 30 kN (radial direction). The toroidal forces on IWS blocks at the toroidal end are high (see Fig. 4). The EM forces due to eddy currents have also been calculated and generally they are smaller than those due to ferromagnetic effect.

Detailed IWS design has progressed, also taking into account VV manufacturing designs. The basic IWS assembly scheme remains the same and it also shows compatibility with the T-shape adapters

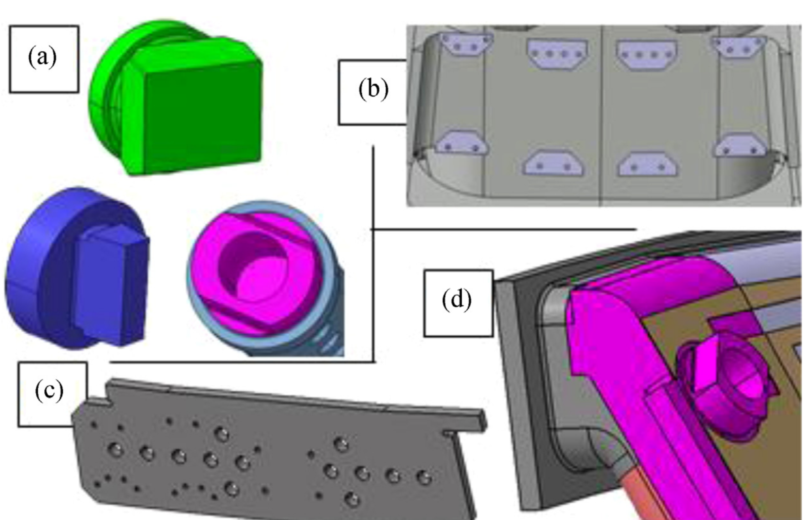

Fig. 2. Designs after modifications (described in Section 2.1).