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ITER vacuum vessel design and construction

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ABSTRACT

According to recent design review results, the original reference vacuum vessel (VV) design was selected with a number of modifications including 3D shaping of the outboard inner shell. The VV load conditions were updated based on reviews of the plasma disruption and vertical displacement event (VDE) database. The lower port gussets have been reinforced based on structural analysis results, including non-linear buckling. Design of in-vessel coils for the mitigation of edge localized modes (ELM) and plasma vertical stabilization (VS) has progressed. Design of the in-wall-shielding (IWS) has progressed in details. The detailed layout of ferritic steel plates and borated steel plates is optimized based on the toroidal field ripple analysis. The procurement arrangements (PAs) for the VV including ports and IWS have been prepared or signed. Final design reviews were carried out to check readiness for the PA signature. The procedure for licensing the ITER VV according to the French Order on Nuclear Pressure Equipment (ESPN) has started and conformity assessment is being performed by an Agreed Notified Body (ANB). A VV design description document, VV load specification document, hazard and stress analysis reports and particular material appraisal were submitted according to the guideline and RCC-MR requirements.

1. Introduction

The vacuum vessel (VV) is a key component of the ITER facility, the primary functions of the VV are to provide the first confinement barrier, withstand postulated accidents without loosing confinement, remove the nuclear heating, and provide a boundary consistent with the generation and maintenance of a high quality vacuum and support in-vessel components and their loads. This paper explains the status of the VV design and preparation for the construction.

2. VV design and recent activities

2.1. Basic design

The VV remains a double-walled torus-shaped structure of SS 316L(N)-IG (ITER Grade) [1]. The main vessel consists of inner and outer shells, poloidal and toroidal ribs and in-wall shielding. Flexible support housings (FSHs) and keys are welded to the vessel shells (as shown in Fig. 1) [2], since 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. The layout of welds on the inner and outer shells is very tight considering accessibility for welding and non-destructive examination requirements defined in the design codes. The triangular support plays an important role in the plasma vertical stability control during minor disruptions, and its position and configuration is optimized based on the plasma vertical stability analysis. Detailed design has been developed for the triangular support considering the fabrication method and the structural integrity.

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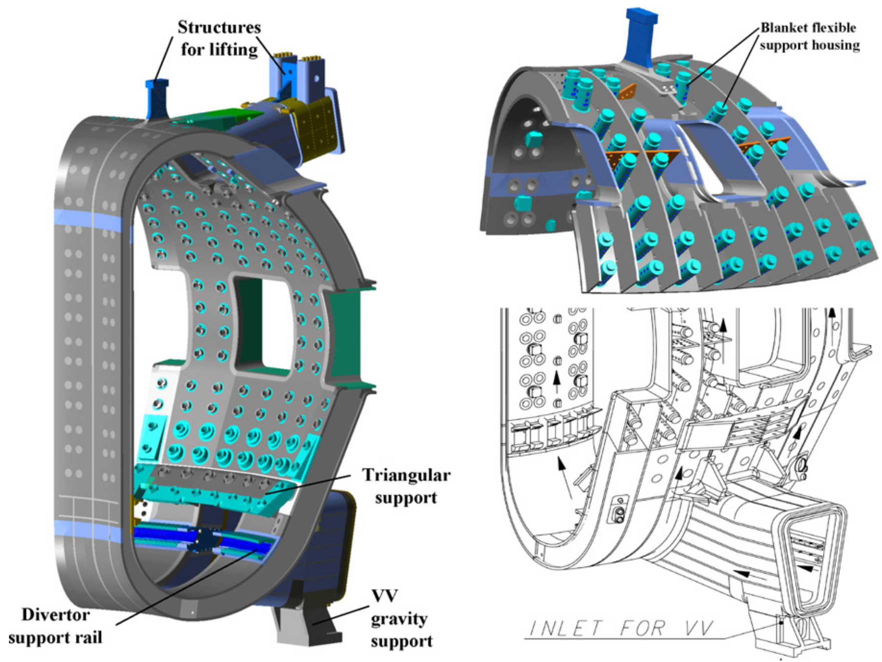

Fig. 1. Vacuum vessel design (reference design).

2.2. Recent activities of VV design and analysis

2.2.1. Study of design variations and selection of design option

A design variation of the reference vacuum vessel "Short housing concept (SHC)" has been studied with aim to improve fabricability of the VV and to reduce the fabrication cost. In the outboard region, the blanket support housing (FSH) is shorter and it is not directly joined to the outer shell in this concept (see Figs. 2 and 3). The main advantages of this concept are (i) possible mitigation of fitting requirements for welding between the outer shell and FSH and (ii) cost reduction in forged material for FSH. Structural analysis has been performed under the coolant pressure, EM loads on the blanket support structures and those on IWS blocks. As shown in Fig. 4, the maximum displacement and stress are too high in the case of SHC without toroidal gussets. When toroidal gussets are used for reinforcement, stresses and displacements (rotation angles of FSH) are less than the allowable limits, as shown in Table 1. The SHC vacuum vessel with toroidal gussets is shown in Fig. 3.

According to assessment and discussions based on results of the study, it was decided to select the original reference design with the following modifications:

(i) Wider opening of inner shell in field joint. The width of the inner shell splice plates was increased from 120 mm to 160 mm

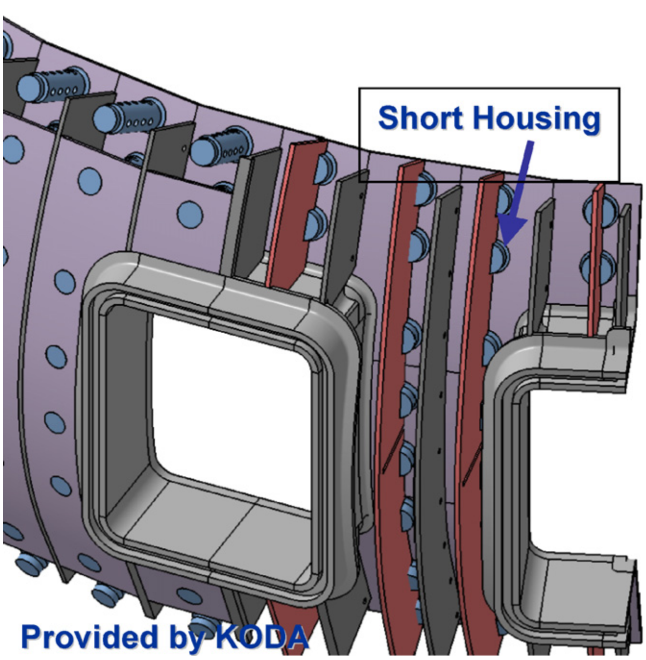

Fig. 2. Short housing concept (SHC).

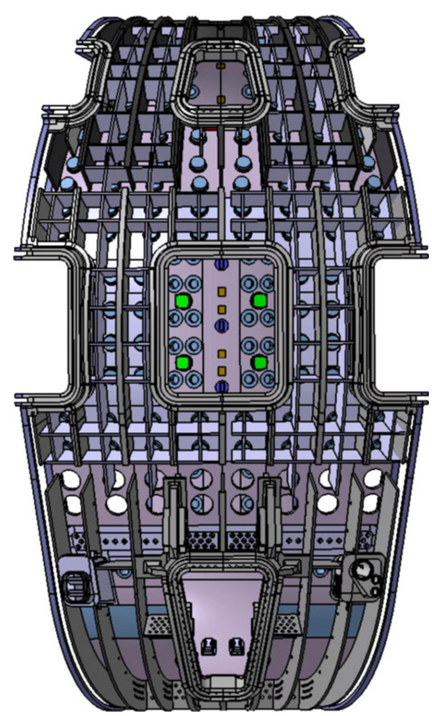

Fig. 3. SHC with toroidal gussets.