The DTT device: First wall, vessel and cryostat structures

Giuseppe Di Gironimo\textsuperscript{a},\textsuperscript{,*}a, Domenico Marzullo\textsuperscript{a}, Rocco Mozzillo\textsuperscript{a}, Andrea Tarallo\textsuperscript{a}, Fabio Villone\textsuperscript{b}

\textsuperscript{a} CREATE, University of Naples Federico II – DII, P.le Tecchio 80, 80125 Napoli, Italy
\textsuperscript{b} CREATE, Università di Cassino e Lazio Meridionale – DIEI, Viale dell’Università, 03043 Cassino, FR, Italy

\section*{A R T I C L E   I N F O}

Article history:
Received 28 July 2016
Received in revised form 21 March 2017
Accepted 30 April 2017
Available online xxx

Keywords:
Conceptual design
3D CAD modeling
Mechanical analysis
FEM
Vacuum vessel
First wall
Cryostat

\section*{A B S T R A C T}
This paper describes the activity addressed to the conceptual design of the first wall and the main containment structures of DTT device. The work moved from the geometrical constraints imposed by the desired plasma shape and the configuration needed for the magnetic coils. Many other design constraints have been taken into account such as remote maintainability, space reservations for diagnostic and heating equipment, etc.

The basic vessel design resulted in an all-welded single-wall toroidal structure made of 18 sectors. Proper supports have been designed for the first wall, which was conveniently segmented in view of remote maintenance. This provisional model allowed evaluating the electromagnetic loads on the metallic structure of the vacuum vessel resulting from the current quench due to a plasma disruption.

After a FEA mechanical assessment, which was conducted according to ASME code, INCONEL\textsuperscript{®} 625 has been provisionally selected as reference material for vacuum vessel. The design principles of the cryostat were chiefly based on cost minimization and functionality; thus it was conceived as a single-wall cylindrical vessel supported by a steel frame structure. The same structure will hold the vacuum vessel and the magnets.

© 2017 Elsevier B.V. All rights reserved.

1. Introduction

According to the European roadmap towards the development of fusion energy plants [1], a solid solution to the problem of heat exhaust is certainly one of the main challenges. Alternative solutions are indeed needed for the divertor system design to mitigate the risk that the conventional solutions tested in ITER may not extrapolate to DEMO.

From this point of view, the Divertor TOKAMAK Test facility (DTT) is conceived as bridge between today’s proof-of-principle experiments and DEMO. In particular, DTT will have the potential to bring alternative divertor solutions to a sufficient readiness level to be adopted on DEMO [2].

DTT will operate in parallel with ITER, likely before its high performance operations. Therefore, DTT will support and complement the ITER experimental program, paying particular attention to high priority issues like disruption avoidance/mitigation, R&D needs in plasma facing components, pacing of Edge Localized Modes (ELM), and plasma control [6]. In the frame of DTT project, the authors have been involved in the conceptual design and the very preliminary structural assessments of the vacuum vessel, the first wall and the cryostat structures.

The work moved from the geometrical constraints imposed by the desired plasma shape and the configuration needed for the magnetic coils. Many other design constraints have been taken
into account such as remote maintainability, space reservations for diagnostic and heating equipment, etc. In order to investigate different geometrical configuration the DTT CAD design is based on a parametric approach [7].

The main design requirements and the results of our assessments are thus being discussed in the next sections.

2. The vacuum vessel and the first wall

The Vacuum Vessel (VV) will be located inside the main magnet system and will provide an enclosed, vacuum environment for the plasma. It will also act as a first confinement barrier. Its main components are the main vessel, the port structures and the supporting system. Moreover a first wall (FW) surrounds most of the inner vessel wall (Fig. 1). The main vessel is a torus with “D” shaped cross-section, segmented in 18 sectors, 20° wide each. The design of the VV shall meet the following main requirements:

- The main vessel shall provide a boundary consistent with the ultra-high vacuum (UHV) requirements;
- The main vessel shall support the in-vessel components (e.g. first wall, divertor system, etc.) in nominal and off-normal/fault operating conditions;
- The vacuum vessel, together with the in-vessel components, shall provide a specified toroidal electrical resistance (estimated in about 150 μΩ);
- In-vessel components shall be compatible with remote handling operations;
- The poloidal curvature of VV shall be consistent with the presence of the in-vessel coils;
- The main vessel shall be endowed with 5 access ports for each sector and feedthroughs for in-vessel components;
- The position and the geometry of the ports shall be consistent with both the poloidal and the toroidal field coils (TFCs) and their supporting structure;
- At least one port per sector must be aligned with plasma center;
- At least one port per sector shall allow for the (de) commissioning of the divertor;
- At least one port shall allow for the installation of a tangential neutral beam injection (NBI) system.

The main vessel design is an all-welded single-wall structure. The 18 sectors are joined by field welding.

The maximum thickness of the shell is 35 mm. The VV profile in a poloidal plane is made by single curvature segments. Thus the resulting shell will have a double curvature at the outboard side and a single curvature at the inboard side, where the shells of the central segment are cylindrical. The shell shall be manufactured by hot forming/bending and welding. Given the single-shell design, a proper heat shield, similar to the one already provided for Wendelstein 7-X [4], will be subject of future studies. The heat shield will be designed in order that the VV achieves a reference temperature of 100 °C.

Overall external dimensions of the vacuum vessel are 3660 mm in height with a diameter of 2540 mm at the inboard side and a diameter of 6890 mm at the outboard side (Fig. 2).

The material choice for vacuum vessel has a significant influence on performance, fabrication characteristics, mechanical strength, chemistry properties, and construction cost. The primary candidate for the vacuum vessel material would be AISI SS-316L(N), owing to its large database and its fabricability by conventional technology. However, compared with AISI SS-316L(N), INCONEL® 625 has a higher electrical resistivity and better mechanical properties (Table 1).

Moreover, given the low irradiation levels [3], no significant decreasing in the main mechanical characteristics of Inconel 625 is expected [5].

<table>
<thead>
<tr>
<th>Property</th>
<th>AISI SS-316-L(N)</th>
<th>INCONEL® 625</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density [g/cm³]</td>
<td>~8</td>
<td>~8.5</td>
</tr>
<tr>
<td>Module of Elasticity [GPa]</td>
<td>~200</td>
<td>~200</td>
</tr>
<tr>
<td>Yield strength [MPa]</td>
<td>~230</td>
<td>~400</td>
</tr>
<tr>
<td>Tensile strength [MPa]</td>
<td>~550</td>
<td>~800</td>
</tr>
<tr>
<td>Electrical Resistivity @ 20°C [μΩ cm]</td>
<td>~74</td>
<td>~130</td>
</tr>
</tbody>
</table>

Fig. 1. Isometric view of a Vacuum Vessel sector with schematic representation of magnets and principal in-vessel components (FW and divertor).

Fig. 2. Overall dimensions (in mm) of main vessel sector (top and side views).

دریافت فوری
متن کامل مقاله

امکان دانلود نسخه تمام متن مقالات انگلیسی
امکان دانلود نسخه ترجمه شده مقالات
پذیرش سفارش ترجمه تخصصی
امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
امکان دانلود رایگان ۲ صفحه اول هر مقاله
امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
دانلود فوری مقاله پس از پرداخت آنلاین
پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات