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Overview of main-mechanical-components and critical manufacturing aspects of the Wendelstein 7-X cryostat

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ABSTRACT

Wendelstein 7-X (W7-X) will be the world's largest superconducting helical advanced stellarator. This stellarator concept is deemed to be a desirable alternative for a future power plant like DEMO. The main advance of the static plasma is caused by the three dimensional shape of some of the main mechanical component inside the cryostat. The geometry of the plasma vessel is formed around the three dimensional shape of the plasma. The coils and their support structure are enclosed within the outer vessel. The space between the outer, the plasma vessel and the ports is called cryostat because the vacuum inside provides thermal insulation of the magnet system which is cooled down to 4 K. Due to the different thermal movements of both vessels and the support structure have to be supported separately. 10 cryo legs will bear the coil support structure. The plasma vessel supporting system is divided into two separate systems, allowing horizontal and vertical adjustments. This paper aims to give an overview of the main mechanical components of the cryostat. The authors delineate some disparate and special problems during the manufacturing of the components at the companies in Europe. It describes the current manufacturing and assembly.

1. Introduction

Wendelstein 7-X is presently under construction at the Max-Planck-Institut für Plasmaphysik in Greifswald, Germany. W7-X is provided with an internal vacuum vessel, the 'plasma vessel' (PV), whose complex toroidal shape follows the designed contour of the stellarator plasma. The plasma vessel is the first barrier for the ultra-high vacuum ($\leq 10^{-8}$ mbar) of the plasma chamber. To control the plasma form it is necessary that all the 20 planar and 50 non planar coils are positioned within a tolerance of 1.5 mm. To meet this requirement a complex coil support structure was created. The superconducting magnet system, the coil support structure, the liquid helium cooling pipes and the thermal shield are enclosed between the plasma vessel and a second external toroidal vacuum vessel, the 'outer vessel'. An intermediate vacuum ($\leq 10^{-6}$ mbar) is established between the vessels. The ports will join the plasma vessel through the cryostat with the outer vessel. Also the different support structures for the plasma vessel and the coil support structure have to lead through the cryostat. For technological aspects the entire W7-X machine is divided into five similar modules. Each module consists of two flip symmetrical half modules. So it was possible to manufacture up to ten equal parts and connect them to bigger components (Fig. 1).

2. Outer vessel

Also the outer vessel (OV) consists of 5 similar modules, but as an exception the OV is divided in an upper and lower shells. The vessel is designed as a torus with an outer diameter of approximately 16 m. The internal diameter of the cross section is 4.4 m. It is made of austenitic steel 1.4429 (X2CrNiMoN17-13-3) and the wall thickness is 25 mm. The outer vessel serves as the outer vacuum protection for all cold components inside the cryostat. The thermal insulation of the magnet system is provided by a high

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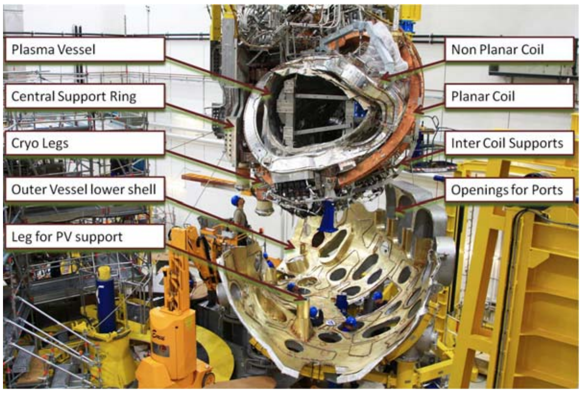

Fig. 1. Main components of the first module of the Wendelstein 7-X cryostat.

vacuum in combination with the super isolation and the active cooled thermal radiation shield. Because the surface of the outer vessel is at ambient temperature, it will be covered by the super isolation shield inside the cryostat. The access to the plasma vessel or the cryostat is achieved via ports and domes. 524 domes were welded onto the torus [1]. The outer vessel is borne by 15 supports, which are directly connected to the machine base.

One of the great difficulties during the manufacturing and assembly of the outer vessel is the weak structure of the separate shells. Therefore different stiff workarounds were created to hold on the achieved geometry at the separate assembly steps (Fig. 2).

All modules of the outer vessel are manufactured. At present three modules have been insulated with the thermal isolation and assembled on the machine base. The manufacturer is MAN DT GmbH

3. Ports

For providing access to the plasma vessel 254 ports have to be installed between plasma vessel and outer vessel inside the cryostat. The thermal movement of the plasma vessel requires that all ports are equipped with bellows which vary between 100 mm circular and 1170 mm × 570 mm rectangular sizes. During various load-cases the axial and lateral stiffness of all bellows will create a resulting spring-force which acts directly on the vessel supports. The ports can be divided into two main groups. The so-called diagnostic ports contain the different systems for observing the plasma. The supply ports are used for the heating systems (i.e. ECRH, ICRH and NBI), the supply lines of in-vessel components and maintenance.

All ports are delivered to the Greifswald site. The ports were built by the Swiss company Romabau-Gerinox AG, Weinfelden. At present the port preparation has been started. Each port will be covered by an own thermal insulation. The assembly at the first two modules has been started (see Fig. 3).

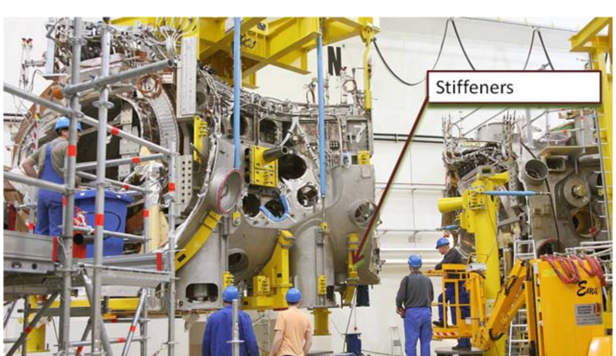

Fig. 2. Movement of the second module on the machine base.

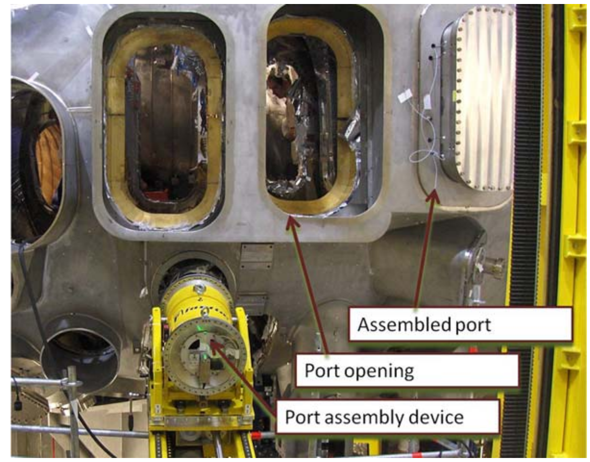

Fig. 3. Port assembly.

4. Plasma vessel and supports

4.1. Plasma vessel

Five similar plasma vessel (PV) modules are joined together along dial–poloidal and radial–toroidal planes. The shape of the plasma vessel cross-section changes within each module from a triangular to a bean form and back again to a triangular form. Because of this complicated form, surfaces switch between convex and concave. The maximum outer diameter of the torus is approximately 12 m; the minimum inner diameter is 8 m. The wall is made of the austenitic steel 1.4429 (X2CrNiMoN17-13-3) and has a thickness of 17 mm [2]. The inner surface will be protected against the plasma heat by in-vessel components. On the outside are welded cooling pipes. The vessel and pipes are covered with the thermal shield consisting of an actively cooled glass fibre and copper shell with multi-layer super insulation which minimizes the thermal radiation from the plasma vessel to the coils (see Fig. 4).

The manufacturing of the plasma vessel started with small cut plates which were welded together to bigger and bigger parts. A specific developing program was necessary to find out the right way of cutting and welding.

Fig. 4. Plasma vessel section covered with thermal insulation.