First Wall Design for the Ignitor Machine

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Ignitor Project

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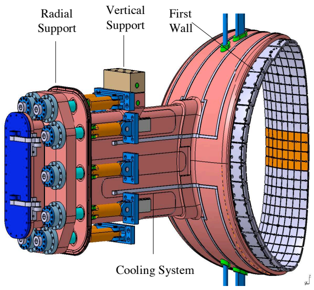
Introduction

Ignitor is a compact, high magnetic field tokamak (13T) aimed at reaching ignition conditions in a DT plasma [1]. The first wall (FW) of the Ignitor machine (plasma currents of 11 MA) covers the entire surface of the Plasma Chamber (PC) with the exception of the port regions. Ignitor has been conceived as a "limiter" machine where the FW acts as "bumper limiter" or "whole limiter". Under ignition conditions, a maximum thermal load of 1.8 MW/m^2 is found when plasma movements of ± 1 cm around the equilibrium configurations are considered (the expected average heat flux is 0.7 MW/m^2).

The Poloidal Field System of Ignitor can produce X-point configurations in addition to the optimized limiter ones to allow an easier access to H-mode regimes. The double-null just inside the first wall results in a reduced plasma currents of 9 MA.

The accuracy of the position of the tiles is prescribed to be better than 2 mm all around the torus. The attachment system of the FW at the PC has been designed to avoid unscrewing or losing the pre-load due to vibration and temperature gradient and to comply with the requirements of remote maintenance.



IGNITOR Plasma Chamber module view.

First Wall Description

The first wall protection is made up by TZM (Molybdenum) tiles mounted on Inconel 625 tile carriers. Each tile carrier holds 8 tiles [4]. The thickness of the complete assembly is 23 mm, from the PC wall to the exposed tile surface.

In order to minimize dangerous thermal load concentrations, the tiles relative to the magnetic field lines have a very high accuracy. The manufacturing and assembly procedures are aimed to reach the following tolerances:

- ± 0.1 mm step between adjacent tiles, on the same tile carrier;
- ± 1 mm overall assembly tolerances with respect to their theoretical position.
- ± 0.2 mm step between tiles of the adjacent tile carrier.

Each chamber sector is covered by ~ 90 tile carriers.

The tile carriers are attached to the Plasma Chamber (PC) by studs directly welded to the Plasma Chamber wall on the inboard side and on plates bolted to the PC ribs on the outboard side.

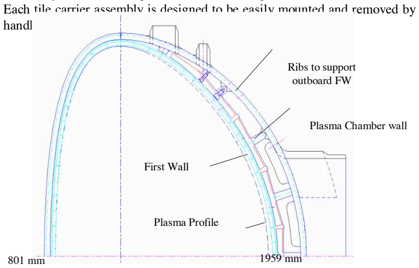
Spacer washer allow for alignment setting.

The size of the TZM tiles is determined on the basis of the electromagnetic loads during plasma disruptions.

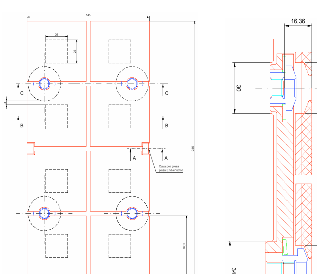
Each of the tile carriers is mounted on the PC wall through 4 studs.

The tile is brazed to a square back plate which is fastened to the carrier by a countersunk head screw. The square back plate is engaged in a trapezoidal pocket in the carrier which will prevent any rotation of the tile. The preload on the screw is reacted by the tile abutting on the bottom of the pocket.

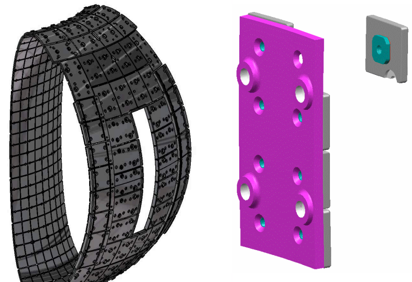
Each tile carrier assembly is designed to be easily mounted and removed by remote handl



Plasma Chamber cross section



Tile Carrier view.



First Wall module view.

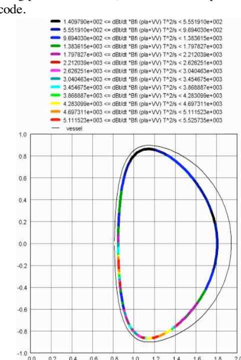
Electromagnetic loads on FW

The simulation of the worst disruption event in IGNITOR has been performed using the MAXFEA code. The assumed reference plasma disruption was a Vertical Displacement Event (VDE) of the plasma column with a slowly decreasing current, followed by the appearance of halo currents when the safety factor q_{95} (at the 95% flux surface) decreases below 2. The thermal quench and then the fast plasma current quench phase are assumed to occur when q_{95} falls below 1.5.

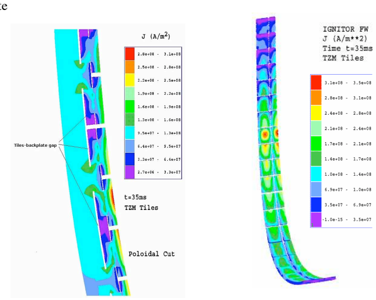
The 2D analysis of the excitation loads during the downward Vertical Displacement Event (VDE) showed that the most loaded region is the inboard lower quarter of the poloidal section. A detailed 3D finite elements model of this region has been developed in order to evaluate the electromagnetic loads during the reference VDE.

An EM zooming procedure allowed the replacement of the out-of-model plasma, poloidal coils and passive structures with current filaments around the modelled region, reproducing the same field configuration. The obtained model extends along the toroidal direction for half a tile carrier (5 degrees) and includes one and half tiles for each row.

Eddy currents and EM loads produced by the interaction of eddy currents with both the toroidal and poloidal (including plasma and coils) field have been preliminary evaluated using the EMAS finite elements code.



Bdot of field orthogonal to FW times toroidal field (integrated over a time of 0.5 ms) for IGNITOR downward VDE- Thermal quench at $q_{95\%}$= 1.5.



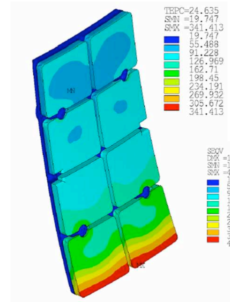
Plots of the eddy current density distribution at the time when the loads are maximum.

First Wall Design

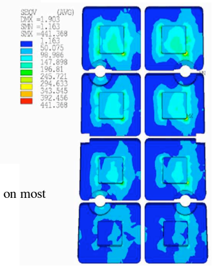
A detailed 3D finite elements model has been developed in order to evaluate the electromagnetic loads on FW tile carriers during the reference VDE. A thermo-structural analysis, of the most stressed tile carrier, with a cycled load has been completed.

The study performed with ANSYS Code in non-linear analysis. The results show a temperature increase up to 341 °C (peak value 1.8 MW/m2) for a single run of 4 sec. The stresses and deformations on the component which is undergone to a cycled load are in the limit of the allowable values.

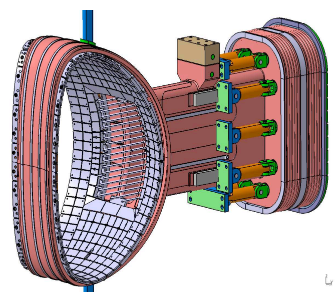
The lay out of the first wall has been finalized taken into account all requirements of the IGNITOR Machine.



Temperature distribution on most stresses tile carrier.



Maximum VM stress (MPa) on tile carries during the disruption (at t=53 ms) after four cycled load..



ICRH Faraday Shield pictorial view integrated with FW

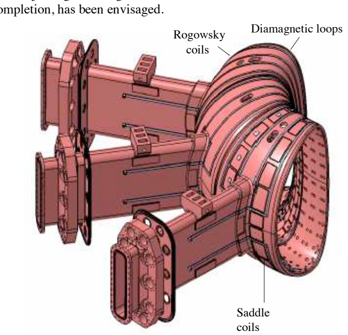
Magnetic Diagnostic

Electromagnetic diagnostics are adopted to measure plasma parameters such as current, loop voltage, horizontal and vertical position, plasma beta, toroidal and poloidal modes. The limited space available between tiles and vessel in Ignitor leads to geometrically tight magnetic probes (Fig. 3). and the very intense neutron flux expected in Ignitor demand the use of fully inorganic insulating materials.

The magnetic coils system must be closely integrated with the plasma chamber before the welding of the individual sectors. An adequate level of redundancy is being considered.

The electrical diagnostic placed inside the plasma chamber have been included in the tile carrier design. The first wall has been tailored related to ICRH Faraday Shield (Fig. 6) and to clear the view through vertical port openings.

The tiles surrounding the horizontal port do not obscure the line of sight to view the plasma. The first wall of the poloidal area surrounding the sector joining welding, which has to be installed after the torus completion, has been envisaged.



PC view equipped with electromagnetic diagnostics.

References

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