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Design and test program of a simplified divertor dummy coil structure for the WEST project

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HIGHLIGHTS

- The mechanical design and integration of the divertor structure has been performed.
- The design of the casing and the winding-pack has been finalized.
- The coil assembly process has been validated.
- The realization of a coil mock-up scale one is in progress.

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ABSTRACT

In order to fully validate actively cooled tungsten plasma facing components (industrial fabrication, operation with long plasma duration), the implementation of a tungsten axisymmetric divertor structure in the tokamak Tore-Supra is studied. With this major upgrade, so-called WEST (Tungsten Environment in Steady state Tokamak), Tore-Supra will be able to address the problematic of long plasma discharges with a metallic divertor target.

To do so, it is planned to install two symmetric divertor coils inside the vacuum vessel. This assembly, called divertor structure, is made up of two stainless steel casings containing a copper winding pack cooled by a pressurized hot water circuit (up to 180 °C, 4 MPa) and is designed to perform steady state plasma operation (up to 1000 s).

The divertor structure will be a complex assembly ring of 4 m diameter representing a total weight of around 20 tons. The technical challenge of this component will be the implementation of angular sectors inside the vacuum vessel environment (TIG welding of the coil casing, induction brazing and electrical insulation of the copper winding). Moreover, this complex assembly must sustain harsh environmental conditions in terms of ultra high vacuum conditions, electromagnetical loads and electrical isolation (13 kV ground voltage) under high temperature.

In order to fully validate the assembly and the performance of this complex component, the production of a scale one dummy coil is in progress.

The paper will illustrate, the technical developments performed in order to finalize the design for the call for tender for fabrication. The progress and the first results of the simplified dummy coils will be also addressed.

1. Introduction

In order to provide ITER relevant plasma conditions for the validation of a tungsten PFC (Plasma Facing Component) technology, the creation of an X-point magnetic configuration in the upper and lower area of the Tore-Supra vacuum vessel has been proposed [1,2]. To do so, it is planned to install an axisymmetric divertor (coil in casing) covered with two sets of actively cooled PFCs (see Fig. 1) [3,4].

Technical developments have been performed in order to finalize the design for the call for tender phase of the Tore-Supra WEST divertor structure. Moreover, in order to fully validate the assembly

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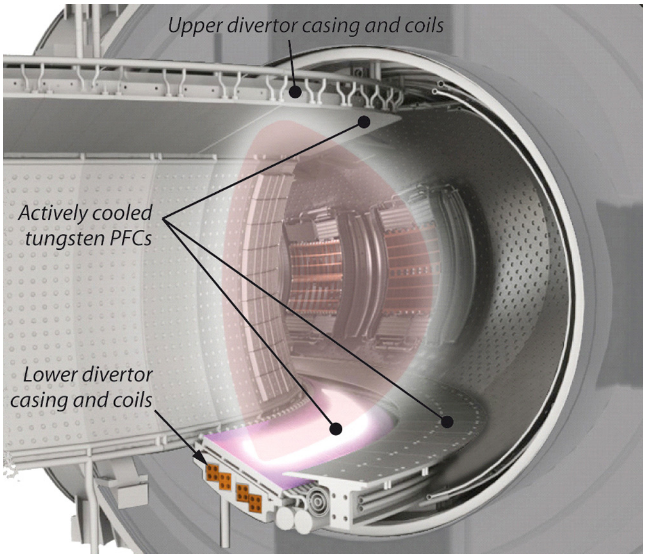

Fig. 1. 3D view of the divertor implementation in Tore-Supra.

and the performance of this complex component, the production of a scale one dummy coil is in progress.

2. Design description of the divertor coils

The divertor structure is made up of two stainless steel casings (4 m diameter) containing a copper winding pack cooled by hot pressurized water (180 °C, 4 MPa). These two casings are located at the top and bottom of the vacuum vessel. Each stainless steel casing is composed of six U-shaped 60° sectors mechanically attached together by a bolting system and closed after coil insertion by six bolted 60° cover plates (see Fig. 2).

Thus the windings are fitted closely in the casing. Vacuum tightness is performed by lip welding on the casing allowing us to operate the coil windings under atmospheric pressure (see Fig. 3). The conductor (copper–silver alloy) has a rectangular cross section of (32 mm × 30 mm) with a bore of 20 mm. The conductor turns are assembled from preformed pieces by induction brazing inside the vacuum vessel in order to form a coil of 4 m diameter and 8 turns.

3. Dummy coil description

Due to the mechanical complexity of this component, a simplified divertor structure model (coil and casing) has been set up in order to validate the manufacturing and the assembly procedure especially for the upper coil setting. To be representative, this mock-up will represent a scale one assembly of three conductors

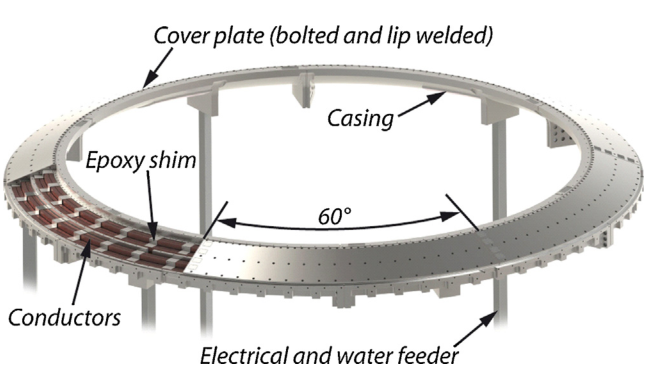

Fig. 2. View of the casing and the winding pack.

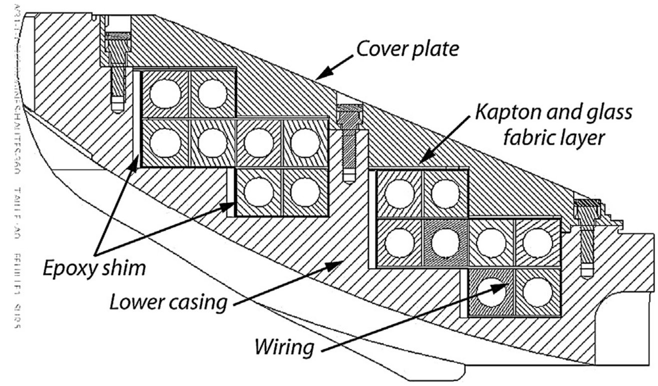

Fig. 3. Cross section of the lower casing.

(4 m diameter). This coil will be connected to a representative cooling system. In parallel it will allow to carry out and will enable us to perform electrical tests.

Fig. 4 represents the mockup on its assembly support. The associated tests are scheduled to be done during the second half of 2013.

4. Dummy coil test site

The dummy coil support is constituted of eight vertical brackets maintaining the casing in a representative in-vessel position. This will allow assembling the conductors in a realistic vessel environment. The dummy casing is constituted of eight 45° stainless steel sector bolted on the dummy coil support. Eight bolted cover plates will close the U-shaped casing after the insertion of the conductors.

In the bottom area of the dummy coil support eight vertical electric telescopic cylinders are positioned. All these cylinders are connected to a monitoring system. The 8 cylinders are controlled in position individually, in pairs or simultaneously. The flexibility of all these cylinders allows precise positioning of the pre-formed and ring-shaped conductors before the brazing operation and the insertion inside the casing structure. This insertion will be done thanks to a positioning tool situated at the extremity of each cylinder which takes into account the mechanical references of the casing (see Fig. 5).

According to this process, during the assembly, the winding follows the geometric reference defined by the casing. This methodology allows us to produce a tight winding pack within the outer casing wall. Inside the casing, the conductors are individually put in place and pressed together thanks to dedicated tools. In the inner

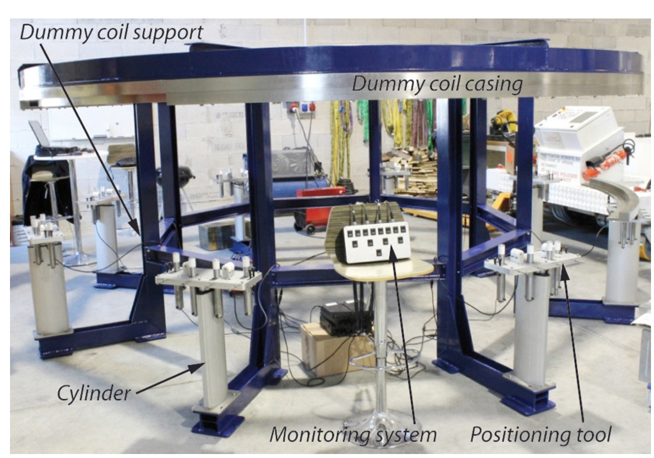

Fig. 4. Divertor dummy coil.