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Conceptual design for a bulk tungsten divertor tile in JET

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Abstract

The ITER-like Wall project (ILW) for JET aims at providing the plasma chamber of the tokamak with an environment of mixed materials which will be relevant for the actual first wall construction on ITER. Tungsten plays a key role in the divertor cladding. For the central tile, also called LB-SRP for "load-bearing septum replacement plate", bulk tungsten is envisaged in order to cope with the high heat loads expected (up to 10 MW/m^2 for 10 s). The outer strike-point in the divertor will be positioned on this tile for the most relevant configurations. Forschungszentrum Jülich (FZJ) has developed a conceptual design based on an assembly of tungsten blades or lamellae. An appropriate interface with the base carrier of JET, on which modules of two tiles are positioned and fixed by remote handling procedures, is a substantial part of the integral design. Important issues are the electromagnetic forces and expected temperature distributions. Material choices combine tungsten, TZM™, Inconel® and ceramic parts. The completed design has been finalised in a proposal to the ILW project, with utmost ITER-relevance.
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1. Introduction

With ITER on the verge of being built, the ITER-like Wall project (ILW) for JET aims at providing the plasma chamber of the tokamak with an environment of mixed materials which will be relevant for decisions related to the first wall construction. From the

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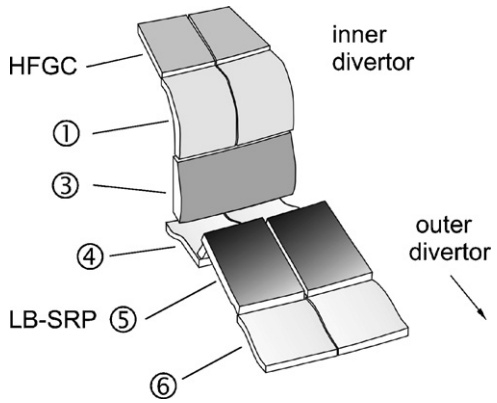

Fig. 1. Schematised divertor view (inwards) shows the position of the LB-SRP (tile no. 5). The grey shading enhances the readability of the picture but has otherwise no significance. HFGC: high-field gap closure tile, LB-SRP: load-bearing septum replacement plate.

point of view of plasma physics, this encompasses aspects of the possible plasma configurations and of plasma–wall interactions. Whereas beryllium will be used for the vessel's first wall, tungsten plays a key role in the divertor cladding. For the central tile, also called LB-SRP for "load-bearing septum replacement plate", bulk tungsten is envisaged in order to cope with the high thermal loads expected (up to 10 MW/m^2 for about 10 s). This is indeed the preferred plasma-facing component for positioning the outer strike-point in the divertor. The location of this tile is shown in Fig. 1.

A conceptual design for this tile has been developed, based on an assembly of tungsten blades or lamellae. It has been selected in the frame of an extensive R&D study in search of a suitable, inertially cooled component. As reported elsewhere [1], the design is driven by electromagnetic considerations. The lamellae are grouped in four stacks per tile, which are independently attached to an equally re-designed supporting structure, hereafter called "the wedge". An adaptor plate, a new design too, takes care of appropriate interfacing to the base carrier of JET, on which modules of two tiles are positioned and screwed by remote handling (RH) procedures. The compatibility of the design as a whole with RH requirements is another essential ingredient which has been taken into account.

Along with due consideration of the electromagnetic forces and of the expected temperature distributions, compliance with the requirements of the plasma–wall interactions and with the JET configuration is required. Material choices combine tungsten, TZM^{TM} (a molybdenum-based alloy), Inconel® and ceramic parts (ZrO_2 and alumina). Most of these materials have been tested by exposure of small test modules to an electron beam or to fusion plasmas in the JUDITH facility and in the TEXTOR tokamak [2], respectively. The completed design has been proposed to the ILW project.

2. Frame for the concept development

The new design for bulk tungsten is expected to accomodate the following boundary conditions and requirements:

- load onto a tile $\leq$7 MW/m^2; goal for the present development 10 MW/m^2, taking account of the reduced surface with castellation and power deposition by ELMs. All loads should hold for a 10 s exposure. The specification is for about 1000 cycles;
- values for the magnetic field, field variation and halo current through the module $|B| = 4.5$ T, $|\dot{B}| = 100$ T/s and $I_{halo} = 18$ kA per module, that is 9 kA/tile;
- overall weight limited to $\leq$80 kg for reasons, among others, related to the application of remote handling through the whole installation procedure;
- in order to be perfect substitutes for the present CFC modules (Dunlop DMS 704, Fig. 2), the tungsten modules should have similar dimensions. This means, for example, that the upper tile surface must present a shape close to the original 3D design, and must be positioned identically. A slight vertical deviation, i.e. modules which would be 5 mm higher (at most), may be acceptable.

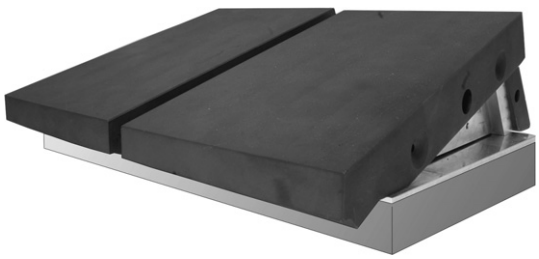

Fig. 2. Present mock-up for the LB-SRP (load-bearing septum replacement plates) show the arrangement of two 3D-shaped tiles in a module. A carbon fibre composite is used.

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