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Progress in the design of Normal Heat Flux First Wall panels for ITER

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HIGHLIGHTS

- Improved detail design of several NHF FW panels for ITER.
- Implemented design solutions to improve the manufacturing of NHF FW panels.
- Performed FEM simulations for the overall assessment of NHF FW panels.
- Performed detailed analyses for integration of diagnostics in the NHF FW panels.

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ABSTRACT

A typical NHF FW panel consists of a series of fingers, which represent the elementary plasma facing units and are designed to withstand 15,000 cycles at 2 MW/m^2. The fingers are mechanically joined and supported by a back structural element or “supporting beam”. The structure of a finger is made of three different materials: stainless steel for the supporting structure, copper chromium zirconium for the heat sink, and beryllium as armour material. Due to their location and to the interfaces with other systems (e.g. Diagnostics, Remote Handling), the NHF FW panels are divided in different main and minor variants.

The aim of this paper is to present the design work performed towards the PA signature. CAD detailed models have been created in CATIA for main and minor variants. Examples of local design solutions, as well as design work to achieve the global configuration of specific modules are provided. Finite Element (FE) analyses have been carried out, in order to simulate the operational scenario of ITER and assess the thermo-mechanical behaviour of the most important FW panels against the required design criteria. This design and analyses activity is required to progress towards the finalization of the detailed design of the NHF FW main and minor variants.

1. Introduction

The objective of ITER is to design, construct and operate a tokamak, twice the size of the largest current devices, with the goal of demonstrating the scientific and technical feasibility of fusion power. Blanket Modules (BMs) are among the most challenging components of the ITER reactor, as they represent the innermost part of the reactor directly exposed to the plasma. Each BM is composed of a First Wall (FW) panel, mechanically connected to a Shield Block (SB), the latter being attached to the Vacuum Vessel (VV) by means of flexible supports and keys [1]. In the framework of ITER construction, F4E is responsible for the in-kind supply of all the Normal Heat Flux (NHF) FW panels. Significant progress has been recently made in the design of the NHF FW panels and, following the achievement of the important milestone of the Blanket Final Design Review (FDR) in April 2013, F4E and IO are currently working on the finalization of the design of all NHF FW panels, towards the signature of the Procurement Arrangement (PA), which represents the transition from design to manufacturing phase.

The total number of NHF FW panels in the scope of EU can be grouped in approximately 30 variants, according to specific design configuration due to the integration/interface with other systems (Diagnostics, Remote Handling, etc.). For the sake of simplicity, the main variant(s) can be considered as the standard panel for

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the corresponding poloidal location inside the blanket. In general the design of a minor variant is different from the corresponding main variant only for small design features (e.g. small cut-out at the extremities of the FW panel) without significant modifications of the design. However, this has to be considered only as guideline, since in some cases, due to the significant differences existing between a minor variant and the corresponding main variant, appreciable design optimization might be needed in order to meet all the operational, structural and manufacturability requirements. As a consequence, significant effort has been devoted after FDR both on the development of detailed CAD models in CATIA and on the FEM simulations of the main and minor variants, in order to increase the confidence in the design of the NHF FW panels while progressing towards the PA signature. The activity on FEM analyses has been focused on the overall assessment of some main variants (FW 11A, FW 11B and FW 13AD), whose CAD models have been developed as part of the on-going modelling activity in preparation for the PA signature. Furthermore, some important design issues relevant to all the NHF FW panels (e.g. pads design and sizing, and diagnostic integration) have been also studied by means of dedicated numerical FE analyses. The main objective of this paper is to present some examples of the CAD modelling activities and of the FEM analyses that have been performed in preparation for PA signature.

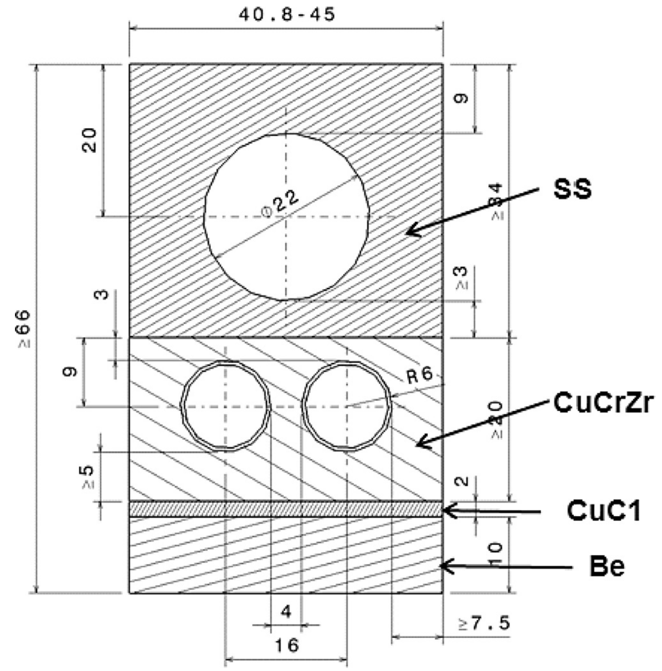

Fig. 2. Cross-section of a typical finger in a NHF FW panel, showing main design features.

2. CAD design activity

A typical NHF FW panel consists of a series of fingers mechanically joined and supported by a back structural element called "supporting beam". A finger is made of three different materials: stainless steel for the supporting structure, copper chromium zirconium for the heat sink and beryllium as armour material. In a typical finger, two cooling SS pipes are embedded in the CuCrZr heat sink [1]. The exploded view of a typical NHF FW panel can be found in Fig. 1, where all the different components of the FW panel are shown. In particular, the finger structure is composed by the components numbered 11–15. The typical cross section of a finger is in Fig. 2.

Modelling activity in CATIA has been carried out according to the Enovia CAD methodology defined in [2]. CAD activity has been performed on main and minor variants of NHF FW panels located in the 3 ITER blanket regions previously described. In this section, some examples of design solutions implemented in CAD are shown in order to highlight the challenges faced in the design of the NHF FW panels. In particular, the design of main variants FW 10A, FW 18 ANU and of the minor variant FW 12 AW are presented.

2.1. Design of FW 10A

FW 10A, located in the top region of the blanket, is characterized by a region with poloidal shaping, which has a significant inclination with respect to the flat region of the panel (see Fig. 3).

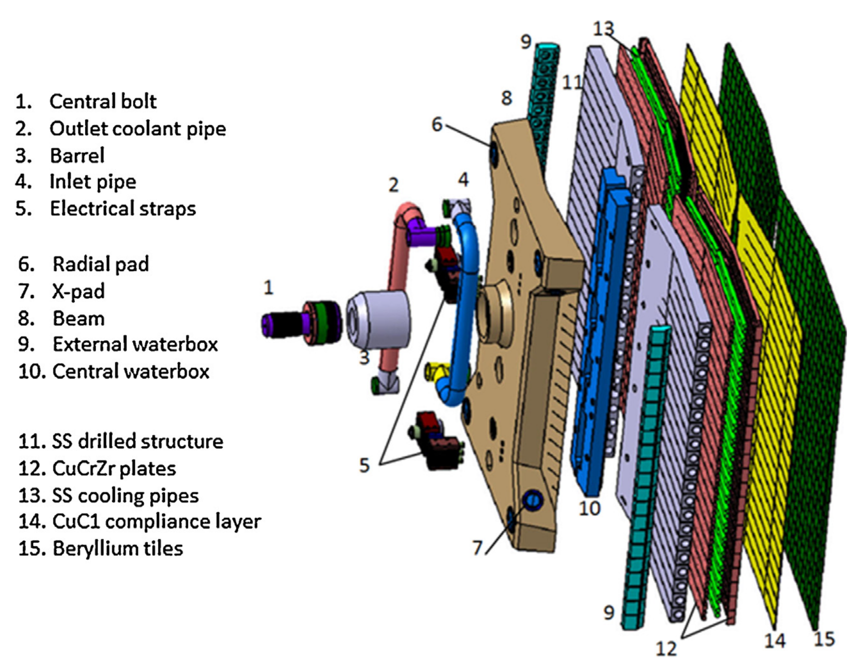

Fig. 1. Exploded view of a typical NHF FW panel.