Fatigue lifetime of repaired high heat flux components for ITER divertor

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The ITER divertor system is aimed at controlling the plasma density, exhausting the alpha particles and reducing the impurity content of the plasma, it consists essentially of two parts: a massive support structure called cassette body and the Plasma Facing Components (PFC). The cassette body is aimed at supporting the PFC, routing the water coolant into the PFC and providing neutron shielding. The divertor consists of 54 cassettes placed in a circular array. The PFCs are actively cooled thermal shields devoted to sustain the heat and particle fluxes under operational conditions (10-20 MW/m^2). The PFCs of the divertor are the dome, particle reflector plates, inner and outer vertical targets (VT) constituted of units. Each unit is composed of tens of CFC monoblocks (lower part of the VT) and W monoblocks (upper part of the VT). The CFC/W monoblocks are bonded to the CuCrZr coolant tube via a Cu interlayer. Previous studies showed that the most critical process in the fabrication of PFCs is the realisation of bond between the CFC/W armour and the CuCrZr heat sink. Since tens of thousands of armour/heat sink joints will be produced by the industry during the manufacturing phase of ITER PFCs, statistically, there is a non negligible probability that joints with defects will be delivered. These defects may be a critical concern with regards to heat exhaust capability and lifetime of PFCs. Consequently, the development of a relevant repairing process is necessary to limit the number of extra manufactured units which could lead to delays in manufacturing all the units filling the relevant quality criteria for the VT.

In this frame a batch of components with repaired CFC and W monoblocks were delivered to CEA/IRFM by two European manufacturers (PLANSEE and ANSALDO Ricerche) to evaluate and assess their repairing process before the launching of the manufacturing of the series. These components, including all the main features of the VT for ITER Divertor, were tested by means of the electron beam facility FE200 (European facility located at Le Creusot, France) with heat fluxes in the range of 5-20 MW/m^2 in steady state conditions. The main results of these tests are discussed in this paper in terms of heat removal capability and fatigue lifetime. In addition, the analysis relies on calculations based on the FEM simulations and on the comparison with results obtained with non destructive examination (IR thermography) undergone before, and after the thermal tests.

For repaired components, first results showed promising behaviour in terms of heat flux removal capability but it seems that the bonding of structural and heat sink materials is still considered unfavourable regarding high temperature deformation and cyclic fatigue for heat fluxes higher than 10 MW/m^2.