Influence of CFC quality on the performance of TS limiter elements under cyclic heat loading

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The actively cooled finger elements of the Tore Supra toroidal pump limiter have been subjected so far to heat fluxes in the range of 5-6 MW/m². With the recent upgrade of heating power it is expected to reach the design heat flux in the range of 8-10 MW/m².
During the fabrication of these 600 finger elements, flat CFC tiles were bonded via a AMC layer to a CuCrZr copper alloy heat sink structure. For the roughly 12000 tiles it was necessary to rely on two different elaboration batches of the apparently same CFC grade namely so-called SEP N11-92 (fabricated in 1992) and N11-98 (fabricated in 1998). While the AMC bonding process was optimized only for the 92-batch, it came out during testing that the bonding quality was degraded for the 98-batch and therefore an important number of tiles has been repaired during the fabrication campaign. Due to lack of time for the fabrication period, this degradation of performance has never been investigated in details.
In spite of previous but limited high heat flux (HHF) test campaigns performed on full scale finger elements in the e-beam facility FE200, which have been always performed at the design heat flux level around 10 MW/m², additional tests were necessary at lower heat loads in order to evaluate, compare and understand the fatigue behaviour of 92- and 98-batch finger elements.
Therefore two HHF test campaigns in 2009/2010 were performed on the ion beam GLADIS facility (IPP-Garching, Germany). During the first campaign a “virgin” 92- batch element has been compared with a “plasma exposed” 98-batch element which has been removed from the Tore Supra limiter for dedicated analyses. The second campaign included the same 92-batch element and a “virgin” 98-batch finger element.
The damage criterion was a CFC surface temperature enhancement of 50% during thermal cycling. The 92-batch element survived more than 3000 cycles without damage at 10 MW/m² (corresponding to 8 MW/m² at Tore Supra cooling conditions with pressurized hot water) during the two campaigns; however in each campaign different tile areas were loaded. The 98-batch elements behave similar in the two campaigns that is damage after roughly 100-200 load cycles at 8 MW/m² in steady state conditions (10 s on). The main outcome of these tests is the observed stabilisation of damage evolution when the cycled heat load is reduced to 5-6 MW/m² on such elements. Than 3000 cycles are sustained without problems.
Detailed results of these two HHF test campaigns are reported in this paper. Calculations based on FEM simulations are compared with results of the HHF tests. Microstructural analyses such as SEM imaging, XPS and SIMS measurements on the CFC/AMC-copper interface have been performed for better understanding of the bonding quality difference.

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