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PRE-BRAZED CASTING

A NEW METHOD TO JOIN CFC COMPOSITE TO COPPER FOR THE MANUFACTURING OF SMALL SCALE MONOBLOCK MOCKUPS

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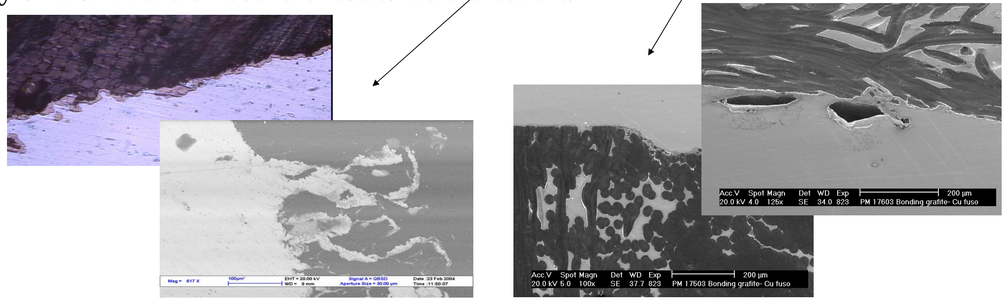
ABSTRACT

ENEA is involved in the European International Thermonuclear Experimental Reactor (ITER) R&D activities and in particular for the manufacturing of high heat flux plasma-facing components, such as the divertor targets, the baffles and the limiters: During the last years ENEA has manufactured actively cooled mock-ups by using different technologies, namely brazing, diffusion bonding and hot isostatic pressing (HIPping). A new manufacturing process has been set up and tested. This technique is the HRP (Hot Radial Pressing) based on performing a radial diffusion bonding between the cooling tube and the armour tile by pressurizing only the internal tube and by keeping the joining zone in vacuum and at the required bonding temperature.
It was successfully applied for the manufacturing of W armoured monoblock mockups.
The next step now is to apply the HRP technique for the manufacturing of CFC armoured monoblock components. For this purpose some issues have to be solved like as the low CFC tensile strength, the pure copper interlayer between the heat sink and the armour necessary to mitigate the stress at the joint interface and the low wettability of the pure copper on the CFC matrix.
The aim of the activity was fixed in the manufacturing of small scale CFC armoured mockups.
An ad hoc rig able to maintain the CFC in a compressive constant condition was also designed and tested.
The casting of a soft copper interlayer between the tube and the tile was performed by a new technique: the Pre-Brazed Casting (PBC, ENEA patent).
The first mock-up with three NB31 CFC tiles was successfully manufactured and it was tested in the TSEFEY-M electron beam facility at St. Petersburg (Russia). It reached 1000 cycles at 25 MW/m^2 without suffering any damage.
This activity was performed in the frame of an ITER-EFDA contract.

PBC - PRE BRAZED CASTING FOR CFC TILES

The mock-ups usually consist on monoblock CFC tiles that are joined to the copper alloy tube and a pure copper interlayer is required between the tile and the tube. This interlayer acts as a soft material that absorbs the stresses during exercise and the high demanding thermal tests.
This interlayer is obtained by casting the pure copper in the drilled hole that will host the tube.
The Pre-Brazed Casting (PBC) is an ENEA proprietary method that consists on a preliminary standard brazing phase with a commercial Ti-based alloy and a successive copper casting under vacuum.
The tile is also machined in order to prepare the surface by threading the pre-drilled hole with a special tool.
An ad hoc rig is used for the casting.
The micrographs show the joint zone between the copper and the CFC. It is visible the TiC zone resulting from the brazing phase.
Two types of CFC were investigated: the Dunlop 678 and the NB31 by SNECMA and on both the results were excellent.



CONCLUSIONS

The capability to manufacture W straight and curved monoblock high heat flux components by HRP was already assessed and after this experimental activity this manufacturing route can be applied also to CFC monoblock components.
The ‘compressing rig’ concept to maintain the CFC in a compressive constant condition solves the problem of the low mechanical strength of CFC avoiding the CFC failure during the HRP.
The PBC process solves the problem related to the Cu//CFC joining. The results obtained from the thermal fatigue testing of prototypes together with the preliminary investigations (metallographic, thermal shock tests) confirm that the joint obtained by PBC has a high mechanical strength .

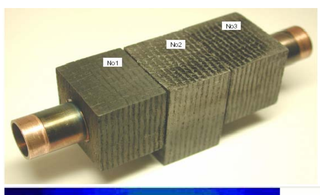
This technique was also used to manufacture a relevant vertical target prototype that covers each technological aspect of a

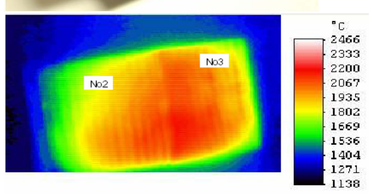
CFC MONOBLOCK MOCK-UPS BY HRP

To use the HRP manufacturing process to CFC monoblock mock-ups some issues has to be taken into account. It is an non-isotropic material and the tensile strength is variable in the three directions. The mechanical strength of the NB31 by SNECMA is: 110 MPa in the (X) direction (ex-pitch), 25 MPa in the (Y) direction (ex-Pan) and 15 MPa in the (Z) direction (needling).
During the HRP process the tube is pressurized up to 60-70 MPa and the stresses are transmitted to the CFC that is unable to withstand to such stresses. Therefore the CFC tiles have to be mechanically contained in order to keep them in a compression status in at least two directions: the X and the Y.
To obtain this compression status an ‘ad hoc’ rig was designed for each tile. This rig has to keep into account that the CTE (coefficient of thermal expansion) of the CFC is almost zero for a wide range of temperature. For this reason every single material puts around to try to compress the tile, after the heating is found with a gap between the tile and the material.
The rig was designed and a FE analysis was performed to choose the best dimensions of the rig and in particular to define the best shape and thickness of the insert components.
The rig consists of a low thermal expansion ring and four different inserts. The ring reacts to the internal pressure and to the thermal expansion of the inserts.

MANUFACTURING AND TESTING OF SMALL SCALE MOCK-UPS

A first small monoblock mock-up in which three CFC tiles was manufactured by HRP. The tiles with two different shape, were prepared by PBC.
The mock-up was tested under thermal fatigue testing in the TSEFEY-M facility (St. Petersburg).
The pictures show the mock-up and the infrared image after 1000 cycles at 25MW/m^2





Other mock-ups have been manufactured following this proven technology that uses the PBC and the HRP together. The shown mock-ups coming from a collaboration with other two firms: ANSALDO RICERCHE (IT) and CSM (IT).

All three mockups are now under thermal fatigue testing in the TSEFEY-M facility (St. Petersburg) and in the JUDITH facility (Julich)