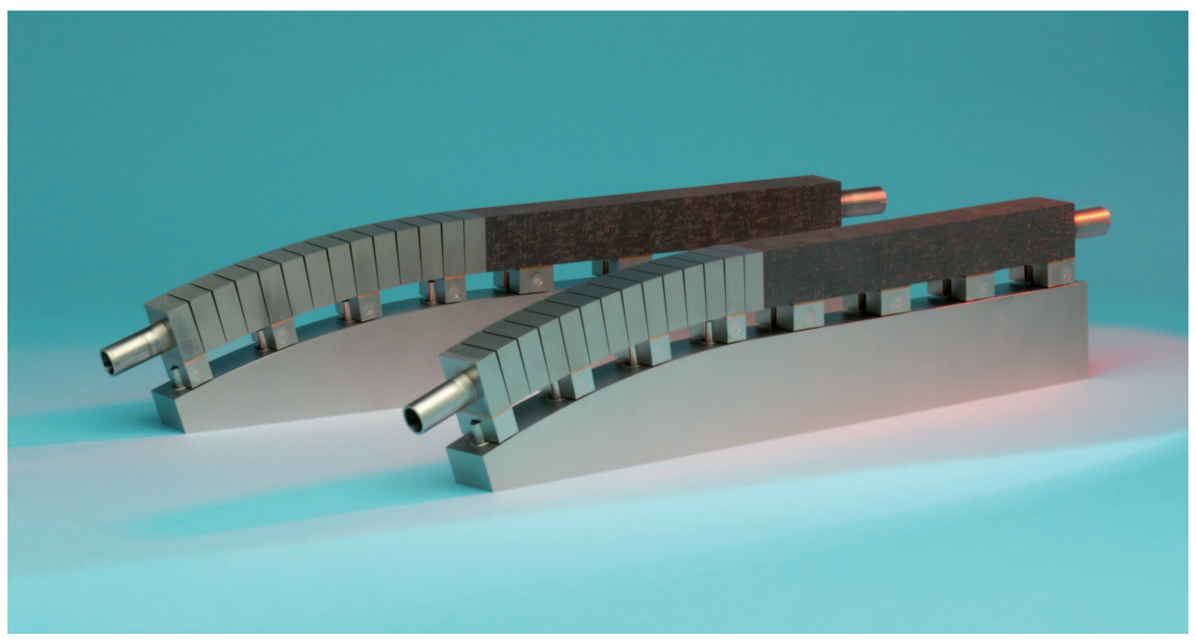
Authors:
T. Huber, PLANSEE SE, Reutte, Austria
H. Traxler, PLANSEE SE, Reutte, Austria
B. Harrer, Upper Austria University of Applied Sciences, Wels, Austria
R. Kickinger, Upper Austria University of Applied Sciences, Wels, Austria
B. Riccardi, Fusion For Energy, Barcelona, Spain

Computed tomography inspection of the CFC monoblock section of ITER Inner Vertical Target prototypes after production, after high heat flux testing and after critical heat flux testing.

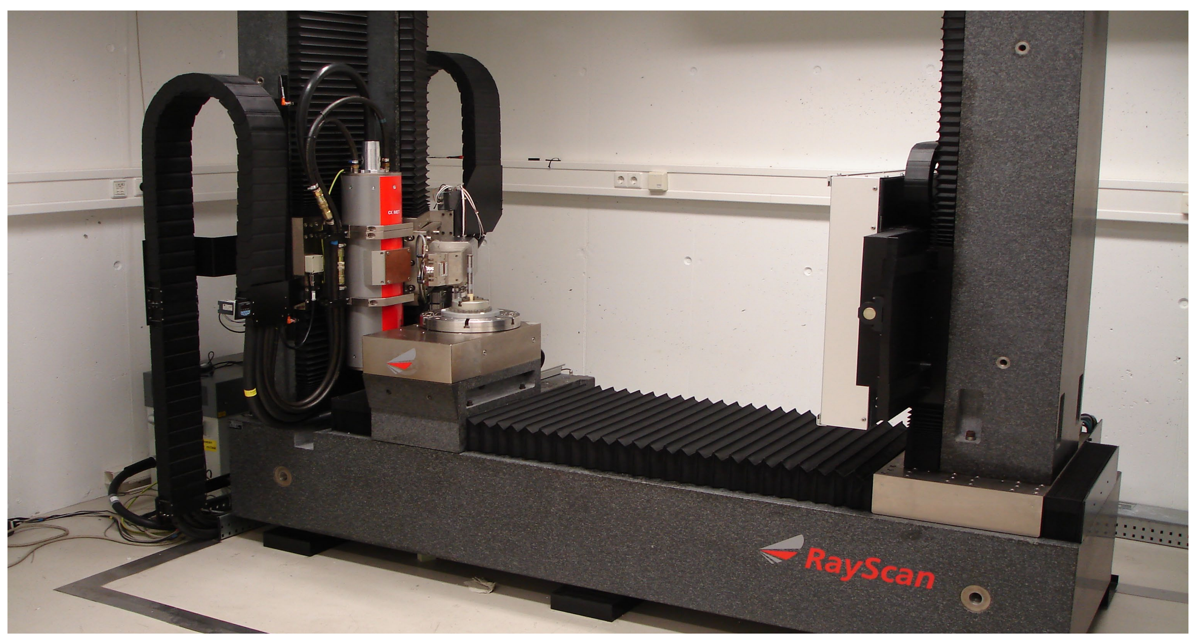
Introduction

The Inner Vertical Target (IVT) as part of the ITER divertor comprises plasma facing materials which are either carbon fibre reinforced carbon composites (CFC) or Tungsten. The ITER relevant design is a full monoblock armouring being actively cooled during operation by a heat sink tube made of a precipitation hardened CuCrZr alloy.

Besides application of standard non-destructive inspection methods as ultrasonic and radiographic inspection of an IVT prototype, a computed tomography was applied on the CFC monoblock section. CT scans were performed and analyzed comparably at three different stages, namely after production, after high heat flux testing (HHF) and after critical heat flux testing (CHF).



ITER inner vertical target prototype components



Computed tomography test facility RayScan 250E

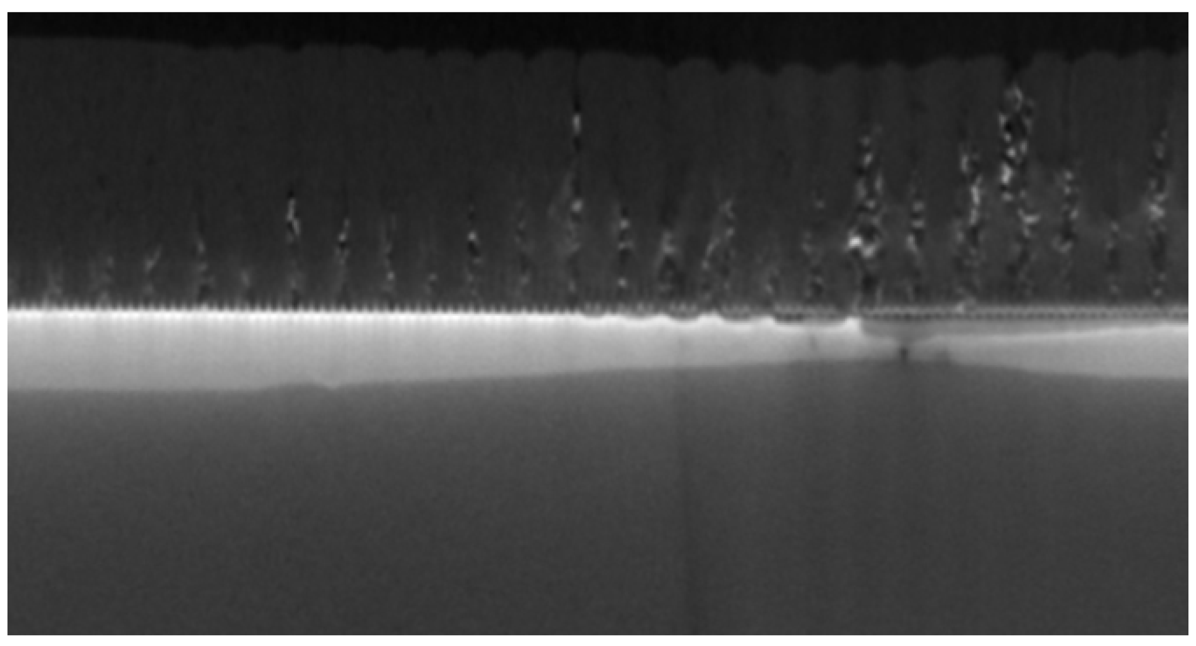
Methodology

Due to measurement-speed and quality, CT-systems with cone beam geometry and 2D matrix detectors have gained a general acceptance in material science as well as in industry.

When using cone-beam CT, a specimen is placed on a rotary stage between the X-ray source and the detector. The specimen is rotated stepwise, taking a projection image at each angular position. A computer cluster then reconstructs the projections to a volumetric dataset. For each position a grey value is calculated from the resulting dataset in the scanned sample volume. The determined grey values correspond to the effective X-ray attenuation coefficient, which is a function of density and atomic number.

CT results after heat flux testing

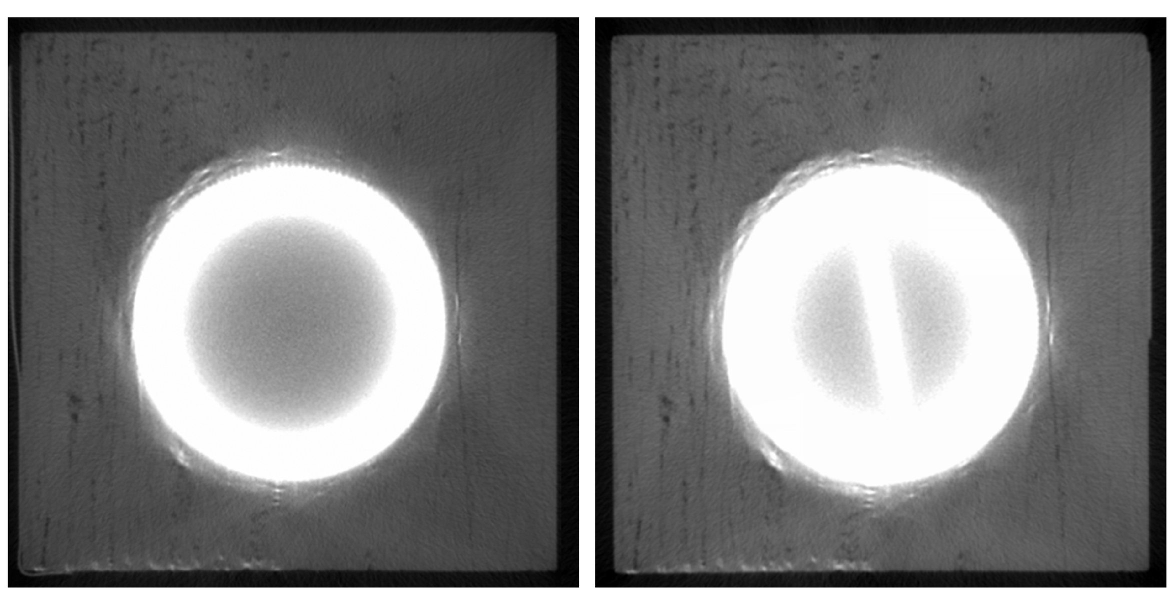
When comparing the CT inspection results before and after high heat flux testing (1000 cycles at 20 MW/m^2) there is no evidence for damages at the CFC/Cu interface. So-called equatorial cracks, which are fibre / matrix separations in the CFC near the AMC interface were already detected after production. These cracks do not disturb thermal flux and did not increase during thermal cycling.



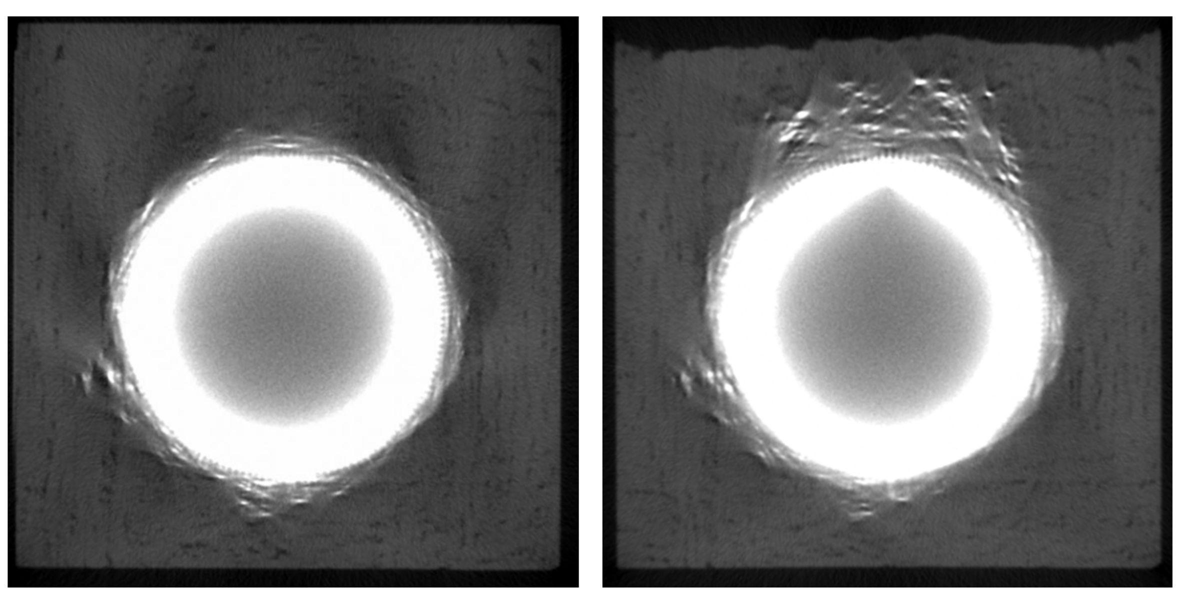
Longitudinal CT section of CFC monoblock after CHF

CT results after critical heat flux

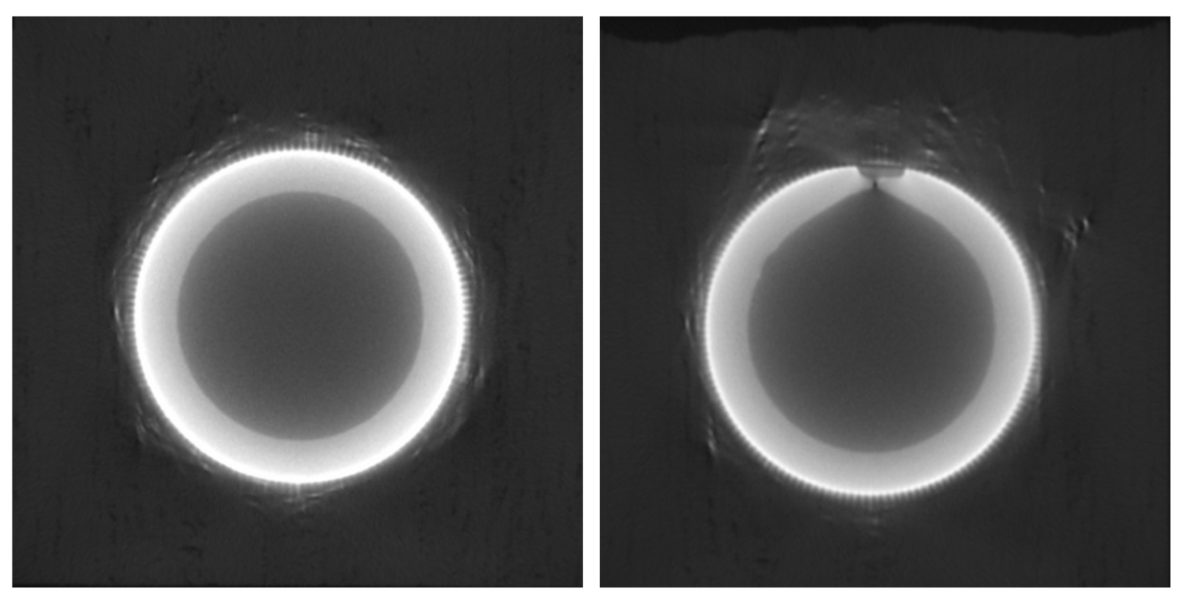
Critical heat flux testing was performed up to 27 MW/m^2, until burn out was observed. Comparing the results after HHF and after CHF testing, strong erosion and copper infiltration towards the plasma surface were detected nearby the CHF center. Leakage of the cooling tube can be observed at the actual CHF center. However, the lower part of the monoblock and its interfaces remain entirely unaffected.



CT cross section of CFC monoblock before and after HHF



CT cross section of CFC monoblock before and after CHF



CT cross section of CFC monoblock before and after CHF

Conclusion

In order to investigate defects as well as defect creation and development in the materials and their interfaces, computed tomography inspection was applied on the straight CFC section of ITER inner vertical target prototypes. CT was performed at three different stages of a components life time, namely after production, after high heat flux and after critical heat flux testing. After HHF testing at 20 MW/m^2 no changes were observed within the component. During CHF testing (27 MW/m^2) copper was melting and thus the cooling tube destroyed. CT enables precise determination of position and size of defects and structures in the CFC and at the CFC/Cu interface. Thus CT is an excellent non-destructive inspection method for product development and quality assurance of CFC components for ITER.

A Step ahead in Technology.

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