Residual Stress Measurements of a CuCrZr Tube Brazed to a W Tile Using Neutron Diffraction

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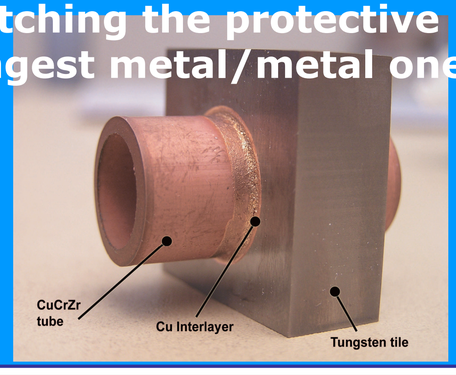
Motivation

- **In fusion related applications plasma facing compounds (PFC) are basically composed of a copper alloy (CuCrZr) heat sink protected by W or C-based materials. The PFC material is joined to the heat sink by means of a high temperature brazing process (up to 1040°C).**
- **The main problem of bonding W or C-based material to CuCrZr is the large difference in their CTE. This difference creates very large residual stresses (RS) at the interface and may result in damage of the joint simply from cooling it from the joining temperature.**
- **A low yield strength material compliant layer, like pure Cu, can be introduced between the protective material and CuCrZr in order to lower the RS by plastic deformation.**
- **Another solution is to introduce a high yield strength material interlayer with CTE matching the protective material, like Mo, in order to transfer the RS from the carbon/metal interface to the strongest metal/metal one.**

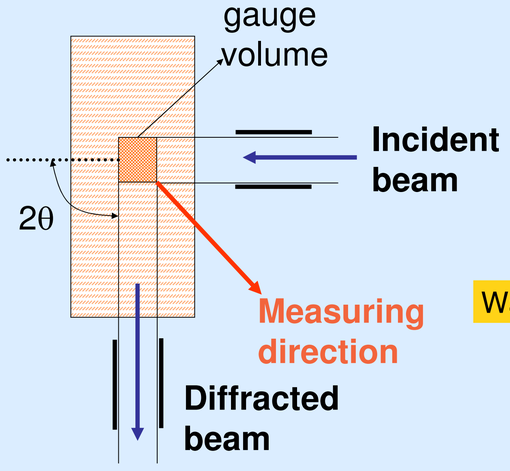
Aim of the work

- **Determination of the internal stresses tensor in the W volume over the weld using neutron diffraction**
- **To assess the integrity of the brazing process using neutron imaging**



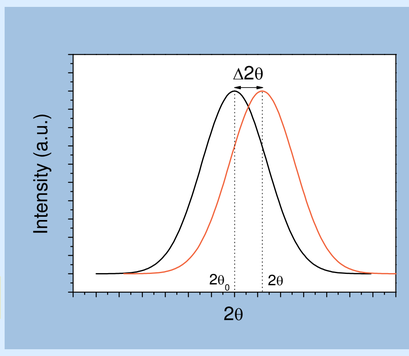
Principles of determining Stress by Neutron Diffraction

Macroscopic internal stresses → Local strains → Displacement of Bragg peaks



$$\lambda = 2d\sin\theta$$

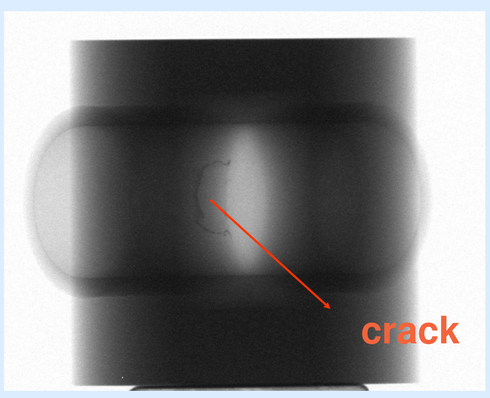
Wavelength λ: constant



Strain: $$\varepsilon_{\phi\psi} = \frac{d^{hkl}(\phi,\psi) - d_0^{hkl}}{d_0^{hkl}}$$

d^{hkl} ⟷ Interplanar distance between crystal planes (h k l)

d_0^{hkl} ⟷ Interplanar distance between crystal planes (h k l) in the absence of internal stresses



Neutron Imaging

Measurements were performed at ANTARES instrument at FRMII - TUM

Gadolinium acid has been used to enhance the contrast

- **Detection of a crack in the brazed region**

Conclusions

- **Neutron diffraction is the only non-destructive technique to determine the residual stresses in the volume of the materials around the joint**
- **The residual stresses of W/CuCrZr components for plasma facing applications have been determined in different regions in the welded area**
- **The maximum stress found are in the tangential direction, they are compressive and reach the value of 260 MPa at about 2 mm away from the brazed region**
- **Both the axial and tangential stresses are negative (compression) near the brazed region and up to about 4 mm away from it**
- **The radial stresses present little variation and they are compressive as we move from the middle of the W to its free surface**

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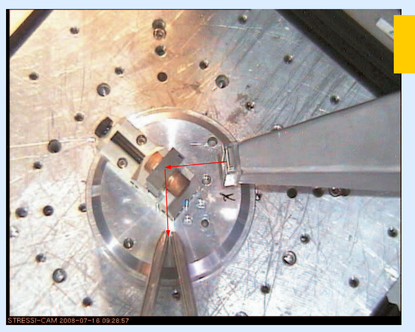
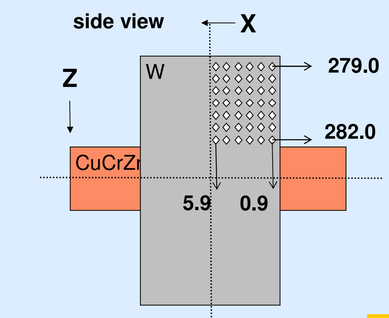
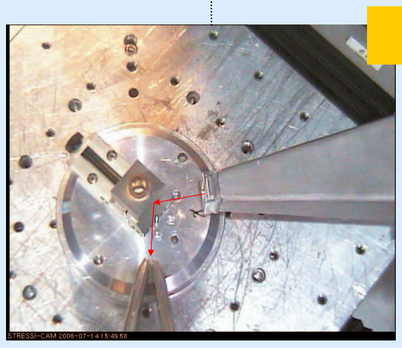
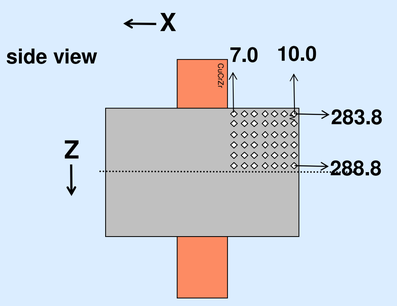
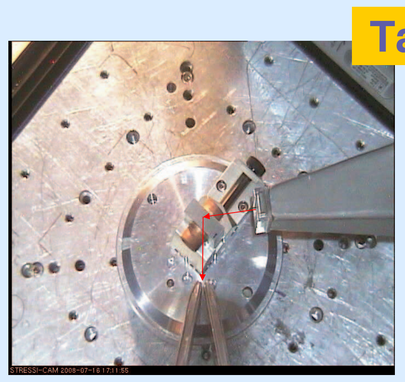
Experimental Set-up





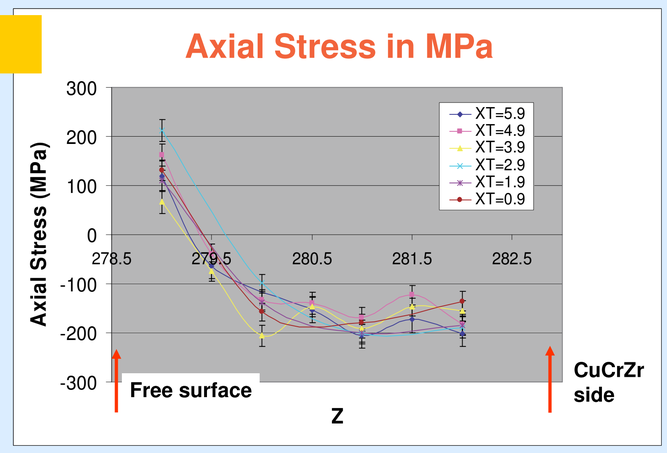






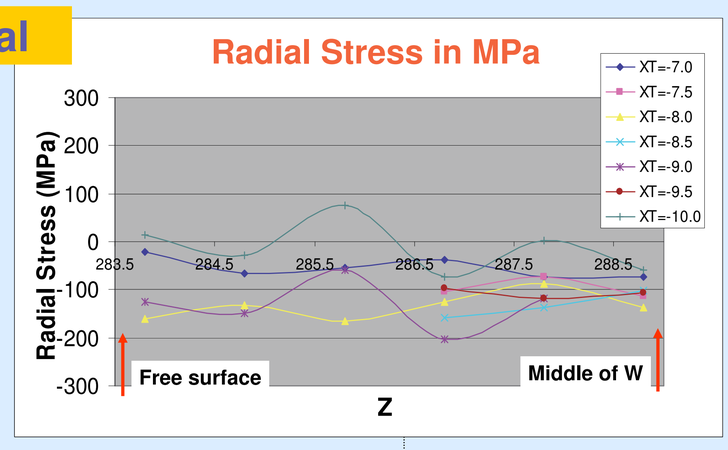
Results - Stresses

Axial



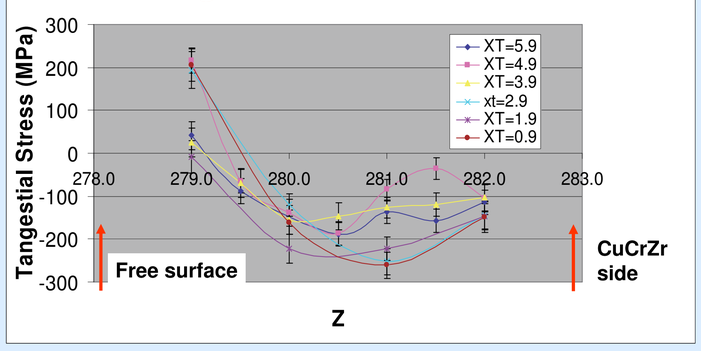
$$\sigma_{ax} = \frac{E}{(1+\nu)(1-2\nu)}\left[(1-\nu)\varepsilon_{ax} - \nu(\varepsilon_r + \varepsilon_t)\right]$$

Radial



$$\sigma_r = \frac{E}{(1+\nu)(1-2\nu)}\left[(1-\nu)\varepsilon_r - \nu(\varepsilon_{ax} + \varepsilon_t)\right]$$

Tangential



$$\sigma_t = \frac{E}{(1+\nu)(1-2\nu)}\left[(1-\nu)\varepsilon_t - \nu(\varepsilon_{ax} + \varepsilon_r)\right]$$

Measurements were performed at STRESS-SPEC instrument at FRMII-TUM