

Evaluating the micro-mechanics and residual stresses generated in W/CuCrZr dissimilar joints used in fusion reactors

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Abstract

The EU DEMOnstrative power plant (DEMO) project aims to develop next-generation fusion reactors with the focus of proving its commercial viability [1]. One of the challenges of DEMO is the harsh radiation environment that will expose its components to challenging working conditions such as high heat fluxes (HHF) and neutron irradiation. Hence, ensuring the materials chosen for the reactor components can adequately withstand such environment is critical to ensuring the safe and reliable operation of DEMO. In addition, the use of dissimilar joints is necessary from a design perspective in some components. This presents other challenges due to the introduction of residual stresses that are a consequence of the high temperature joining techniques typically used to create these joints. Such stresses can severely impact the service life of components and even cause premature failure if not accounted for.

In this study, Plasma Focused Ion Beam Digital Image Correlation (PFIB-DIC) and nanoindentation methods were used in conjunction to provide a detailed analysis of the micromechanics and type II residual stresses across Tungsten(W)/ Copper Chromium Zirconium (CuCrZr) dissimilar joint samples with a pure Copper (Cu) interlayer. The W/Cu/CuCrZr sample is a mock-up of the critical divertor component cooling system used in the current EU DEMO conceptual design [2]. This novel combination of methods allowed the consideration of the residual stress state in a non-biaxial manner by using the ring-core method for the strain relief, with an indentation made onto the ring-core pillar, and the use of Lee's nanoindentation model II to obtain the residual stresses [3],[4]. The distribution of residual stresses relative to the interface between the dissimilar materials was largely dependent on the texture and the grains considered; CuCrZr and W exhibited a random distribution which is due to the random textured polycrystalline nature of both samples that can influence the stress results on such a fine scale. On the other hand, the pure Cu layer grains were large enough such that the stress mapping was considered over a single grain. Results showed high compressive residual stresses near to the Cu/W interface as expected due to Cu having a significantly higher coefficient of thermal expansion than W. These results are complimented by microstructural analysis using Electron Back Scatter Diffraction (EBSD) grain orientation maps. These findings are important in the context of better understanding the residual stresses generation within the divertor component.

References

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