O-15

Development and Testing of a Novel FAST-Diffusion Bonding Process for Joining Eurofer97 Steel to Tungsten in Plasma Facing Components

Daniel Wilkison, Patrick Grant, Enzo Liotti

Department of Materials University of Oxford, United Kingdom

Manufacturing plasma-facing components for nuclear fusion reactors involves joining an armour material with a structural material used in the vacuum vessel. Tungsten (W) is a strong candidate for the armour material due to its high melting point, excellent thermal conductivity, low vapour pressure, low tritium retention, and high resistance to sputtering. For structural materials, low-activation steels like EUROFER 97 (E97) are favoured for their superior mechanical properties. However, joining W to E97 is challenging due to significant mismatch in their melting points, thermal expansion rates, and the formation of brittle intermetallic phases.

To address these issues, approaches such as interlayers, functionally graded layers, and dense vertical crack coatings have been developed and have shown partial success on small-scale joints. Recently, V. Ganesh et al. [1] compared these approaches to direct diffusion bonding of W to E97 performed with field-assisted sintering technique (FAST), also known as spark plasma sintering (SPS). The FAST diffusion bonding method produced joints capable of withstanding higher heat loads than joints produced with interlayers or functionally graded layers. However, the reason why FAST diffusion bonding can overcome the stress created by thermal expansion mismatch and produce W-E97 joints with excellent resistance to thermal cycling remains unknown.

To answer this question, this work identifies the key mechanisms underlying FAST diffusion bonding that address the challenges of W-E97 joining. These mechanisms are first analysed with finite element modelling and then validated through a comparative study using the Magnum PSI facility at the Dutch Institute for Fundamental Energy Research. The joints are subjected to fusion-relevant thermal conditions and cyclic heat loads produced by hydrogen plasma. Finally, we demonstrate the suitability of FAST diffusion bonding for joining other dissimilar material systems, including W-CuCrZr joints. Together with the Dr. Fritsch Group, we demonstrated the scalability of FAST diffusion bonding by producing tiles as large as 10 cm $\times$ 10 cm with excellent bonding strength using industry-scale FAST machines.

[1] V. Ganesh, D. Dorow-Gerspach, M. Bram, C. Linsmeier, J. Matejicek, M. Vilemova, Energies 16, 3664 (2023).