

Finer-scale residual stress characterisation in laser-welded Eurofer97 steel for fusion plant

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Abstract:

Residual stresses almost always remain in an object after manufacturing, e.g., welding processing, additive manufacturing and synthesis of composite, ceramics and bio-inspired materials. They can be detrimental or beneficial to the manufacture and performance of engineering components. Inspection of residual stresses is necessary for complex industrial material systems, as undesirable residual stresses can cause premature catastrophic failure of critical components. The Reduced Activation Ferritic Martensitic Steel Eurofer97 is the main material considered for the in-vessel components (e.g. breeding blanket structure) of the demonstration fusion plant DEMO. Laser welding is one of the fastest and most reliable methods and can be used for remote manufacturing and maintenance of components. It is understood that the mechanical properties can be degraded by the heterogeneous residual stresses and crystallographic structures in the weldment, leading to in-service creep stress relaxation cracking and lifespan reduction. The multi-scale residual stress evaluation could provide valuable insights into keeping the structural integrity of the fusion plant components. In this work, the as-welded Eurofer97 sample was butt-welded by the single laser welding technique, and the residual strain is evaluated by three technologies at multi-scale, including neutron diffraction, neutron Bragg edge imaging and Xe⁺ plasma focused ion beam and digital image correlation (PFIB-DIC) techniques. Significant residual strain was observed across the fusion zone (FZ), heat affected zone (HAZ) and base material (BM) in multi-scale. The sharp residual strain gradients quantified by high-resolution characterisations are beneficial to the development of micromechanical rationale for failure mechanisms such as creep cracking initiation. The multi-scale residual strain distribution is correlated with microstructure characterisation and mechanical property using electron microscopy, micro-hardness and nano-indentation methods. Such correlation will contribute to a predictive model to help optimise the mechanical properties and lifetime of components.

Acknowledgement:

The authors give thanks to the Karlsruhe Institute of Technology for providing the Eurofer97 plate for this study and Dr Simon Kirk (UKAEA) for his advice on laser welding. This work has been carried out within the framework of the EUROfusion Consortium, funded by the European Union via the Euratom Research and Training Programme (Grant Agreement No 101052200 — EUROfusion). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor the European Commission can be held responsible for them. Part of this work was supported by EPSRC grants (EP/P001521/1, EP/T012250/1 and EP/W006839/1) and the UK Government Department for Business, Energy and Industrial Strategy. Dr Sui would like to acknowledge funding from the Royal Academy of Engineering under the Industrial Fellowships programme.

Reference

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