A Novel Pathway for Multi-scale High-resolution Time-resolved Residual Stress Evaluation of Laser-welded Eurofer97

Bin Zhu1, Yiqiang Wang2, Jiří Dluhoš3, Andy J. London2, Michael Gorley2, Mark J. Whiting1, Tan Sui1*

1. School of Mechanical Engineering Sciences, University of Surrey, Guildford, Surrey, UK.
2. United Kingdom Atomic Energy Authority, Culham Centre for Fusion Energy, Culham Science Centre, Abingdon, Oxon, UK.
3. TESCAN ORSAY HOLDING, a.s., Libušina třída 21, Brno, Czech Republic.

* Corresponding author: t.sui@surrey.ac.uk

Nuclear fusion power has the potential of becoming a clean, zero-carbon and inexhaustible energy source of electricity production, to diminish supplies of fossil fuels and threats of climate change catastrophe. Eurofer97 is a primary construction material for in-vessel fusion power plant components, such as pipes, breeding blanket and divertor cassette. As the irradiated circumstances, the assembles and maintenance must be completed autonomously [1]. Laser welding is a promising joining technique that is used extensively in a wide range of industries for the joint with complex material system [2]. However, the laser welding induces significant residual stresses, up to c.800 MPa, as a result of the thermal distortion and the martensite phase transformation incurred during welding [3]. The heterogeneous residual stress induced by welding can interact with the microstructure, resulting in a degradation of mechanical properties and a reduction in joint lifetime. To build a high-precision residual stress predictive tool for optimizing manufacturing processes and extending in-service time of engineering components, a multi-scale, high resolution quantitative residual stress measurement is necessary to reveal the relationship between residual stress, microstructures and mechanical properties. Here, a Xe+ plasma focused ion beam, with digital image correlation (PFIB-DIC) are used to quantify the residual stress distribution across the weldment. A high-resolution and time-resolved residual strain is obtained at a finer scale, which provides critical information to develop micro-mechanical rationale for failure analysis. Nanoindentation was also used to cross-validate the residual stress distribution from the Xe+ PFIB-DIC technique. The stress ratio \((k)\) gained from PFIB-DIC technique overcomes the key limitation of nanoindentation residual stress measurement [4].

References:


