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

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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].

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