Validation of the Residual Stress Measurement for a Eurofer97 Laser Welded Joint

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Abstract

A large research effort is being put into nuclear fusion for generation of electricity, this push is ever more important as the world works towards decarbonising. One goal is to the realisation of DEMO class reactors, where the aim is to demonstrate the generation of baseload electricity from fusion. One area of development is the reactor's structure, where a Eurofer97-Eurofer97 laser welded joint has been proposed. Eurofer97 is a European grade of reduced-activation ferritic/martensitic (RAFM) steel [1]. Several RAFM steels were developed for use as the structural member for reactor first wall structures, where they will be subjected the extreme environments of fusion [2]. As the components are large scale, a joining technique must be employed. Due radioactive environment within the reactor any maintenance must be completed through robots, therefore laser welding is the joining technique proposed for this manufacture of these joints and subsequent maintenance. As the development of these DEMO class reactors focuses on commercial feasibility, their structures are developed for a long service life. In this case, a full understanding of the detrimental residual stress generated in the joint during laser welding is required. Otherwise, residual stress can lead to catastrophic failure through complex interaction within the microstructure [3].

There are three types of residual stress, which exist over different length scales: Type I covers the macro stresses, such as over a whole joint; Type II is smaller and concerns intergranular stress; and the smallest of all is Type III, which exists at the nanoscale or known as intragranular stress [4]. Many techniques can be used to measure residual stress, but they tend to be either destructive in nature or are limited in spatial resolution. For destructive techniques there is layer removal [5] and hole drilling [6]; limited spatial resolution examples are synchrotron-based X-ray diffraction [7] and neutron diffraction [8]. In between are two methods, these are nanoindentation [9] and focused ion beam with digital image correlation (FIB-DIC) [10]. These techniques provide cross validation to each other, as the methodology of the FIB-DIC manufactures a stress-free site which can be created as a baseline for the nanoindentation measurements. These techniques will be used together on the validation of the multiscale characterisation on a Eurofer97-Eurofer97 laser welded joint, this has been recently published [11].

To continue this papers work, at the University of Surrey using a Tescan FERA III more of these stress-free references were created. Using a standalone nanoindenter, these several stress-free references were indented onto and a 9 mm nanoindentation linescan was completed. This work will then be correlated with previous data collected for the published paper, it will look to compare various nanoindentation instruments with the FIB-DIC to probe into the reproducibility in using such methods for the characterisation of residual stress.

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