Experimental report

18/08/2022

Proposal: 1-02-342 **Council:** 4/2021

Title: Reveal residual stress-mechanical performance interaction of laser-welded Eurofer97 via in-situ neutron diffraction

Research area: Engineering

This proposal is a resubmission of 1-02-308

Main proposer: **Yiqiang WANG**

Experimental team: Bin ZHU
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Local contacts: Thilo PIRLING

Samples: As-welded_Eurofer97
PWHT_Eurofer97

Instrument	Requested days	Allocated days	From	To
SALSA	4	4	17/09/2021	21/09/2021

Abstract:

To facilitate Remote Maintenance (RM) of demonstration fusion plant, the RM teams at Culham Centre for Fusion Energy (CCFE) utilise lasers to join EUROFER97 components. However, this rapid welding process generates significant residual stresses inside the polycrystalline materials. The heterogeneous residual stresses can associate with the elastic-plastic anisotropy at the grain scale, leading to Bauschinger effect and tension-compression asymmetry in polycrystalline materials. However, the mechanistic connections between the residual stresses and mechanical behaviour of laser-welded Eurofer97 steels remain unexplored. The current proposed study aims to a fundamental understanding the underpinning deformation mechanism associated with strain softening and residual stresses of laser-welded Eurofer97. The correlations between microstructures and mechanical performance will also be conducted. This work contributes to the PhD of Bin Zhu, which is co-funded by Surrey Doctoral College Studentship in collaboration with CCFE/UKAEA. This proposal is resubmitted with significant improvements.

SALSA Experimental Report Form

1 PRINCIPAL INVESTIGATOR

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2 EXPERIMENT DETAILS

Reference Number: 1-02-342
Title: Reveal residual stress-mechanical performance interaction of laser-welded Eurofer97 via in-situ neutron diffraction
Equipment/Facility Used: SALSA
Dates Scheduled: 17 Sep 2021 to 21 Sep 2021 Days: 4

3 EXPERIMENT OBJECTIVES

To palliate the deleterious effects of residual stresses on a laser-welded Eurofer97 component, we aim to fundamentally understand the mechanistic connections between the residual stresses and mechanical behaviour of laser-welded Eurofer97 steels. *In situ* neutron diffraction experiments provide a powerful approach to unravel the lattice strains and associated microstructures as well as their evolution under applied loads. The main tasks in this experiment were to perform *in situ* neutron diffraction to quantify the evolution of lattice strains in both base material, fusion zone and heat affected zone during uniaxial loading. These understanding plays a pivotal role in avoiding failure of fusion components and can benefit the development of predictive tools regarding the structural integrity of fusion power plant.

4 EXPERIMENT REPORT

The strain characterisation was performed using the SALSA monochromatic neutron diffraction instrument with a gauge volume of $0.6 \times 0.6 \times 2\ mm^3$ to obtain high-resolution strain data in the sub-regions of the weldment. A wavelength of 1.685 Å was used to measure the *<110>//LD* grain family in the loading direction. Through-thickness residual strain and strain evolution were measured on laser-welded and PWHT samples. To ensure the quality of the diffraction patterns, 1500 neutron statistics were acquired at each datapoint.

The preliminary results of through-thickness residual strain distribution and strain evolution under the tensile loading is summarised in **Fig. 1**. Further analysis is still ongoing to investigate the underpinning deformation mechanism of Eurofer97 joint.

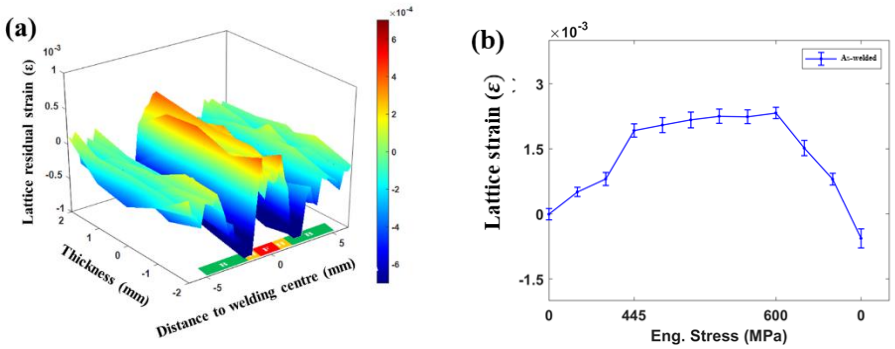

Fig 1 (a) The through-thickness residual strain distribution (b) the strain evolution under tension.

5 LIKELY OUTCOMES FROM EXPERIMENT

- High impact journal publication
- The results will contribute to a PhD thesis
- Conference oral presentations or posters
- Fellow-up experiment at SALSA to investigate residual stress effect on other mechanical properties, such as fatigue.