Experimental report

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Proposal: **1-04-164** **Council:** 4/2019

Title: Welding parameter study on the residual stress in a P91 bead-on-plateweld

Research area: Engineering

This proposal is a new proposal

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Samples: P91 steel

Instrument	Requested days	Allocated days	From	To
SALSA	4	2	12/10/2019	14/10/2019

Abstract:

The purpose of this proposal is to apply for beam time at ILL using the strain imager SALSA in order to measure the residual stress distribution in two bead-on-plate specimens of P91 martensitic steel. The results of the experiment will be used to validate the numerical studies for the prediction of the residual stress during the welding process and they will contribute to understanding of residual stress development in 9Cr martensitic steels. The lattice strain will be measured and the residual stress will be determined in the specimens at a number of key locations. The measurements will also be compared with the respective results of other neutron diffractometers and with finite element predictions.

Experimental Report – Proposal No. 1-04-164

Welding parameter study on the residual stress in a P91 bead-on-plate weld

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Abstract/Aim

The aim of this experiment is to quantify the residual stress in two P91 bead-on-plate welds providing validation for the numerical tools being developed in the Mechannics project. Moreover, the results are used as a comparison with respective residual stress measurements conducted at Engin-X (Rutherford Appleton Laboratory, Oxford, UK) and E3 (Helmholtz Zentrum Berlin, Berlin, Germany) diffractometers. The results have been submitted for presentation for the ASME PVP 2020 conference, [1].

EXPERIMENT

Two bead-on-plate welds of P91 martensitic steel were manufactured with the manual metal arc (MMA) welding process with different welding speed (v = 2.8, 4.1 mm/s) resulting in two heat inputs (Q = 1045, 731 J/mm, respectively). Two stress-free slices were extracted from plates manufactured with similar welding parameters in order to determine the lattice parameter of the weld in stress-free conditions. The geometry of the manufactured plates is shown in Figure 1. The two specimens were measured along the lines L1, L2 and L3 illustrated in Figure 1, located on plane A at middle length. A gauge volume of 0.6 × 0.6 × 2 mm^3 was used to measure the scatter angle (θ) in order to evaluate the residual stress within the welds.

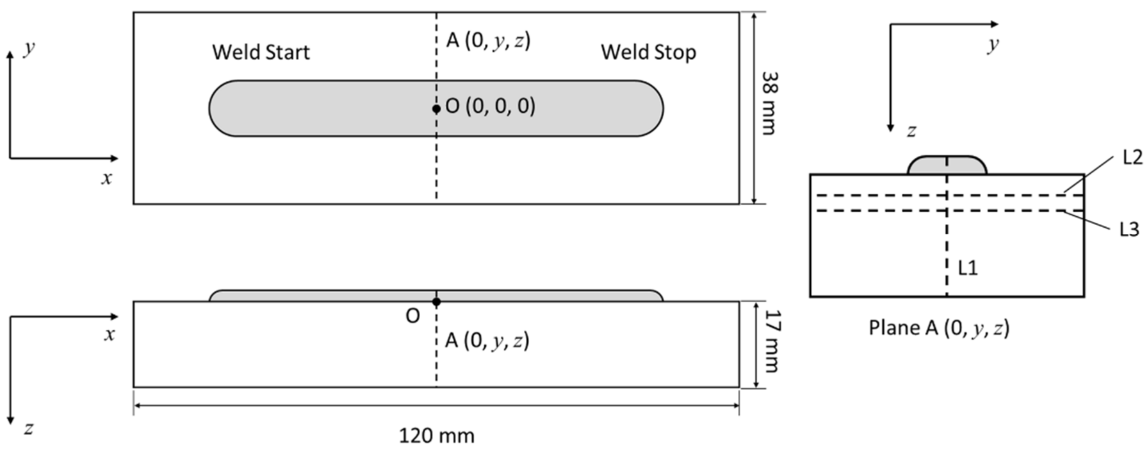

Figure 1. Schematic diagram of the weld and plate, defining the plane A, the measurements lines (L1, L2, L3), coordinate direction and identifying the weld start and stop positions.

RESULTS AND DISCUSSION

Figure 2 shows the distribution of the longitudinal stress along lines L1 and L2 for the two plates. The heat input did not have a significant effect on the peak stress or the distribution of the longitudinal stress within the plate. Some difference is seen along line L1 close to the heat affected zone (HAZ) and fusion zone (FZ), z < 2 in Figure 2(a), with the high input weld showing a region of large compressive stress in the HAZ and FZ.

The transverse stresses along the lines L1 and L2 within the two specimens are presented in Figure 3. The distribution of the transverse stress are similar in both specimens apart from in the HAZ and FZ in Figure 3(a).

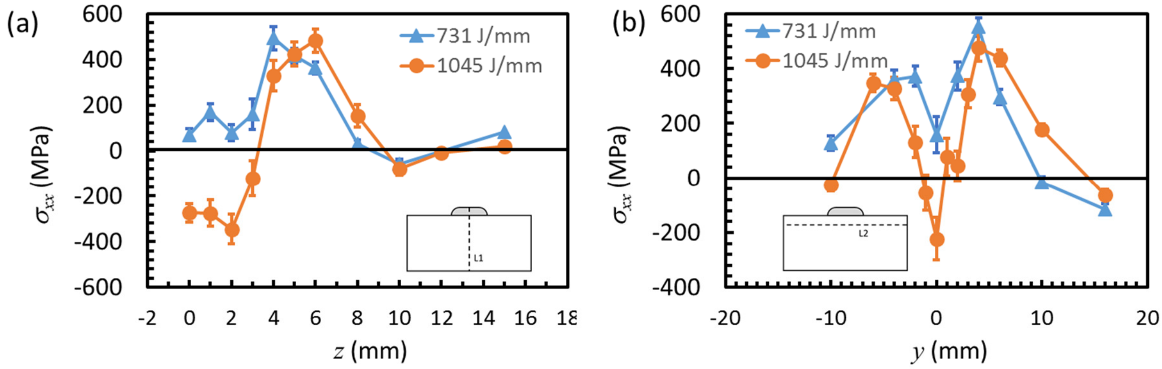

Figure 2. Comparison of longitudinal stress (σ_{xx}) between the plates manufactured with different heat input (a) along line L1 and (b) along line L2.

Figure 4 shows the stress distribution normalised by the yield stress of the material of the weld specimen manufactured with low heat input, Q = 731 J/mm. The current measurement is compared with previous measurements carried out at the diffractometers Engin-X (Oxford, UK) and E3 (Helmholtz Zentrum Berlin, Berlin, Germany) and the respective normalised Bayesian average of the NET Task Group 1 measurements on a 316 L stainless steel. The measurements at the three diffractometers showed good agreement (Fig. 4) and the stress profile resulted from the measurements show a reasonable similarity with the respective Bayesian average of the NET specimen. Both the Engin-X and E3 measurements showed a compressive longitudinal stress near the HAZ and FZ for this heat input. The NET measurements did not extend into the HAZ.

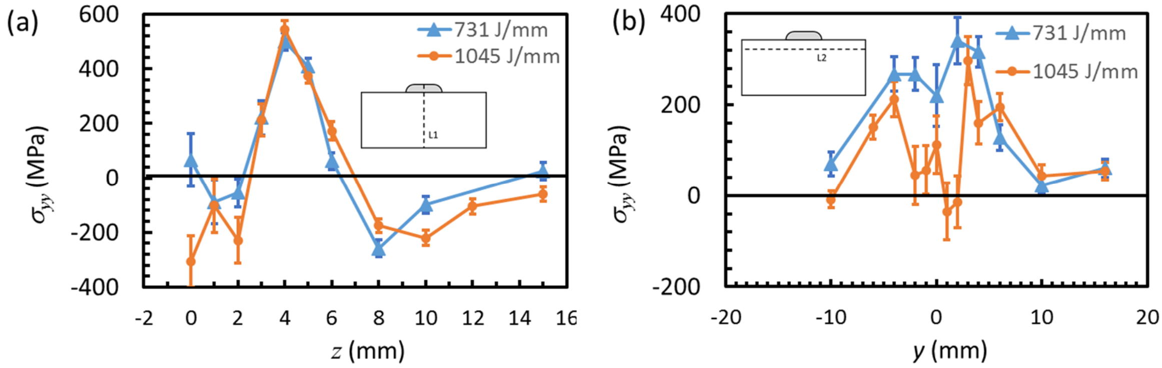

Figure 3. Comparison of transverse stress (σ_{yy}) between the plates manufactured with different heat input (a) along line L1 and (b) along line L2.

FUTURE WORK

The residual stress measurements will be used to validate numerical predictions using 3D finite element analysis. Further residual stress measurements will be carried out at the same specimens after implementing post-weld heat treatment (PWHT) allowing the effect of stress relief mechanism will be investigated.

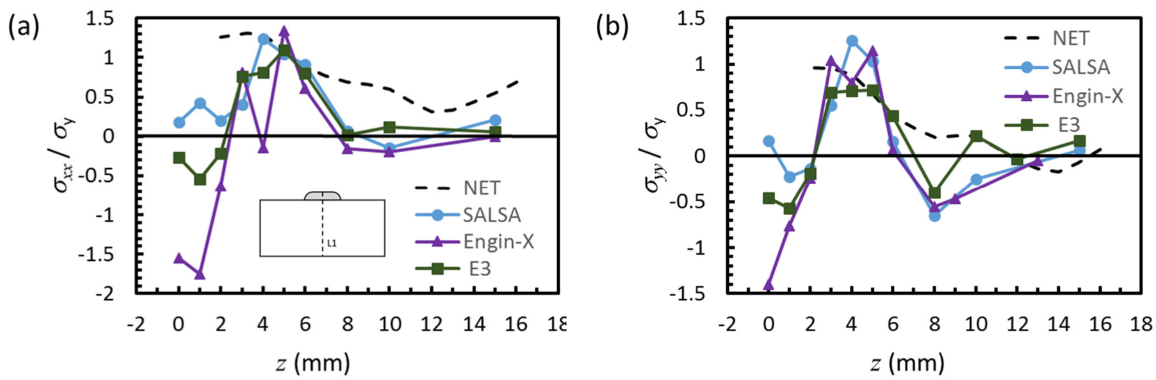

Figure 4. Comparison between normalised stress distributions along the line L1 of the NET TG1 specimen [2] and the measurements carried out in the P91 plate manufactured with heat input, Q = 731 J/mm at SALSA (ILL, Grenoble), Engin-X (Rutherford Appleton Laboratory, Oxford) and E3 (HZB, Berlin) (a) longitudinal stress (σ_{xx}/σ_y) and (b) transverse stress (σ_{yy}/σ_y)

References

[1] S. A. Alexandratos, R. C. Wimpory, T.-L. Lee, P. MacArdghail, S. B. Leen, N. P. O'Dowd, (2020), "Comparison of residual stress measurements on single bead-on-plate welds of a martensitic steel using neutron diffraction", *Proceedings of the ASME 2020, PVP2020 July 19-24, Minneapolis Minnesota, USA* (Under Review)

[2] R. C. Wimpory, C. Ohms, M. Hofmann, R. Schneider, A. G. Youtsos, (2009). "Measurement of residual stress in materials using neutrons". Int. J. Press. Vessel. Pip., 86, pp. 48–62.