178 Fracture behaviour of welded joints

M. Mostafavi[1,a], M. Mokhtari[1], C Simpson[1], Z Davey[1], M Gleeson[1]

[1]Department of Mechanical Engineering, University of Bristol, Queen's Building, Bristol, UK

[a]m.mostafavi@bristol.ac.uk

Abstract Despite the development of advanced manufacturing technologies, welding remains a popular option for joining components. The structural integrity of welds has always been an important academic and industrial topic. Although the new welding technologies promise the automisation thus cost reduction in manufacturing technologies, there is still is room for established welding techniques in producing bespoke structures. In this project, manual arc weld has been used to produce a large number of welded plated in various conditions. Synchrotron X-ray diffraction was used to measure the residual stress in the plates and more importantly, evaluate the variation of the residual stress field in the plate. A series of fracture tests were conducted on the welded sample both on the weld and on the parent material to assess their variability and investigate whether the residual stress distribution and fracture toughness distributions are correlated.

Introduction

The influence of welding on the integrity of components has been researched extensively. Two main factors influencing the integrity of weldment are residual stresses and change of microstructure. Both factors can vary considerably in weldments that are nominally the same. It is therefore of interest to investigate the variation in the fracture toughness of weldments and correlate it with the variation in its residual stress and microstructure.

Experiments

In this work, a total of ten 25 mm thick 400×400mm plates made of ASTM A131 Grade DH36 steel were welded. Manual arc weld in a double-V butt weld geometry was used with 7 passes on one side followed by 9 passes on the other. No post-weld heat treatment was carried out.

In order to measure residual stress, strain measurements were made in the transverse orientation at the Diamond Light Source on the I12:JEEP beamline. In this experimental session energy dispersive X-ray diffraction (EDXRD) was used, with lattice spacing and therefore strain being assessed at 23 azimuthally arrayed locations (evenly spaced around a semi-circular detector). This detector array allowed for the simultaneous measurement of both longitudinal and transverse strain. A gauge volume of 1 mm x 1 mm x ~14 mm was used (the gauge length of 14 mm is controlled by the incoming slit size). Measurements were once again made on the same stress-free reference samples. Data processing and strain analysis was completed using the pyXe strain analysis software [1]; the process is discussed in more detail in [2].

After the measurement of residual stresses, compact tension specimens were extracted from the plates far away from the weld (parent material) and from the weld (see Fig 1a). The specimen dimensions were in accordance with ASTM E399 with a sample width W = 50mm. Wire electro-discharge machining was used to cut a sharp notch (wire diameter 0.1 mm) up to half width of the sample (a/W = 0.5). The notch was followed by a fatigue pre-crack of nominally 2 mm induced by R ratio 0.1 and a maximum stress intensity factor not exceeding 10 $MPa.mm^{0.5}$. The samples were then loaded in tension with the load and crack mouth opening displacement measured using a clip gauge recorded synchronized by the controller of a servo-hydraulic test frame. Once it was judged that the maximum load was achieved, the sample was fatigued again to allow for possible crack extension measurement. Fig 1b shows the fracture surface of such sample while in the grip.

a) b)

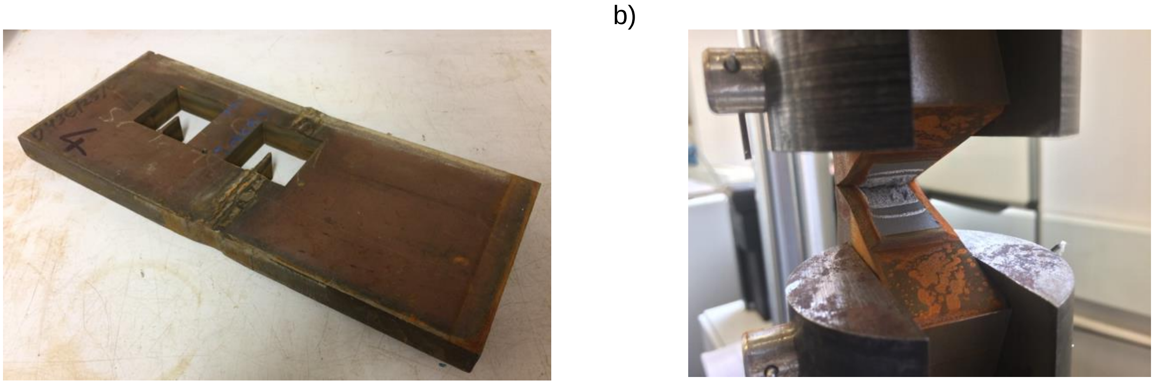

Fig 1 – a) welded plate with compact tension samples cut our using electro discharge machining from the parent and the weld b) example of the fracture surface of sample made of parent material

Results and discussion

Fig 2 a and b show the variation of residual strains measured in the welded plates the coordinate system is selected so that the weld is at position 0. It can be seen that the variation of residual stress within the plates is relatively low (less than 0.05%). Fig 2 c and d show the load – crack mouth opening displacement of the parent of weld respectively. The fracture mechanism changed from ductile crack growth to fast fracture between the two types of samples. Since the residual stress field is not triaxial, it can be argued that the change of mechanism was due to the microstructural change the welding produced rather than mechanical residual stress. Micrographs of the parent and weld materials are given in Fig 2 e and f which show columnar and elongated grains in the welded region as opposed to near symmetric grains in the parent.

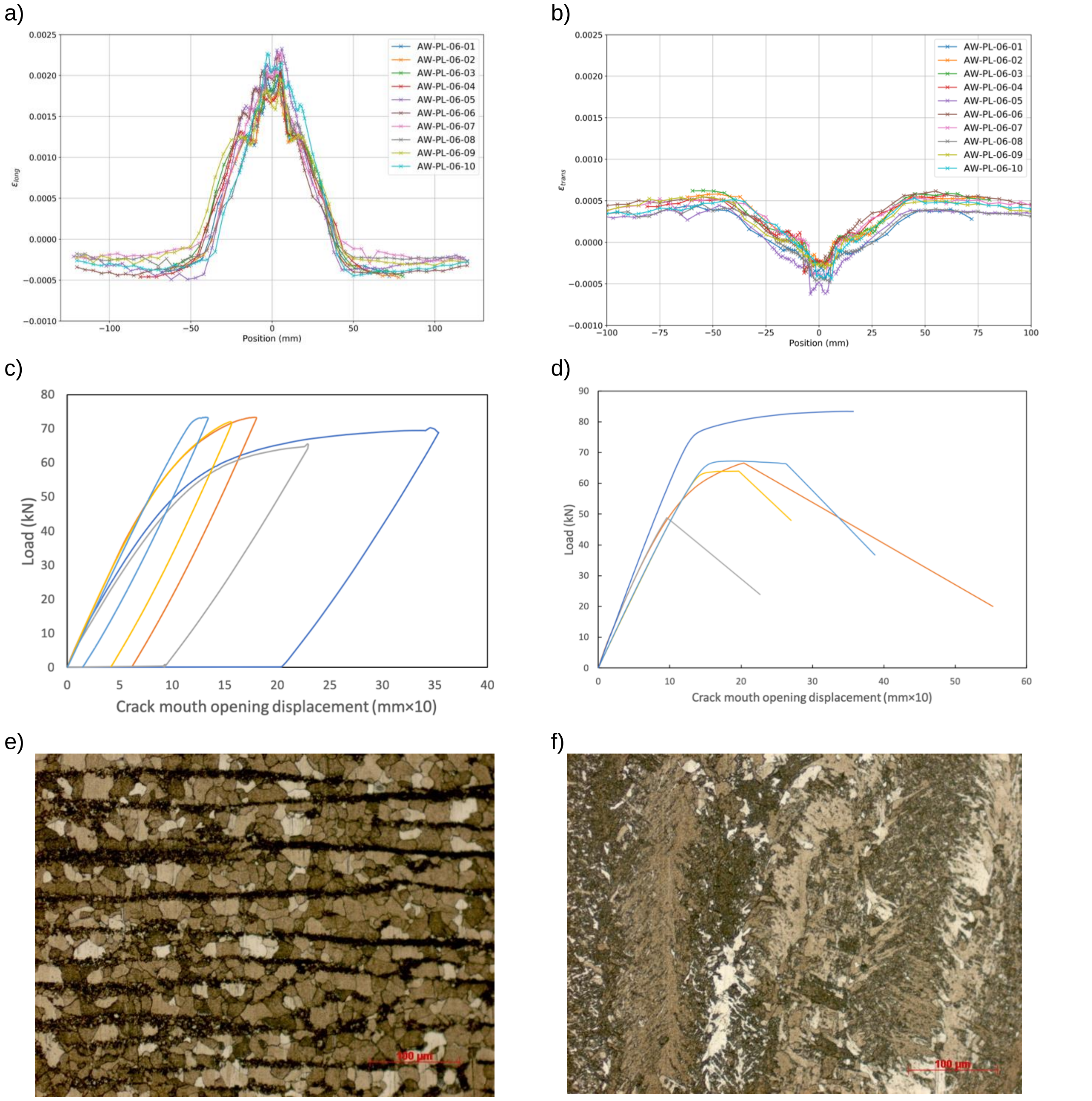

Fig 2 – Results a) Longitudinal residual stress measured in 10 plates b) Transverse residual stress measured in all plates c) load – crack mouth opening displacement of compact tension samples

Acknowledgement

This work was carried out under project FORCE under the contract with Department of Business, Energy, and Industrial Strategy led by Frazer Nash Consultancy. Cammell Laird is thanked for producing the welded plates and Diamond Light Source is gratefully acknowledged for providing access during beamtime

References

[1] Simpson, C. A. (2016, April 21). pyxe: XRD Strain Analysis. https://doi.org/10.5281/zenodo.50185

[2] Simpson, C. A. et al. Quantifying fatigue overload retardation mechanisms by energy dispersive X-ray diffraction