Mapping the spatially varying yield strength of welded joints.

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Abstract. This work advances the experimental validation of a methodology for the automated spatial mapping of heterogeneous elastoplastic properties in welded joints. The methodology, previously developed and verified using numerical data, extends the virtual fields method through the automated spatial parameterisation of constitutive parameters [1]. Previous experimental work on laser-welded, dissimilar metal joints between Grade 91 and 316L stainless steel showed promising results but were limited by insufficient plastic deformation throughout the weld region due to premature cracking. In this work, electron beam welded (EBW) butt joints between two 14 mm thick Grade 91 plates are investigated. Preliminary analysis of the measured data shows deformation throughout the weld, heat affected zone (HAZ) and base metal. These measured deformation fields will be used to identify spatially varying maps of yield strength, and the resulting distributions will be validated through comparison with indentation hardness measurements and electron backscatter diffraction (EBSD) measurements. Overall, the work supports the continued development of an experimentally validated methodology, enabling heterogeneous characterisation for various industrial applications.

Introduction

The design and performance validation of welded joints remains a critical structural integrity issue in many engineering industries. Knowledge of heterogeneous mechanical properties would improve the fidelity of structural analyses, enhancing insight into failure mechanisms and reducing conservatism, while also informing manufacturing processes such as welding and post-weld heat treatment. A previously developed methodology extends the virtual fields method (VFM) through the automated spatial parameterisation of constitutive parameters, building on work such as [2,3], to enable the automated mapping of heterogeneous elastoplastic properties [1]. Using synthetic numerical data, the approach demonstrated the recovery of spatially varying yield strength distributions without prior knowledge of the properties. Earlier experimental validation attempts on dissimilar-metal, laser-welded specimens were informative, however, the early onset of cracking limited plastic deformation throughout the weld. This work advances the experimental validation of the method through the characterisation of electron beam welded GR91 – GR91 welds.

Methods

Finite element analysis was used to design specimens that promote plastic deformation throughout the EBW Grade 91 joints while ensuring sufficiently low through-thickness stress variation. Three geometries were selected, and tensile specimens of 0.8 mm thickness were extracted from the welded plate using electro-discharge machining. Mechanical testing was performed on thirteen welded specimens and eleven base metal specimens, with stereo digital image correlation used to measure the full-field deformations (see a photo of the setup in Fig. 1). Work is ongoing to identify spatially-varying maps of the yield strength from the resulting strain data using the developed identification methodology. In parallel, indentation hardness mapping and EBSD are being performed to provide independent comparison data and support interpretation of the identified maps.

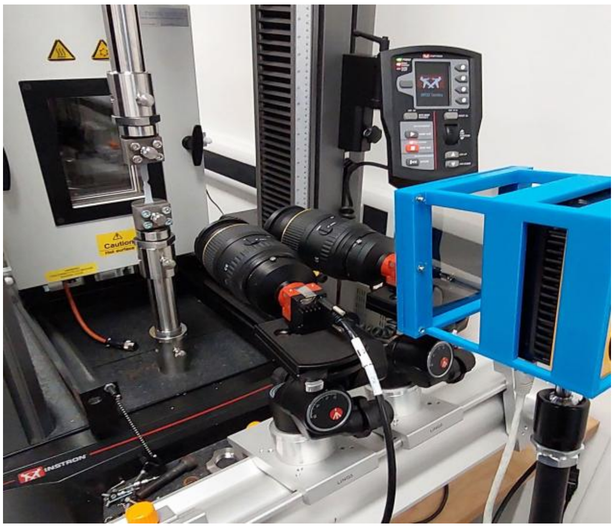

Figure 1: Experimental set

Preliminary results and discussion

Preliminary evaluation of the strain data indicates that several specimens exhibited deformation throughout the weld metal, HAZ and surrounding base metal before failure (see Fig. 2). This suggests the specimen geometries successfully promoted plasticity throughout the weld region, improving the information available for identification of the mechanical properties. The conference presentation will report the processed DIC fields, the identified yield strength distributions, comparisons with hardness and EBSD measurements, and the implications of these findings for the continued development and deployment of the methodology.

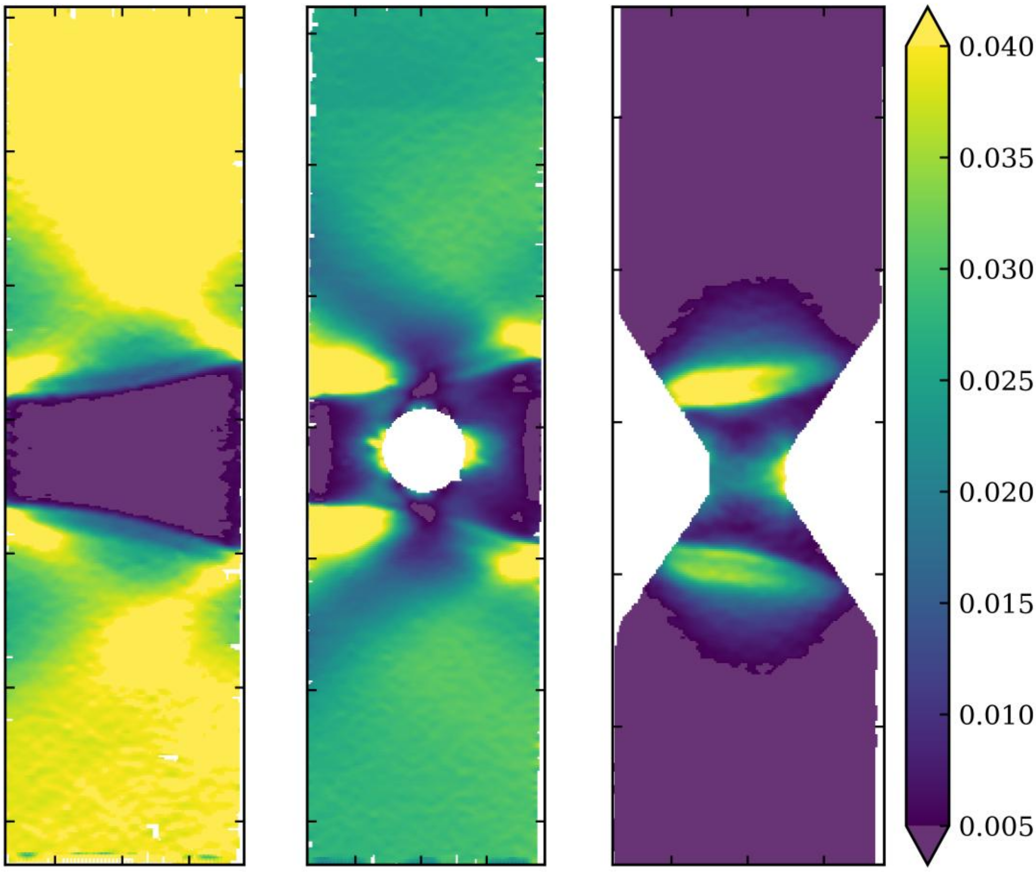

Figure 2-Preliminary equivalent strain fields for the different welded geometries.

Conclusion

This work presents the characterisation of yield strength across electron beam welded Grade 91 butt welds. The identified yield strength maps will be compared with indentation hardness and EBSD measurements to assess their credibility. Overall, the work contributes to the continued validation and development of a methodology for characterising heterogeneous mechanical properties for a range of research and industrial applications.

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