Experimental validation of the spatial mapping of plastic properties in welds with the VFM

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Abstract. Welding is a common method for joining metal components. Because of the complex thermomechanical history, elasto-plastic properties vary within the weld. Digital Image Correlation (DIC), combined with the Virtual Fields Method (VFM) offers a unique opportunity to map elasto-plastic properties in welds. This paper proposes an application example.

Possible Sessions: Material Testing 2.0, Optical and DIC Techniques

Introduction

The characterization of the mechanical behaviour of welds is complex because of the spatially variable properties with the weld and the heat affected zone. In the past, Digital Image Correlation has been used to address this complexity but exclusively on butt welds in tension perpendicular to the weld line, either using the assumption that the stress is uniform [1] or with the Virtual Fields Method [2]. In the former, one has to assume that the properties are uniform per transverse section, while the VFM allows for spatial parameterisation [2, 3]. However, a specific difficulty arises when the weld is overmatched or when dissimilar materials are welded and the weld yield stress is higher that that of the base material. This is the case here where a steel/steel laser weld is considered. If a butt weld is tested in tension, the base material will yield and no information will be available in the weld region. To overcome this problem, the paper shows how the geometry of the test can be tuned to ensure that the weld zone develops enough plastic strain for identification. Of course, in this case, the constant stress approach cannot be used anymore. Here, the VFM will be employed and the properties parameterized as constant throughout each transverse section.

Experimental setup

Figure 1 – Experimental setup

The experimental setup is depicted in Fig. 1. Two back-to-back cameras have been used as in [4] to account for possible out of plane movement and out of plane bending. For such high magnification (close to 1), stereo DIC proved impossible because of the size of the lenses. Speckling was performed with an air brush and the MatchID DIC package was used to process the data.

The specimen is a laser weld between a GR91 steel grade and 316L stainless steel. GR91 has a high yield stress of more than 600 MPa, while 316L offers a much lower yield stress, at around 350 MPa. To promote localization in the weld zone, several designs were explored numerically. Finally, the geometry shown in Fig. 2 was adopted. The pink zone represents the laser weld line. The specimen was loaded in tension and images were continuously recorded until cracking occurred.

Results

Fig. 3 shows the plastic equivalent strain at the end of the test. The two yellow hotspots represent cracks and these strain values should be ignored. One can see however that plastic strains are present in the weld, though not in the entire welded zone. The identification was performed up the to onset of the cracks using slice-wise virtual fields as in [5]. A linear isotropic elasto-plastic model was selected. Yield stress and hardening modulus were obtained as shown in Fig. 3. At the bottom of the map, the yield stress of 316L is retrieved, while at the top, the yield stress of GR91 is broadly recovered (on average over all the slices), but the results are much noisier as there is much less plastic deformation there. In the weld, the yield stress is between that of 316L and GR91, at around 500 MPa. The hardening modulus shows little contrast and stays close to 3 GPa, which was the initial value used for the optimization process. This insensitivity of the hardening modulus is likely due to the plastic strains remaining small because of the onset of cracking in the weld.

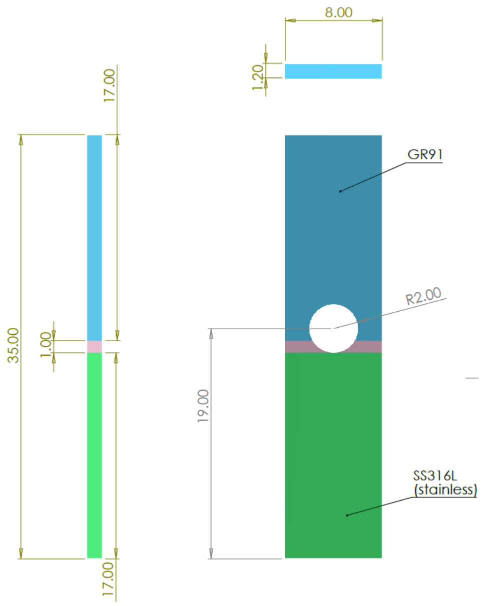

Figure 2 – Specimen geometry with dimensions in mm.

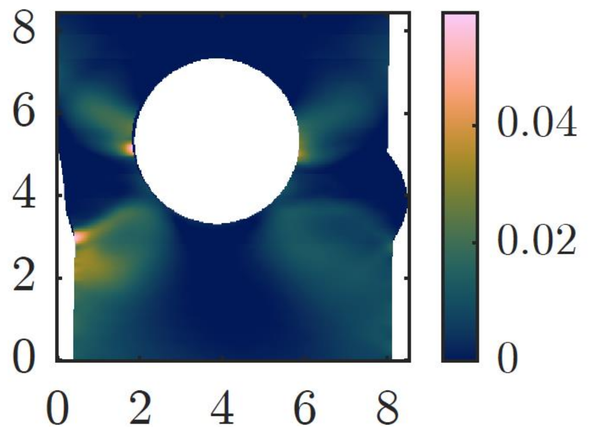

Figure 3 – Equivalent plastic strain at the last load step

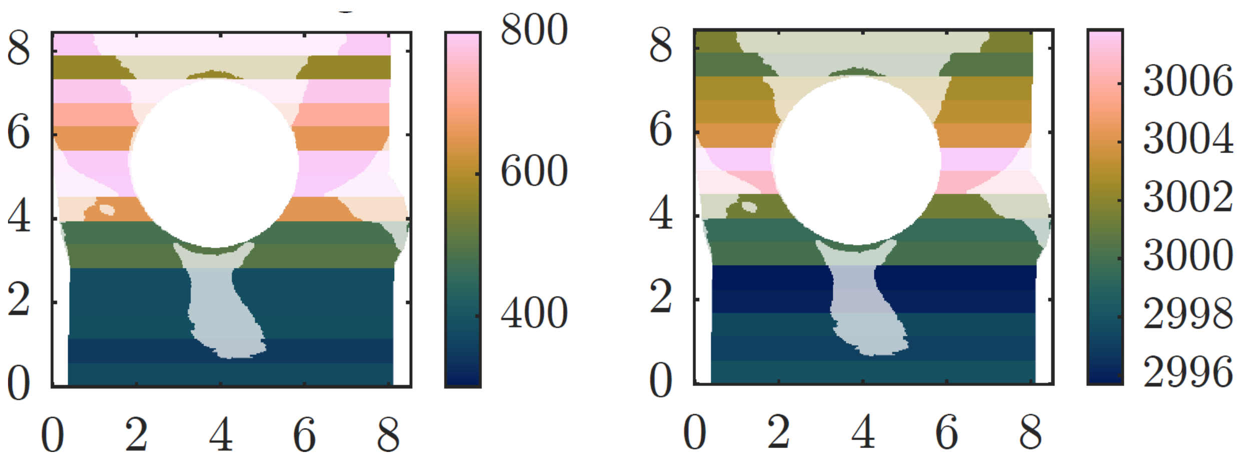

Figure 4 – Identified yield stress (left) and hardening modulus (right)

Conclusion

These initial results show that the geometry selected was successful to generate plastic strains in the weld, allowing for identification of the yield stress. Future work involves comparison with a hardness map and the use of an automated parameterization tool.

References

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