Experimental report

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Proposal: **1-02-196** **Council:** 4/2016

Title: Towards reliable residual stress measurements in dissimilar metal welds

Research area: Engineering

This proposal is a new proposal

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Samples: Steel

Instrument	Requested days	Allocated days	From	To
SALSA	3	3	31/08/2016	03/09/2016

Abstract:

The proposed experiment forms the initial studies of M. Rahman, an ILL PhD thesis student, investigating methods of improving the measurement of residual stress in dissimilar metal welds. In the proposed experiment we intend to start the process of formalising the methodology for dealing with and quantifying the errors specific to determining residual stress in dissimilar metal welds by simplifying the measurements with idealised samples. In particular, in this experiment we plan to investigate the issue of pseudo strains in association with internal material boundaries by making simple, bi-material interfaces. This work will form a key step to isolating the main sources of error. The findings will support the planned inclusion of a best practice guide for neutron diffraction measurements on DMWs in the UK nuclear industry, R6 structural integrity code.

ILL Experimental Report Instrument: SALSA Exp. Nº: 1-02-196

Towards reliable residual stress measurements in dissimilar metal welds

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Abstract

The focus of this experimental work lies on investigating methods of improving the measurement of residual stress in dissimilar metal welds, and form the initial studies of M. Rahman, an ILL PhD thesis student. This experiment was designed with the intention to start the process of formalising the methodology for dealing with and quantifying the errors specific to determining residual stress in dissimilar metal welds by simplifying the measurements with idealised samples. This experiment is the phase-1 investigation of the development process as we focus on the experimental effects of a bimetallic interface by removing other possible influences such as stress gradients, material inhomogeneity etc. Two different grades of austenitic steel were used to simulate the interface effect. The differences in the peak position and peak-width (fWhM) of the two materials are found to be 0.1° and 0.12°, respectively. These characteristics are representative of a parent-to-weld filler material system having similar properties resulting in heavily overlapping diffraction peaks at the interface. Further in-depth analysis of these data is ongoing to identify the critical features generated by the sample-instrument interactions due to the presence of the bimetallic interface. These features will be used as conditional constraints in the development of a deconvolution method leading to the possible correction of the pseudo-strains.

Introduction

Whilst decades of welding research have contributed to increased reliability of procedures for simulating the welding process for similar materials, characterisation of weldments joining dissimilar metals (DMWs) is far more challenging for both measurement and modelling communities. Such joints between different sections of a structure are needed to combine different material property requirements to meet plant design/operating constraints (e.g. changing temperature and load service conditions). This can be as drastic as welding Nickel to Stainless steel or quite subtle, such as dissimilar steels or dissimilar nickel alloys. In all cases, DMWs join highly complex engineering materials, resulting in extremely complex microstructural gradients.

One reason why characterisation of residual stresses in DMWs is particularly bothersome can be because the gauge volume may be partially in one material and partly in the other. This will introduce a pseudo-strain due to the combined effect of geometric and attenuation shift of the effective centroid of the sampled gauge volume (SGV). This is comparable to those experienced with surface measurements or with partially submerged gauge volumes, however, further complicated due to the inability to visually locate the boundary. In addition to this anomalous peak shift, DMW interfaces are notoriously challenging to account for due to the variation of submersion (through relative translation of SGV) of constituent materials having distinct but close enough 2θ angles that their independent peaks cannot be identified from the diffraction intensity profiles. Furthermore, accurate strain measurement is drastically complicated by inherent steep stress gradients and complex variations in d0. The common method used to resolve this issue is to omit unrealistic results from the final data set. This often means removing the most interesting/critical part of data. Although analytical methods are available for accounting for the effect of a partially submerged gauge volume, no effort has been reported to isolate critical parameters in metal-metal boundaries, and this formed the basis of this experiment.

Experimental details

Two different set of samples with different interface geometry were used for this experiment. Each set was made of two parts of austenitic steel. One block was made from 316H stainless steel rod and the other was made from heat treated (air quenched) 304 stainless steel. Sample set-1(S1) was made using both material having a relative orthogonal interface. The other set (S2) had an inclined interface of 60°. Both parts of each sample set were machined precisely using wire-EDM. The combined dimensions of each sample set were 80x8x8 (mm). During machining extra care was given to keep the recast layer to minimum to avoid any residual stresses been introduced at the surfaces. The bimetallic interface was also carefully made so that the interface surfaces are as flat as possible. This is further ensured by precisely machined jig to hold the two parts of each sample set in position during the measurements. Fig. 1 shows the orthogonal interface sample (S1) securely positioned by the jig and mounted on the instrument table for measurement.

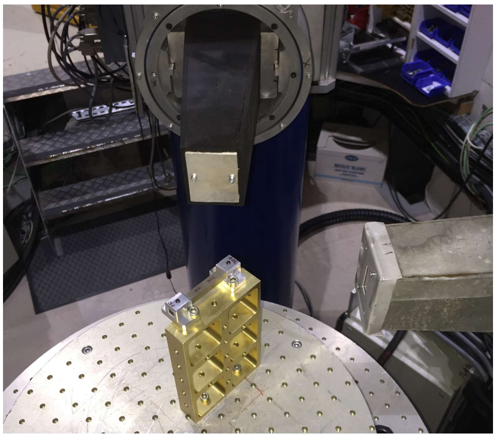


Figure 1: Experimental setup with 316 and 304 SS sample parts positioned together using custom-made jig (Sample S1)

Although, in the proposal the use of 2mm collimator was proposed, the team decided to use the 0.6mm collimator to offer better spatial resolution and reduce the chance of smearing of any key feature. However, this increased the count time significantly. Each scan was 2.4 mm in length with a 0.1mm step size to ensure sufficient data to fit curves to and to ensure data points clear on both sides of the interface. Material to air profiles were also generated by removing one part of each sample set in turn by measuring the exact same locations. Four points were removed from the air-side of the sample setup as the count time was significantly higher due to the minimal submersion of the gauge volume into the material.

Results and discussion

Data of the transmission geometry are treated initially ass the background fitting functions were reasonably linear. On the other hand, diffraction data of all the reflection geometry showed backgrounds that are non-linear. Special treatment of the background data are required before the measurements can be analysed. Fig. 2 shows the measured micro-strains at different distance from the bimetallic interface (at 0 mm).

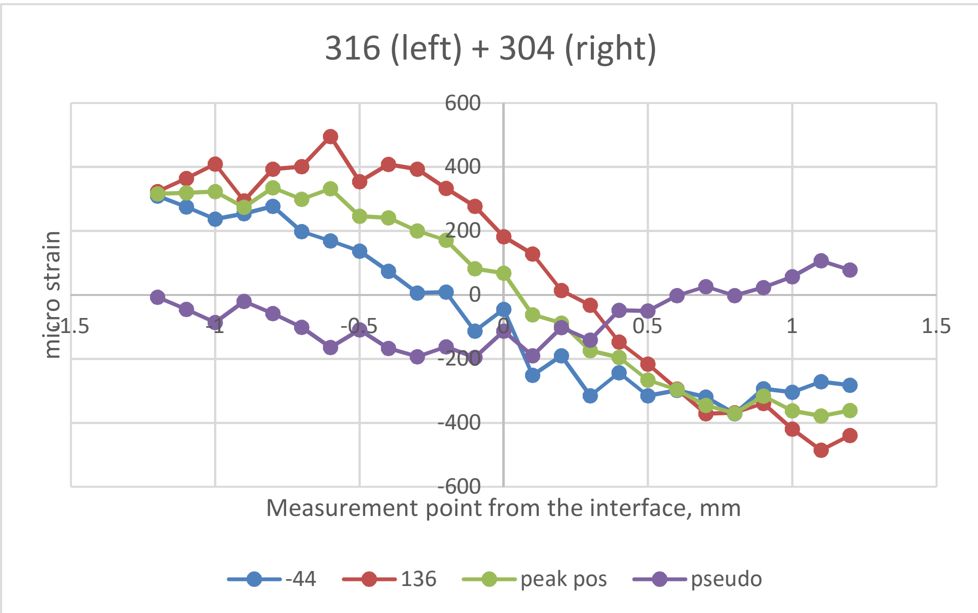
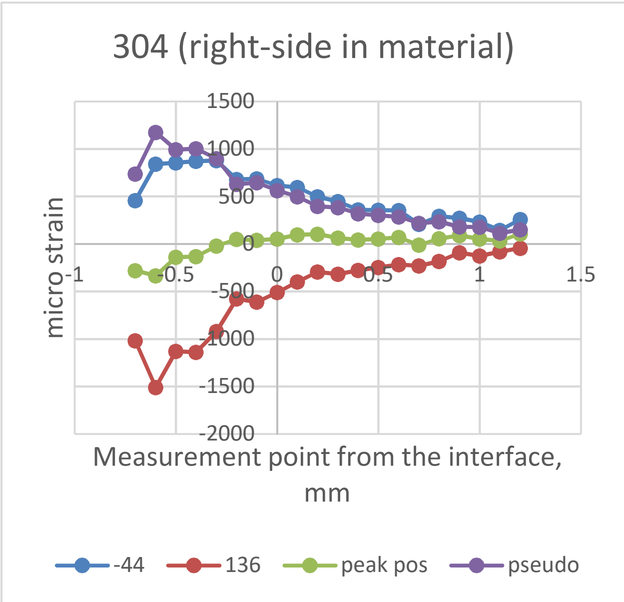
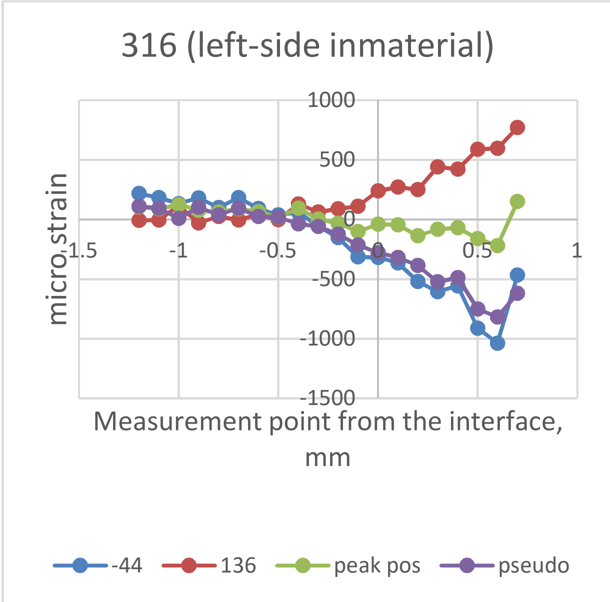


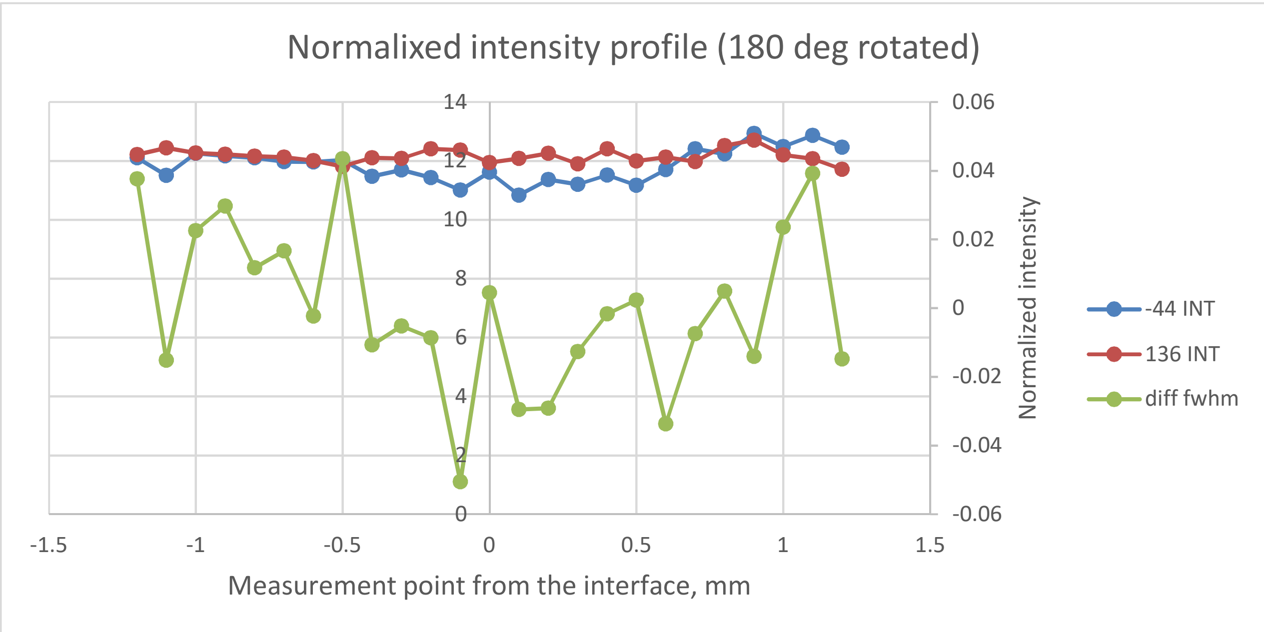
Figure 2: Sample S1 including both parts put together. Each location is measured at omega=-44°and 136°. Peak position indicates the average of the two measurement at each location 180°rotated. Pseudo strains are calculated by talking difference in the tow measurements and dividing it by 2.

The following two figures show the micro-strains been measured for material to air translation.





The above data will be used to reproduce the material-material profiles by averaging data from 316 and 304 measurements. If the data show agreement with the measured material-material profiles then this will be the basis of the new technique that will be applicable to a real dissimilar metal welds.



The above figure shows the normalized (with time) intensity profiles of the measurements in the two-part samples. Measurements were taken at each location twice, but 180°roataed around the centre of the gauge volume. It shows that at the interface the intensity profiles are opening up indicating translational effect of the gauge volume across the bimetallic interface.

Conclusion

There is peak shift of 0.1° between the two materials and fWhM difference is 0.12° degree. The peaks are considerably overlapping providing ideal example of complicated deconvolution method required for correction of pseudo strains. Data from reflection geometry require special fitting function for the backgrounds. From the intensity profiles, the interface effect is clearly represented by the opening up of the profiles at the vicinity of the bimetallic interface.