Experimental report

08/06/2022

Proposal: 1-02-313 **Council:** 10/2020

Title: In situ analysis of residual stresses relaxation and redistribution in welded joints subjected to cyclicsolicitations

Research area: Materials

This proposal is a new proposal

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Samples: HR60

Instrument	Requested days	Allocated days	From	To
SALSA	5	3	15/06/2021	18/06/2021

Abstract:

Modelling and predicting the fatigue durability of welded assemblies is critical in the industry. Current calculations are not accurately predictive and lead to a misestimation of the fatigue life and the appearance of cracks in the heat-affected zone (HAZ), which were not predicted by models. These inaccuracies in the prediction and modelling of the fatigue behaviour of welded assemblies are in particular due to poor consideration of multiscale residual welding stresses and their evolution during use (fatigue, punctual overloads, etc.). This proposal aims to improve fatigue prediction models by taking ointo account the the residual welding stresses as well as their possible relaxation and redistribution during a polycyclic fatigue test (that is to say under stresses below the fatigue limit of the assembly). To do so the volume of heterogeneous heat affected zone will be scanned in volume before, during and after a low stress cyclic solicitation.

Experimental report for proposal 1-02-313

In situ analysis of residual stresses relaxation and redistribution in welded joints subjected to cyclic solicitations

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Allocated days : 4
Date : 15/06/2021 to 18/06/2021

The aim of this study was to better understand the residual stress distribution in the volume of a welded joint similar to the welded assembly found in automobile industry and the evolution of this stress field under solicitation.

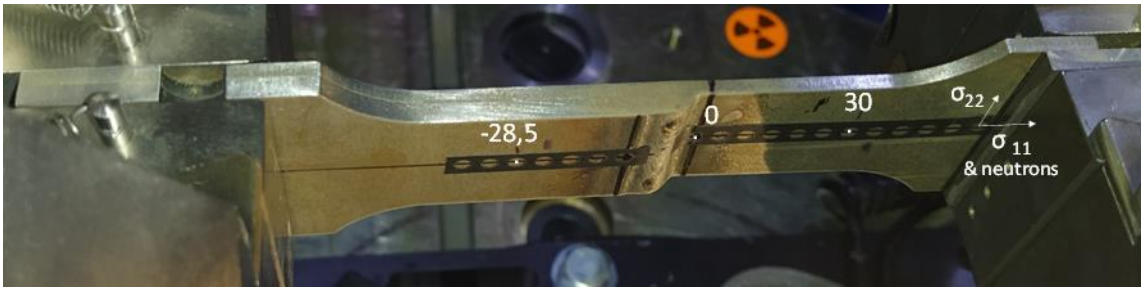

Figure 1: Specimen mounted in a tensile machine on SALSA beamline.

Although the residual stress distributions in welded joints are well described in the literature, it is still difficult to predict the fatigue life of welded assemblies. The many gradients of microstructures, phases, hardness and residual stresses are not taken into account in industrial fatigue calculations, which leads to inaccuracies in critical areas and durability predictions.
Residual stresses and their gradients should be known and taken into account in these calculations. Moreover, mechanical solicitations, even of limited amplitude, can lead to an evolution of residual stresses which must be taken into account.

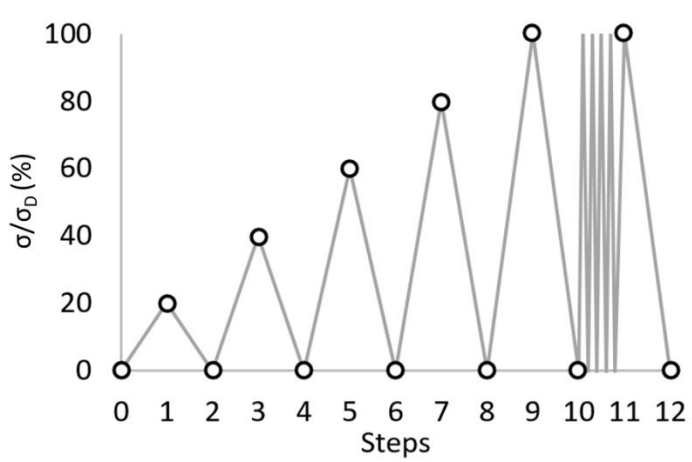

Figure 2 : Stages of the incremental tensile test followed by 10 loading cycles, the points represent the steps where neutron data were acquired.

In this study a MAG welded HR60 steel joint, visible in Figure 1, was characterized in its initial state. It then underwent incremental load-discharge cycles to a stress corresponding to the fatigue limit of the joint, determined in a previous study. It was then subjected to 10 cycles between this load value and a discharged state. Figure 2 shows the step where neutron diffraction data were acquired.

The setup was designed to obtain the signal diffracted by the grains whose (110) planes were in Bragg condition in the tensile direction (shown in Figure 1). The wavelength used was 1.62 A°, the angle between the incident neutron beam and the detector was 47.7020°, the slits used were 0.6 mm and 2mm in order to obtain a probe volume of:

- 2 mm in the longitudinal direction to the weld (where the gradients remain weak),
- 1.484 mm in the depth of the sample,
- 0.656 mm in the transverse direction where the gradients are the most important.

In the transverse direction the measurement points were spaced 1mm apart, three lines were obtained per sheet, the measurements were made over 55 mm around the weld.

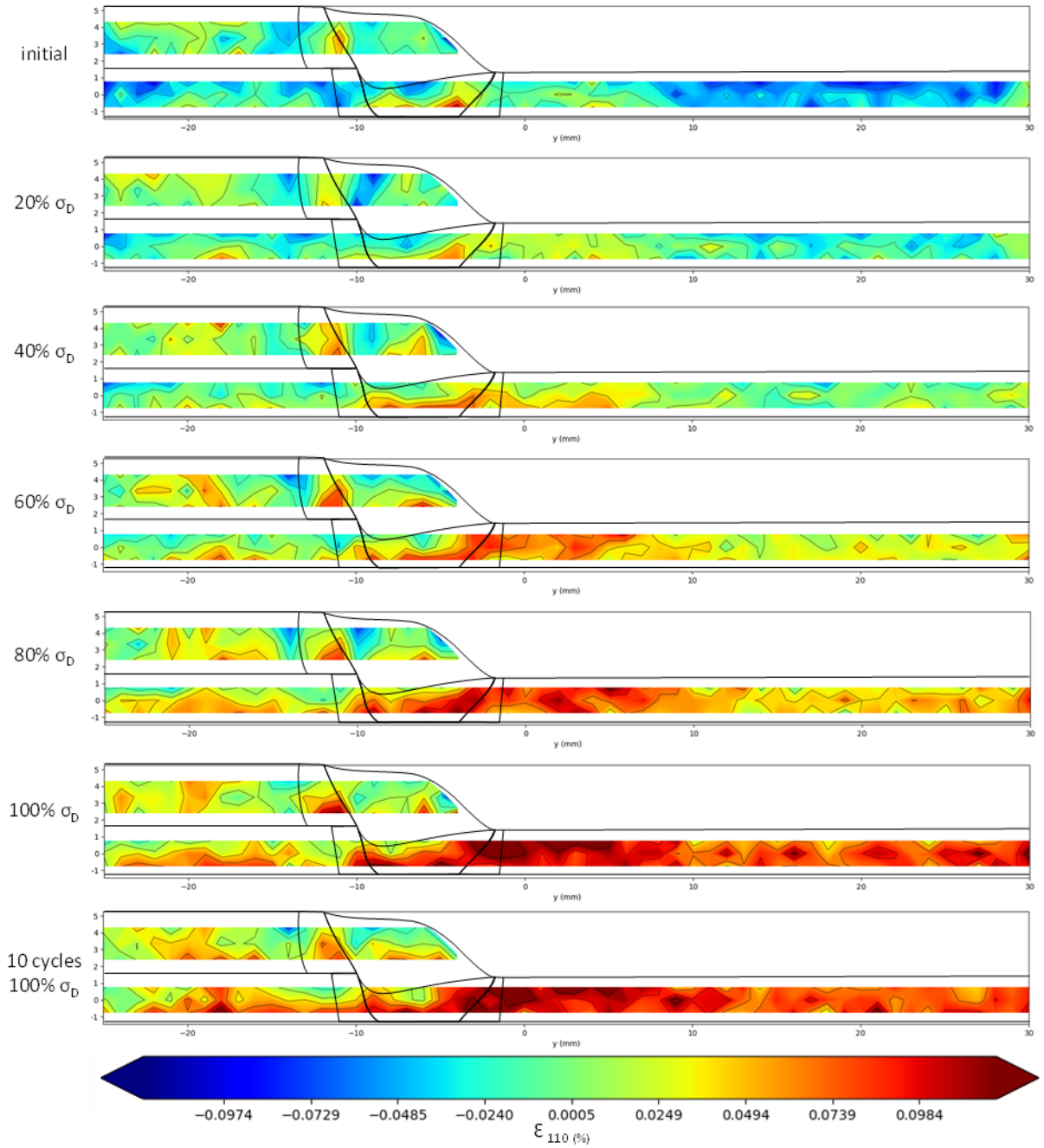

Figure 3: Strain maps of the (110) planes in the tensile direction measured under load during the in situ incremental test and then during the 10th cycle.

The results of the experiment are shown in Figure 3, in the initial state we can see residual stress gradients with tension zones in the ZAT close to the joint and compression zones in the lower plate far from the joint due to mechanical balance.
During the incremental tensile test, there is a clear concentration of stress at the bottom of the weld seam in the lower plate, it is where fatigue crack initiation and propagation are observed industrially. The distribution of strains under loading evolves marginally between the 1st and the 10th cycle.
The results obtained on SALSA will allow a better understanding of what happens in the volume of welded assemblies and will support the XRD surface residual stress measurements. This study is part of a project that aims to improve the methods of calculation of fatigue resistance taking into account the residual stresses and their evolution under stress.