Experimental report

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Proposal: 1-02-188 **Council:** 4/2016

Title: Crack tip loading from residual stress field in a dissimilar metal electron beam welded C(T) specimen after post-weld heat treatment

Research area: Engineering

This proposal is a new proposal

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Samples: P91 and AISI 316LN Stainless steel

Instrument	Requested days	Allocated days	From	To
SALSA	9	9	07/11/2016	16/11/2016

Abstract:

The experiment aims at measuring the residual stresses around the crack tip in order to determine the loading of the crack tip due to residual stresses. It is essential to identify this, as a prior step to studying the interaction of residual stresses with applied stresses [5]. In order to study the interaction of residual/applied stresses, it is first essential to determine the residual stresses. Also, previous neutron diffraction measurements on the welded plate and the C(T) specimen, prior to the introduction of the crack indicate a high magnitude of residual stress along with a very localised plastic zone in and around the weld and HAZ regions on either side of the weld centreline. With the introduction of crack, the residual stresses are relaxed because of some plastic deformation along the flanks of the crack surfaces. Also, post-weld heat treatment would further relax these stresses. Therefore it is essential to identify the residual stress/strain field around the crack-tip to understand the influence of the same on the crack growth.

Preliminary experimental report

Crack-tip loading from residual stresses in a dissimilar metal EB welded C(T) specimen

Instrument: SALSA

Experiment team: K. Abburi Venkata, H.E. Coules, S. Dey, C.E. Truman, T. Pirling

Objectives:

Welding is a source of significant residual stresses in components often to the magnitudes of the yield stress of the material. These residual stresses combine with external loading and contribute (/hinder) to fracture in service. The aim of the experiment was to determine the residual stresses around the crack-tip in dissimilar metal EB welded specimen in C(T) configuration. Because of the EB welding process, the fusion zone and the HAZ are very narrow (~ 1 mm) which required a narrow gauge volume of 0.6 mm x 0.6 mm x 1.0 mm for measuring steep gradients in stress across the crack. The measurements were aimed to be conducted at mid-thickness of the specimen on a grid around the crack-tip. The lattice spacing in all three weld stresses (longitudinal, transverse and normal) directions were required to determine the residual stress field around the crack-tip.

Results:

The experiment was conducted on SALSA instrument at ILL, Grenoble from 7th till 16th of November 2016. Because of the required narrow gauge volumes, the counting times were significantly higher (of the order of 2 hours per point per stress direction) and so points closer to the crack-tip were measured. (± 2 mm across the crack-tip). Also as this is a dissimilar metal weld made of ferritic (P91) and austenitic (316LN) steels, the fusion zone and the HAZ/fusion interface points have a local segregation of both bcc and fcc phases respectively. This required additional measurements to capture the lattice spacing variation in each of these phases separately for the same measurement point. Also, there were problems during measurement because of the movement of the 7th cylinder in the hexapod, which moved the specimen table away from the beam thereby rendering precious time wasted during the measurements. This incident repeated twice during the experiment from mid-night until 7 am.

The measurements were made on (211) peak for the bcc phase and (311) for the fcc phase to minimise the effects of intergranular stresses. The points were measured with a gauge volume of 0.6 mm x 0.6 mm x 1 mm and the points were spaced at 0.5 mm on the grid. The C(T) specimen is made to the standard ASTM specifications. The schematic of the measurement points on the specimen is shown in Fig. 1 along with the d0 specimen. The preliminary analysis of the results indicated the presence of very high compressive residual stresses in the weld fusion zone ahead of the crack-tip with peak tensile stresses pushed into the HAZ on either side of the fusion zone. The residual stress magnitude is significantly high. The preliminary analysis of the results is shown in Fig. 2. The longitudinal residual stresses are significantly high in magnitude indicating that the crack-tip for this configuration (crack in the weld centre) is under compressive loading. Because of the presence of two phases in the weld fusion/HAZ interface, there is the problem of partial gauge volume filling in the points measured along the interface line. This requires special treatment in data analysis to compensate for the partial gauge volume filling while analysing the strains. The final report will be submitted with the subsequent data analysis. Further the results shall be presented at HIDA-7 conference proceedings highlighting the results from the experiment and comparison of it with numerical simulation of crack-tip loading from residual stresses. The final results shall be published in a journal article with open access to the scientific research community. Further the residual stress relaxation during external loading of the crack-tip and its influence on the propensity for elastic-plastic fracture shall be investigated through another in-situ loading neutron diffraction measurement.

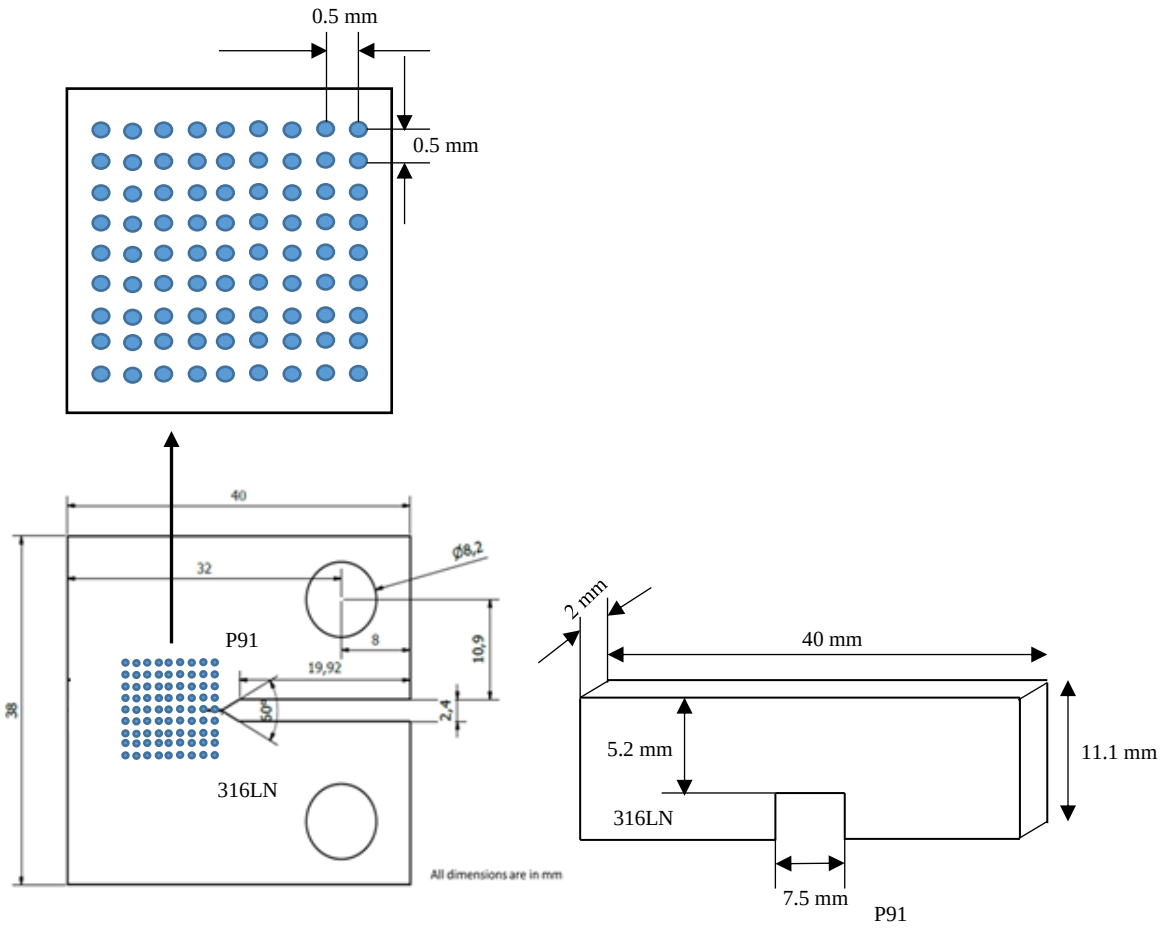

Fig. 1. Schematic of the C(T) specimen with measurement grid (left) and d0 specimen (right)

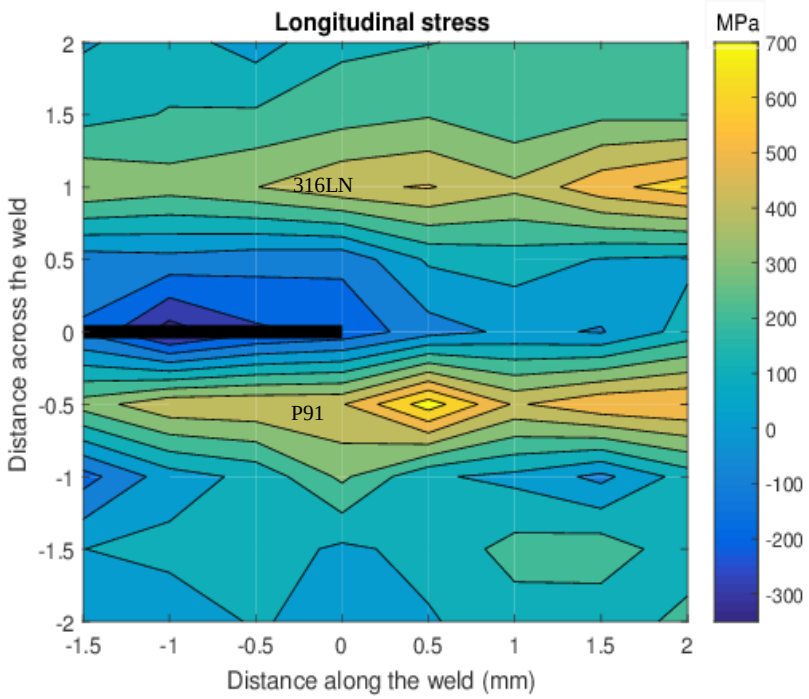

Fig. 2. Measured longitudinal residual stresses around the crack-tip