ESRF	**Experiment title:** Interaction of Creep Crack Initiation and Growth with Residual Stress Fields: Part 1.	**Experiment number**: ME 279
Beamline: ID15A	**Date of experiment**: from: 26/11/01 to: 1/12/01	**Date of report**: 24/02/03
Shifts: 15	**Local contact(s)**: Thomas Buslaps	*Received at ESRF:*

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Report: The occurrance of reheat cracking has been detected in welded 316H type austenitic stainless steel components [1] operating at elevated temperatures and pressures. Reheat cracking occurs during service when the residual stresses induced by welding are relaxed, resulting in the formation of cracks by creep cavitation growth and linkage.

Objective

The objective of this work was to investigate how the initiation and growth of creep cracks in a residual stress field interacts with that residual stress field at high temperature. For this investigation specially designed CT (crack tension) specimens were machined from an ex-service 316H stainless steel steam header. A residual stress field was introduced into the material by deforming the specimens in compression beyond yield. Finite element (F.E.) calculations were made predicting large tensile residual stresses up to 5 mm into the CT notch root after unloading. 2 CT specimens were loaded in the same manner. A 1.5 mm starter slit was spark eroded into the notch root of one of the CT samples, a 1 mm fatigue crack was then grown from the tip of the starter slit. This was to ensure that the crack tip was in the middle of the tensile residual stress field. Residual strains through the thickness of the deformed CT specimen were measured during this experiment in order to characterise the residual strain state of both CT specimens and to validate F.E. predictions. After measuring the residual strains in the material the specimens will be thermally treated in the creep regime of the material (550 °C). After thermal treatment the residual strains will again be measured (part 2 of this experiment) and any change will then be related to any cracking/creep damage within the material.

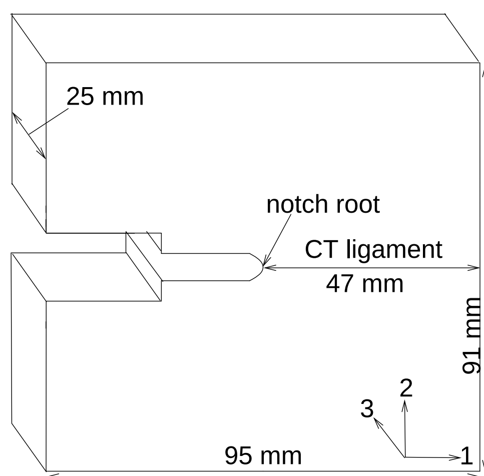

Fig1: Dimensions of the CT speciments

Results

Fig.1 shows the dimensions and geometry of the CT sample. The diffraction angle 2θ was set at 3.3° in order to have sufficient penetration power, giving a path length of just over 25 mm and a gauge length of over 17 mm through the thickness of the sample when using a 0.5 x 0.5 mm^2 slit size. Strains in the 2 directions were measured through the mid-thickness of the sample, along the ligament (see fig.1) of the cracked, uncracked specimens and an undeformed reference specimen. The energy-dispersive detector was used (since measurements were made with a white beam) measuring energies of the diffracted beam from 0-300 keV. This energy range was required in order to monitor at least 5 diffraction peaks for subsequent Rietveld analysis. Counting times were surprisingly short, typically between 40-90 seconds. GSAS was used for analysing the data employing the Pawley approach, fitting the spectra directly on the energy scale. Fig. 2 shows a typical fit made on a spectrum measured during the experiment. Strain profiles along the ligament showed similar trends to FE predictions and neutron diffraction measurements made at the ILL. However, considerable scatter (i.e. up to +/- $2000x10^{-6}$) was encountered in all the data collected even though the degree of uncertainty of the peak fits was relatively low (i.e. +/- $30x10^{-6}$). Fig.3 shows suprisingly large scatter for 10 measurements taken on the same position, without changing the experimental conditions (time difference typically 70 seconds), despite achieving a reasonably good Rietveld fit. Different slit sizes were used for each set of 10 measuremets but no correlation seems to exist between degree of scatter and slit size. This scatter has been successfully identified during a subsequent experiment by modifying the method of analysis (ME-452). This has shown that very good data was obtained, but that careful optimisation of the peak fitting routines were required. The re-analysed data (ME 452) are shown in fig.4 for comparison. This shows very good agreement with parallel measurements undertaken on D1A at the ILL. The next part of this proposal is *critical* (part II, submitted as proposal ME667). We will measure the changes in the residual stress field brought about by reheat cracking after exposure to elevated temperature (550 °C) for 8 months, simulating service conditions. These measurements will be vital to improve existing lifing models for this type of steel. Without these subsequent measurements it is impossible to determine the interaction of the crack with the measured residual stress field at elevated temperature.

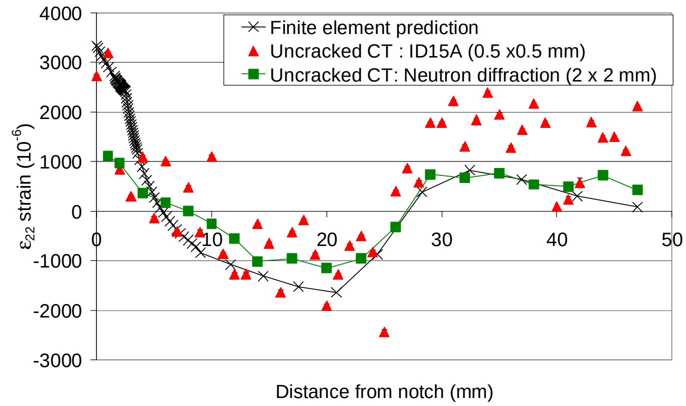

Fig.2: Comparison of residual strains (2 direction) along a deformed CT specimen ligament as measured at ESRF and ILL (D1A) and predicted by finite element modeling

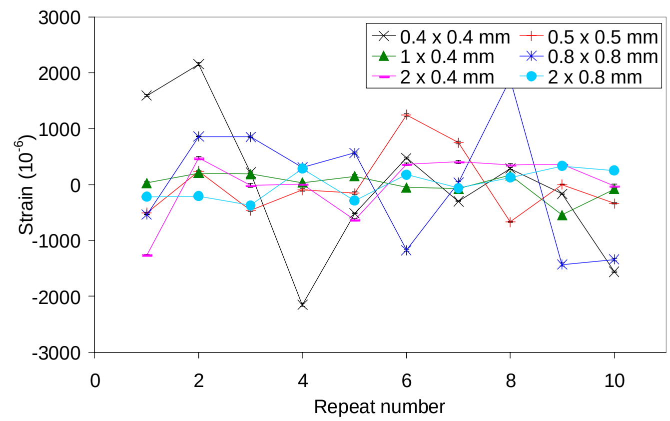

Fig.3: Strain 'measured' for a series of 10 points on the same position of the CT sample, using different incident slit sizes.

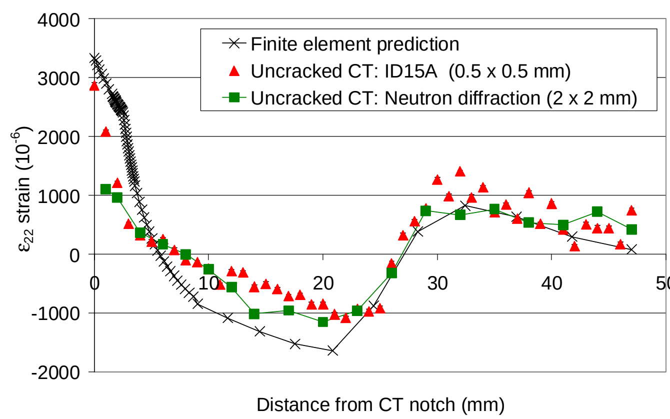

Fig. 4: Same measurements as fig.2. ESRF data has been refitted using a modified analysis routine (see experimental report of ME 452).

References

[1] M. C. Coleman et al. *International Conference on Integrity of High Temperature Welds*, p169-179, London, 1998. Proffesional Engineering Publishing Ltd.