ESRF	**Experiment title:** THE EFFECT OF PROOF LOADING ON RESIDUAL STRESSES IN A CRACKED COMPONENT	**Experiment number**: **ME622**
Beamline: ID31	**Date of experiment**: From: **26/4/03** to **29/4/03**	**Date of report**: 26 Jan 2004
Shifts: 6	Local contact(s): **Dr Michela BRUNELLI**	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

SAYEED HOSSAIN*(1)
AHOSSEIN MAHMOUDI*(1)
DAVID J. SMITH(1)
DANUT STEFANESCU*(1)
CHRISTOPHER E. TRUMAN(1)
PHILIP J. WITHERS(2)

(1) University of Bristol, Department of Mechanical Engineering, Queens Building, University Walk, Bristol BS8 1TR, U.K.
(2) Manchester Materials Science Centre, University of Manchester & UMIST, Grosvenor St, Manchester,

Report:

Introduction

Most engineering components contain residual stresses arising from welding, forming and fabrication etc. Also, proof loading (loading to a specified level to demonstrate component capability) prior to service is common practice. What is not known is how, in a cracked component, the mechanical loading generated during proof loading interacts with the pre-existing residual stress field and consequently influences fracture toughness. Furthermore, proof loading itself can generate residual stresses when the component contains a crack. The aim of this experiment was to measure the residual stress field following different mechanical loadings such as local compression and proof loading to gain a fundamental understanding of the various interactions. Therefore the residual stresses were measured first in an uncracked and then in cracked specimens. Finite element simulations (FE) developed at the University of Bristol showed tensile residual stresses ahead of the crack in the cracked specimens following local compression. The residual stresses measured in parallel using high spatial resolution synchrotron diffraction were used experimentally to validate FE simulations.

Experimental procedure

Local compression [1] was employed to generate a residual stress field within test specimens. In this method, specimens are subjected to a compressive load applied by two flat-ended cylindrical punching tools on opposite sides of the specimen simultaneously. This method was performed on both an uncracked plate (simple plate) and cracked plates (standard compact tension C(T) specimens.) Local compression induces localised plastic deformation, which in turn creates a residual stress field. Two uncracked and two cracked specimens, 62.5x60x15mm and made from Al2650 alloy, were used in this work. The diameter of the punching tools was 25mm. Local compression was applied to the central area of one uncracked plate. For the two cracked specimens, the position of the punch was $x/R=1.0$, where x is the position of the centre of the punch relative to the crack front and R is the radius of the punch. FE analysis suggested that application of local compression at these positions results in tensile residual stresses ahead of the crack. A fourth specimen, also an uncracked plate, was used as a reference plate in order to measure d_0.

The beam line was operated at 60keV, corresponding to a wavelength of 0.20627Å. The incident and receiving slits were of dimensions 0.3mm x 0.3mm. Al-311 reflection was chosen as a reflection representative of the crystalline ensemble. The residual stresses were reconstructed from the measured strains using Hooke's law and assuming a state of plane stress.

Results

Figure 1 illustrates through-thickness variation of the longitudinal and transverse residual stresses of the uncracked-punched specimen, measured in the centre of the punched volume using synchrotron X-ray diffraction. It can be observed that punching generates high compressive residual stresses in the through thickness of the plate in the area under the punch. The results obtained using synchrotron diffraction are compared in the same figure with results obtained from FE simulations. The results show relatively good agreement.

Figure 2 illustrates the residual stress distribution within the cracked C(T) specimens (labelled Sample 1 and Sample 2) measured in the centre of the specimen along a line in the crack plane starting from the crack tip using the synchrotron X-ray diffraction. The residual stresses shown are along a direction normal to the crack plane. Sample 1 was subjected to local compression and Sample 2 was subjected to both local compression and subsequent proof loading. The results are very interesting as they show the interaction between two residual stress fields. This interaction is more obvious in the area near the crack tip as proof loading produces a local residual stress field. Figure 2 also indicates the results of FE simulations on sample 1. Both the FE and measured stresses show tensile residual stress ahead of the crack and are in good agreement.

As a result of this experiment, a paper is being prepared.

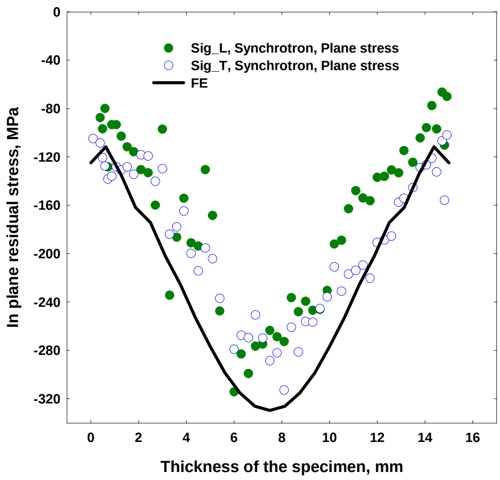

Figure 1: Residual stress variation through the thickness of the uncracked-punched specimen measured in the centre of the punched print using synchrotron X-ray diffraction and FE simulation results.

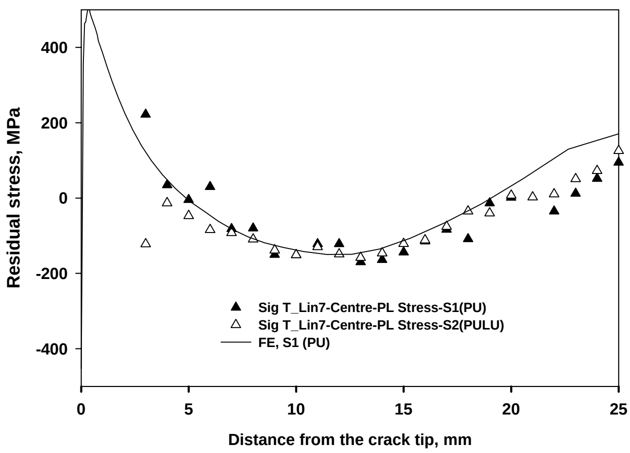

Figure 2: Residual stress distribution in the C(T) specimens measured in the centre of the specimen along a line in the crack plane starting from crack tip using the synchrotron X-ray diffraction for Sample 1 and Sample 2 and FE results for Sample 1.

References

[1] Mahmoudi, A. Hadidimoud, S., Truman, C. E. and Smith, D. J. (2003) Measurement and prediction of residual stress generated by local compression, *Proc. 5th Euromech Solid Mechanics Conf.*, Thessaloniki, Greece.