ESRF	**Experiment title:** Crack closure under plane strain and plane stress	**Experiment number**: MA-858
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Report:

Experimental Results

A series of tests were conducted on compact tension (CT) specimens to measure strain data in the region surrounding the crack tip under plane strain (in the bulk). Energy dispersive mode was utilised, with a fixed 2θ angle of 5°.Using 2 detect ors we could measure the elastic strains in the crack growth and crack opening directions with high spatial resolution.

Samples were machined from two plates of 316 stainless steel. Fatigue experiments were conducted to quantify the effect of an overload on the crack growth rate. This is shown in Fig. 1, where the crack growth rate (da/dN) is plotted versus dimensionless crack length (a/W). Crack growth retardation is clearly observed in the range 0.34 < a/W < 0.4. This characteristic acceleration and retardation of the crack growth rate is often ascribed to closure effects at the surface. However due to the lack of available measurement methods, this innference remains speculation and hotly disputed. Indeed many say that closure cannot arise in thick (plane starin) samples. Consequemntly it was our aim to grow the fatigue cracks to the following number of fatigue lengths prior to, and after, overload (O); O-1, O, O+100, O+5000, O+100,000 cycles and to examine the crack tip stresses throughout a fatigue loading cycle.

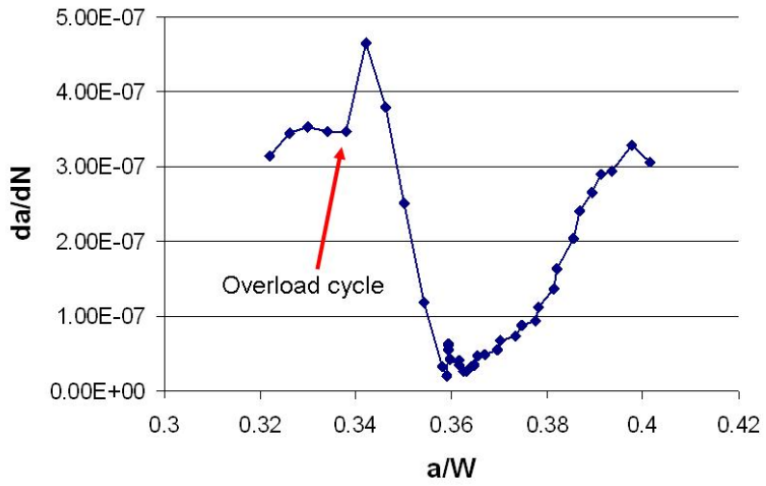

Fig. 1. Fatigue crack growth plot showing crack growth acceleration and deceleration just after an overload cycle was applied.

We have been able to obtain good quality results showing the local crack tip strain field for samples made from Plate 1 (Fig 2). Two line scans were acquired for samples

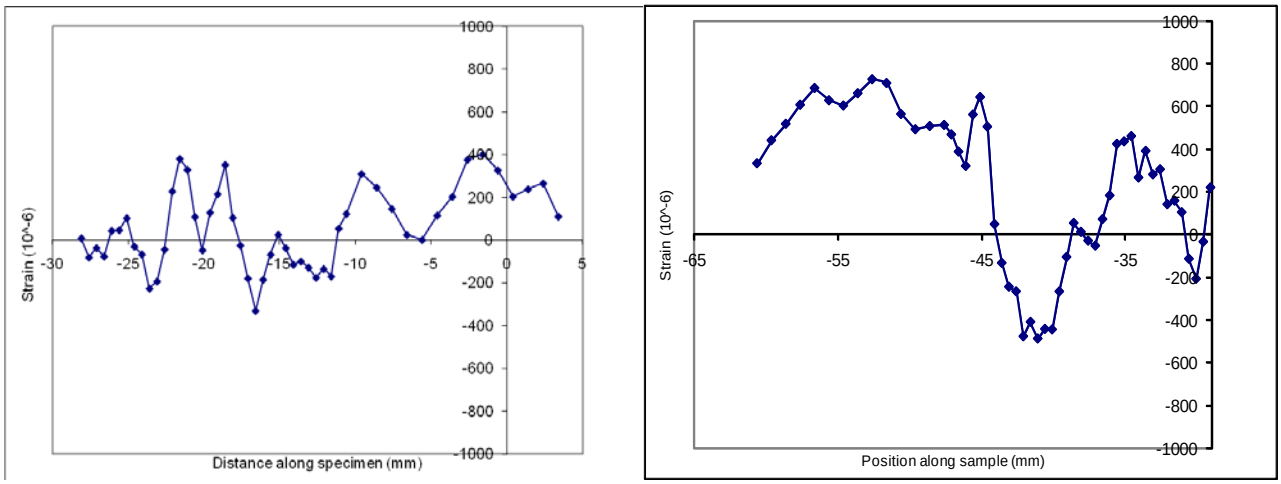

Fig. 2. Crack opening strain profile along the crack plane before (LHS) and after (RHS) applying an overload cycle. Crack tip is located at -15 and -45 mm horizontal coordinate in the LHS and RHS plot respectively. Crack runs in these plots from right to left..

from Plate 1. The results are shown in Fig. 2, where the crack opening strains profile are plotted before and after overload (no load applied at this point). These data were taken with 200 × 200 μm beam size. The results show no evidence of closure (a compressive minima) before overload (Fig. 2 LHS). By contrast, data taken after the overload cycle has been applied (Fig. 2 RHS) shows a marked compressive zone near the crack and balancing tension both infront and behind the tip. This is the first evidence of closure in the region of a plane stress crack tip.

By contrast, the results from samples from Plate 2 were simply very scattered. A number of mitgating actions were taken including increasing the gauge volume and oscillating the specimen but the data remained very scattered. As a consequence we were not able to investigate the full set of crack locations through the acclerated and retarded crack growth regimes.

On return to Manchester we examined the misrostrcucture of Plate 2 and compared it with Plate 1 (Fig. 3). It can be seen that despite being nominally identical to Plate 1 the grain size from the Plate 2 is approximately four times larger. As a consequence only low resolution strain mapping was achieved for this sample and a continuation proposal has been submitted to gather the outstanding results.

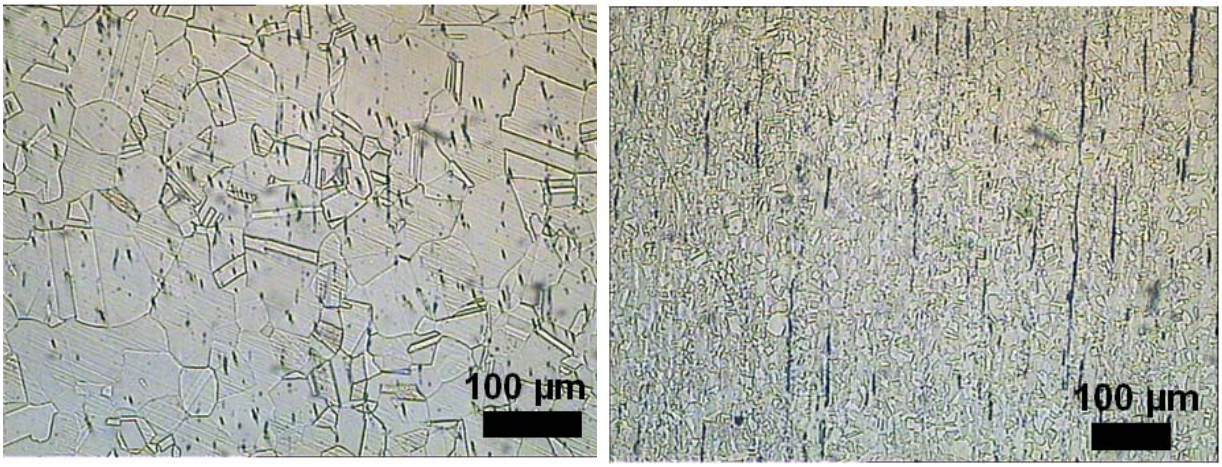

Fig. 3. Optical micrograph of large (LHS) and small (RHS) grained 316 stainless steel.

Implications of the results

The observation of closure under plane stress is highly significant, but we need to complete the dataset before we can publish these findings in detail – so far we have only published an interim paper (see Publictaions).

Publications

Considerations in the use of Diffraction to Study of Fatigue Crack Tip Mechanics, Joe F. Kelleher, Pablo Lopez-Cresco, Feizal Yusof, and Philip J. Withers, Considerations in the use of Diffraction to Study of Fatigue Crack Tip Mechanics, Materials Sci. Forum, (In press).