	Experiment title: Observation of fatigue cracks in an aluminium alloy by X-ray tomography	**Experiment number:** ME207
Beamline: ID19	**Date of experiment:** from: 03/10/00 to: 08/10/00	**Date of report:** 28/02/02
Shifts: 9	**Local contact(s):** P Cloetens	*Received at ESRF:*

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Report:

The incidence of fracture surface contact in the wake of fatigue cracks, and the associated attenuation of cyclic displacements, is known to be critical to crack propagation resistance. Whilst such surface contact (or 'closure') has been widely investigated over the last 20-30 years, measurement methods remain the subject of ongoing controversy, with the most widely established methods (compliance based) offering little micromechanical insight, or indeed any direct information on the active crack tip region. Synchrotron tomography has been identified as a uniquely powerful method to obtain in-situ understanding of plane strain crack tip behaviour [1]. Resolution levels have however been limited to date (around 6 μm), requiring sub-voxel interpolation to be used in the crack tip region. The present experiments represent an order of magnitude improvement in resolution over previous work, utilising a 2048 x 2048 pixel CCD with a 0.7 μ resolution and also the phase contrast technique which improve crack detection. Work has been particularly carried out using the damage tolerant airframe aluminium alloy, AA2024-T351. By extracting relatively small tomography samples from the crack tip of conventional fatigue test coupons, results representative of aerospace engineering performance have been obtained. In-situ straining facilities have been used to assess the progressive loading and unloading process.

Tomography results have been used for both direct imaging of crack paths and 3-D image analysis to extract the crack volume. Figure 1 shows 3-D crack volumes extracted in the loaded and unloaded conditions, rendered and viewed perpendicular to the crack plane.

The white layer represents the unloaded crack, superimposed over the same crack at maximum load in yellow. As representations of the crack volume in each case, discontinuities in the surfaces represent either unbroken ligaments in the crack wake, or regions of fracture surface contact. The regions appearing in yellow clarify areas in the crack wake that have gone from a closed to open condition on loading. Such results identify distributed, relatively small points of contact close to the crack tip (of the order of 10μm across), and large contact areas (of the order of 100μm) occurring to greater distances behind the crack tip. The larger contact areas and their apparent association with ridges running parallel to crack growth direction is consistent with previous reports, whilst the distribution of small contact points approaching the crack tip has not been seen previously.

Given the available spatial resolution, a unique feature of the present work has been the use of micro-porosity and intermetallic particles associated with the underlying material for compliance measurements at a microstructural scale. Figure 2 (a) shows pores used to calculate the crack opening displacements curves in (b). The non-linearity in Figure 2 (plotted for a variety of particle thresholding conditions, T20, T40,T60....) identifies closure conditions in the immediate vicinity, with ongoing measurements for large numbers of particles around the crack plane providing a unique opportunity to assess closure conditions as a function of local crack topology, along with the potential to separate mode I, II and III displacements across the fracture surfaces.

[1] Guvenilir, A, Breunig, T.M., Kinney, J.H. and Stock, S.R., (1999), Phil. Trans. R. Soc. Lond. A, vol.357, 2755-2775.
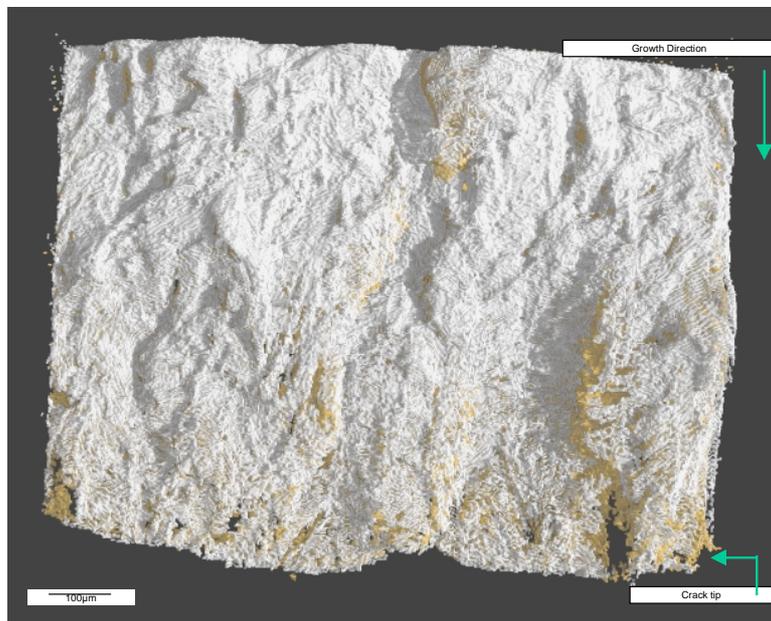
Figure 1: 3D rendering of the crack surface as seen along the stress direction (see the text for details).
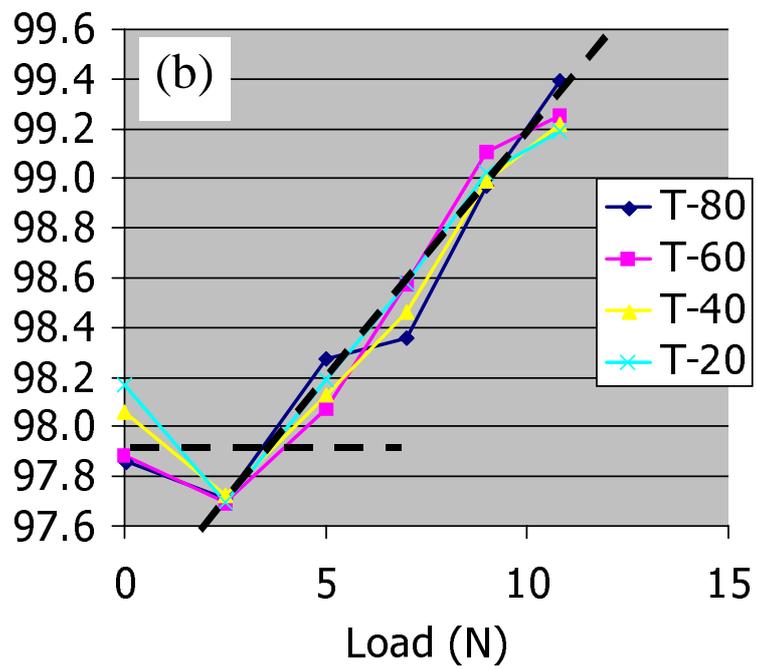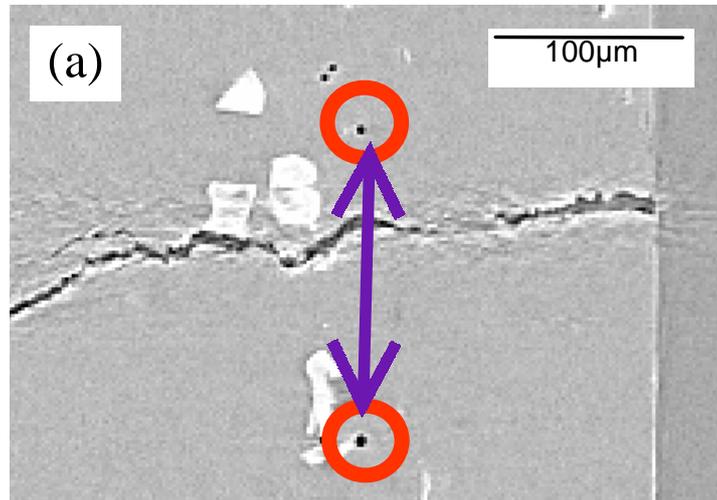
Figure 2: a)Crack profile and porosities (circles) used for determining local compliance curves (b)