ESRF	**Experiment title:** Strain mapping in a metal matrix composite	**Experiment number:** HS467
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Report:

The exceptional stiffnesses and strengths possessed by fibre-reinforced Metal Matrix Composites (MMC's) in tension along the fibre direction have been extensively investigated . These properties have been utilised in the ingenious design of aero-engine components such as blings (bladed rings) and blisks (bladed disks), so that the component experiences purely tensile loading along the fibre direction.

However, the majority of engineering components experience a mixed mode of loading, producing a combination of tensile, compressive and shear stresses. For this reason we examined a fibre-reinforced MMC's behaviour under localised compressive loading.

The samples used were plates of Ti 6-4 alloy matrix reinforced with 100μm diameter SIC fibres. The samples were 21 x 14 x 1.8 mm in size and were indented in-situ in the beam using a ceramic 'knife' as shown in Figure 1. The alumina knife had a tip radius of ~200μm and was indented into the sample to the depth of -1mm. The samples were loaded both parallel (sample 1) and perpendicular (sample 2) to the direction of the fibres.

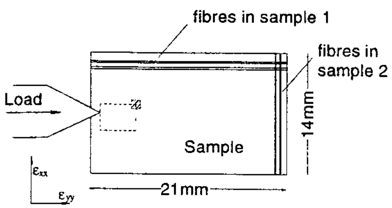

Figure 1. Diagram of the experimental setup

In the case of sample 1, the strain was measured in the direction parallel to the fibres, ε_{yy}. In sample 2, the strain component measured was perpendicular to the fibre direction, ε_{xx}. The monochromator was used to select the beam energy of -40.3keV. Accurate wavelength calibration was performed using a reference silicon sample, and was found to be 0.3081477Å. Slits were used to define an incident beam cross-section of lxlmm. The detector bank was used, with channels l-7 being utilised, to scan the diffraction pattern. An array of measurements was taken below the knife, 5 x 4 mm in lmm steps, as shown in Figure 1. The peaks fitted in order to obtain strain information were located at -10.2" for the titanium matrix, and at ~11.5° for the SiC reinforcement.

In order to obtain better insight into the deformation under the indenter, we recorded SEM micrographs of the indentations made parallel and perpendicular to the fibre direction, which are shown in Figures 2 (a) and (b) respectively. Figures 3 (a) and (b) show the relative strain maps measured in sample 1. Figure 3(a) shows the strain in the titanium matrix. The contours superimposed on the map are the contours of equal strain in the load direction, as predicted by the Hertzian elastic solution for a homogeneous body. It can be seen that these show quite good agreement with the measurements made. Figure 3(b) shows the strain in the reinforcement in the same sample. It can be seen that location of the maximum strain experienced by the fibres lies a few mm's below the point of indentation, not immediately underneath the indentor, as for the matrix.

An explanation for this behaviour can be put forward based on microscopic examination of the sample surface following indentation. It is clear from Figure 2(a) that immediately beneath the indentation the fibres were crushed and broken, so that the matrix deformed plastically around the indenter, distributing and supporting the load. This produced a strain map similar to the elastic solution for a homogeneous body, especially away from the plastic zone. Further below the indentation the fibres are intact, and the load is transferred to them, as would be characteristic behaviour for a fibre-reinforced composite material.

The strain maps measured in sample 2 (loaded perpendicular to the fibre direction) were not so clearly open to interpretation. The strain resolution in the reinforcement was much lower due to the broad, weak peaks (SIC peak intensity in sample 2 was 25% of that in sample l), probably caused by the texture effects in the fibres. Examination of the sample showed that plastic deformation was confined to a region -1mm in depth below the indentation. Thus, the highly strained fibre bundles were confined to a narrow 'boundary layer', and a finer array of measurements, with increased counting times, would be required in order to map the strain in the sample 2, and to examine the load transfer behaviour in this mode of loading.

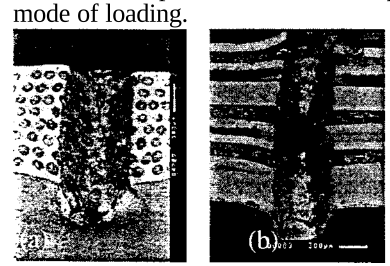

Figure 2. (a) Indentation in sample 1. (b) Indentation in

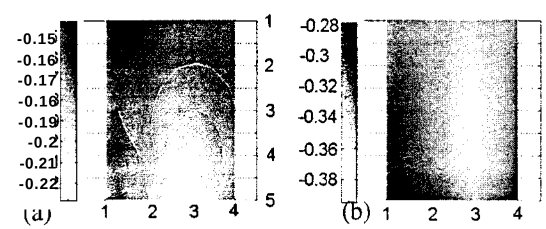

Figure 3. (a) Relative strain map in titanium matrix, showing Hertzian contours of elastic strain. (b) Relative strain map in SIC