Experiment Report Form

The double page inside this form is to be filled in by all users or groups of users who have had access to beam time for measurements at the ESRF.

Once completed, the report should be submitted electronically to the User Office using the **Electronic Report Submission Application:**

http://193.49.43.2:8080/smis/servlet/UserUtils?start

Reports supporting requests for additional beam time

Reports can now be submitted independently of new proposals – it is necessary simply to indicate the number of the report(s) supporting a new proposal on the proposal form.

The Review Committees reserve the right to reject new proposals from groups who have not reported on the use of beam time allocated previously.

Reports on experiments relating to long term projects

Proposers awarded beam time for a long term project are required to submit an interim report at the end of each year, irrespective of the number of shifts of beam time they have used.

Published papers

All users must give proper credit to ESRF staff members and proper mention to ESRF facilities which were essential for the results described in any ensuing publication. Further, they are obliged to send to the Joint ESRF/ ILL library the complete reference and the abstract of all papers appearing in print, and resulting from the use of the ESRF.

Should you wish to make more general comments on the experiment, please note them on the User Evaluation Form, and send both the Report and the Evaluation Form to the User Office.

Deadlines for submission of Experimental Reports

- 1st March for experiments carried out up until June of the previous year;
- 1st September for experiments carried out up until January of the same year.

Instructions for preparing your Report

- fill in a separate form for each project or series of measurements.
- type your report, in English.
- include the reference number of the proposal to which the report refers.
- make sure that the text, tables and figures fit into the space available.
- if your work is published or is in press, you may prefer to paste in the abstract, and add full reference details. If the abstract is in a language other than English, please include an English translation.

<table>
<tr><td>ESRF</td><td>Experiment title:
HIGH RESOLUTION STRAIN MEASUREMENTS IN FATIGUED MULTY-PLY COMPOSITES</td><td>Experiment number:
ME 363</td></tr>
<tr><td>Beamline:
ID11</td><td>Date of experiment:
from: 18 July 2002 to: 22 July 2002</td><td rowspan="2">Date of report:
27 August 2002
Received at ESRF:</td></tr>
<tr><td>Shifts:
12</td><td>Local contact(s):
Dr Ann TERRY</td></tr>
<tr><td colspan="3">Names and affiliations of applicants (* indicates experimentalists):
Prof Philip WITHERS Manchester Materials Science Centre
Dr Michael PREUSS* Manchester Materials Science Centre
Dr Jean-Yves BUFFIERE* University of Lyon
Dr Eric MAIRE* University of Lyon</td></tr>
</table>

Report:

The aim of the project was to strain scan bridging and broken fibres in the region around a fatigue matrix crack in a metal matrix composite material in order study stress partitioning between reinforcement and matrix. These data can then be used to calculate the interfacial shear stress, which yields information about interface strength and damage. For this experiment we used two multiply Ti-6Al-4V/SiC-fibre specimens, which had been fatigued in three point bending to different stress levels (1000 and 1400 MPa). This produced one specimen (S1) where all fibres were intact (low stress level) and the other specimen (S2) containing a number of fibre breaks close to the matrix crack. In both cases the matrix contained a large fatigue crack grown perpendicular to the loading axis.

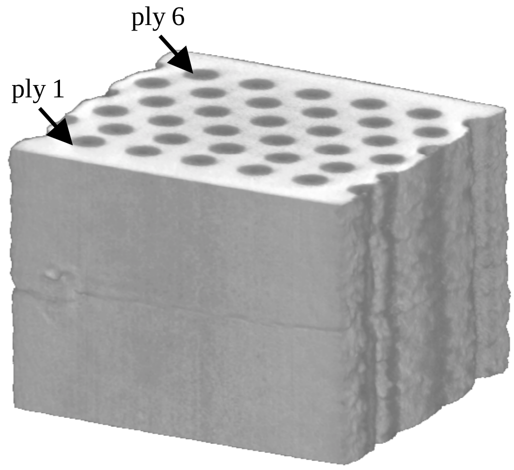

Figure 1: X-ray tomography showing the region around the matrix crack in S2

Before strain scanning, both specimens were examined by X-ray tomography to establish the exact positions of the fibres, the extent of the matrix cracks and the existence of fibre cracks. The tomography studies were carried out on ID19 beam line (ME 112) and at the Manchester Materials Science Centre using a laboratory tomography set-up. S2 showed 3 fibres broken close the matrix fatigue crack in ply 1 (see Figure 1), whereas no fibre breaks were observed in S1.

To perform the strain scanning, the specimens were mounted on a tensile rig, which was placed on an x-y-z stage in the second hutch on ID11. The Specimens were compared in the unloaded and different loading conditions corresponding to the stress concentration at the crack tip during fatigue loading.

The original aim of this experiment was to define a gauge volume small enough to measure one fibre at a time, using a focussed beam and conical slits in conjunction with a Frelon CCD camera. Initial data analysis showed that the (108) SiC diffraction peak did not show any strain variation along the fibres, as we had expected. The reasons for this were not understood, but it was decided with the agreement of the local contact to attempt the experiment without the conical slits, thereby extending the gauge volume to the full specimen thickness whilst retaining the focussed beam. Therefore average strains through the thickness of each ply rather than individual fibre strains were measured.

The results without the conical slit did show strain variations along the fibres as each ply within the specimens were scanned along the fibre direction. An example of a scan along a row of fibres is shown in figure 2.

According to shear lag theory the change in gradient visible in figure 2 at –1mm and 1mm from the crack indicates a transition between bonding and debonding at the interface. Interfacial shear stress (ISS) is at its maximum at these positions in this row.

The characteristic M-shape in the centre of figure 2 is evidence of reverse sliding taking place at loads below the maximum for the specimen.

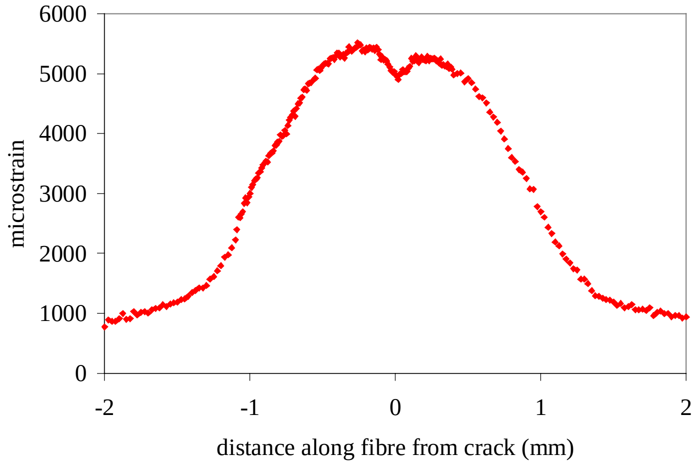

Figure 2: microstrain profile along ply 2 of S2 at 1000 MPa

The data are simplest to compare when displayed as contour plots. Examples of strain in the fibres, matrix strain and ISS are shown in figure 3. The triangular damage zone above and below the crack plane can be seen in the fibres and the matrix. The region is bounded by maximum ISS.

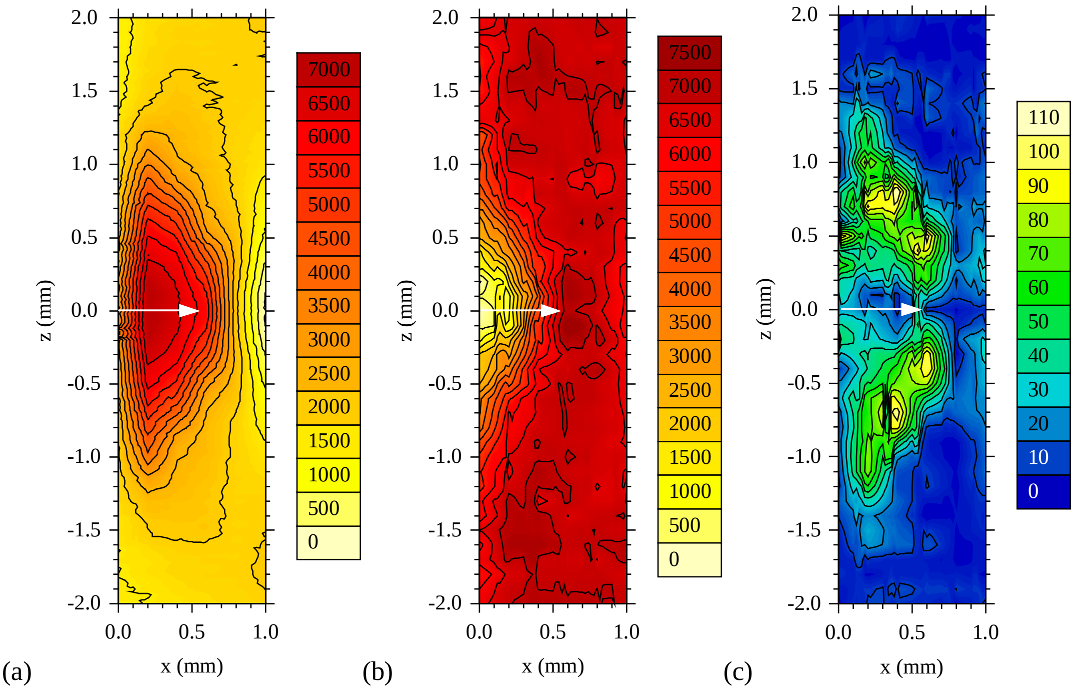

Figure 3: (a) SiC strain (b) Ti strain and (c) ISS in S2 at 1400 MPa

Diffraction peaks for the fibres in the centre of ply 1 of S2 contained a double maximum (see figure 4), indicating that here the diffraction was the result of averaging fibres in 2 different states of strain. When deconvolved two fibre populations are seen, one lowly stressed (broken) and one highly stressed (intact). The deconvolved data are shown in figure 5. Other plies of fibres did not yield a double diffraction peak.

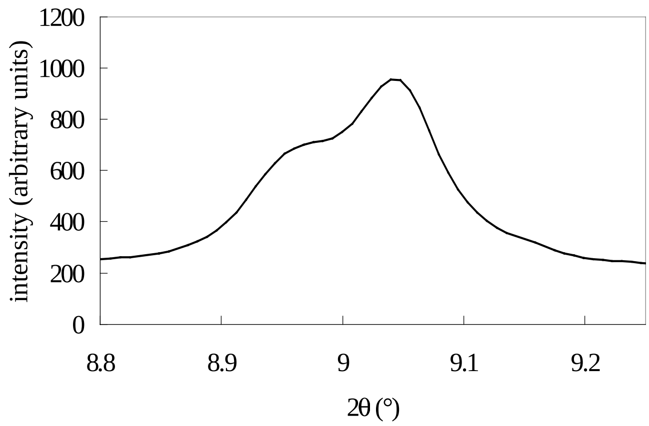

Figure 4: double diffraction peak caused by fibres in different states of strain

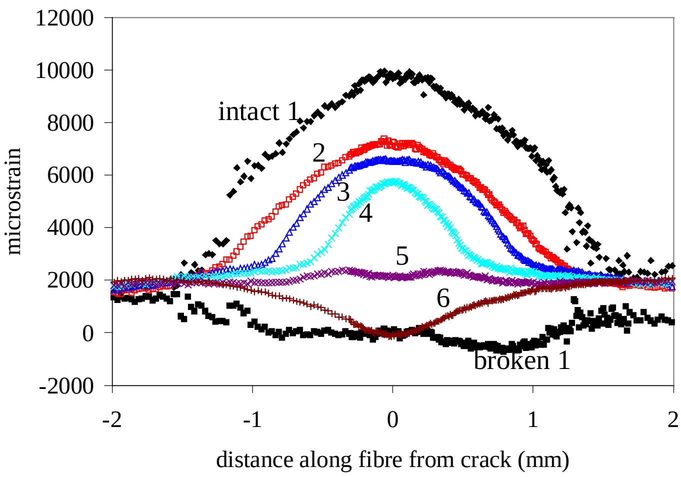

Figure 5: deconvolved data from S2 row 1

We have managed to differentiate between broken and unbroken fibres in ply 1 of S2. What we would like to do in the future is to measure the local environment surrounding broken fibres.