

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.



	Experiment title: Computed tomography studies of failure processes in polymer composite laminate	Experiment number:
Beamline: ID19	Date of experiment: from: 23rd Jan to: 25th Jan	Date of report: 31st Aug
Shifts: 9	Local contact(s): Ludwig/Boller	<i>Received at ESRF:</i>
Names and affiliations of applicants (* indicates experimentalists): Prof. I. Sinclair, Southampton University, UK Prof. S.M. Spearing, Southampton University, UK Dr. A.J. Moffat, Southampton University, UK Prof. J-Y. Buffiere, INSA-Lyon, Fr.		

Report:

Background: The experiment addressed the canonical problem of failure from notches in carbon fibre composite laminates, with the particular aim of providing detailed visualisation and measurements for model initialisation and validation^{1,2}. Via the combination of *in situ* loading of samples and internal 3D visualisation of internal structure, exceptional fidelity of micromechanical measurement has been achieved, with full field 3D microstrain mapping being obtained for the first time in this important class of material. Highlights of this work included:

- (i) *In situ* testing of samples with and without a sparse population of 5 μ m Al particles to act as fiducial marks. Processing constraints required these to be placed at ply interfaces, with an air dispersal process being developed to produce consistent in-plane spacings of the order of 100-200 μ m. Potential effects of this relatively sparse distribution were checked, with both macroscopic measurement of laminate fracture strengths and micromechanical observation of failure (via SRCT) showing no significant effect of the aluminium fiducials on composite behaviour.
- (ii) Large volumes of material were sampled via rastering of the imaging region along the sample length, allowing quantification of failure to higher loads (*cf.* the initial CT element of experiment MA313), as cracks in longitudinal splits progress many millimeters prior to failure.
- (iii) Several material variants were addressed, specifically toughened vs. non-toughened matrices, and quasi-isotropic vs. simple cross-ply laminates.

Parallel use of acoustic emission sensing to detect the early onset of failure unfortunately had to be abandoned due to the loss of key staff in the immediate runup to the experiment, however the opportunity was taken to consider the alternative material variants (noted above) that had not been considered feasible in the original experimental design.

Results: Whilst analysis of the data obtained is ongoing, the comprehensive characterisation of failure that has been achieved is illustrated in Fig. 1 for a toughened matrix cross-ply laminate, from earliest crack onset in the narrow notched region, to just loads just below the ultimate tensile strength (UTS). The microstructural dependence of cracking was clearly seen, with local crack pinning events attributable to the presence of inter- and intra-ply matrix rich regions, and the discontinuous, cross-hatched nature of delamination attributable to a mix of fibre and toughening phase debonding in the resin rich inter-ply region. The present experiment clearly demonstrated and quantified the unexpectedly high levels of unbroken ligament area maintained across delaminations in toughened matrix systems right up to the point of failure.

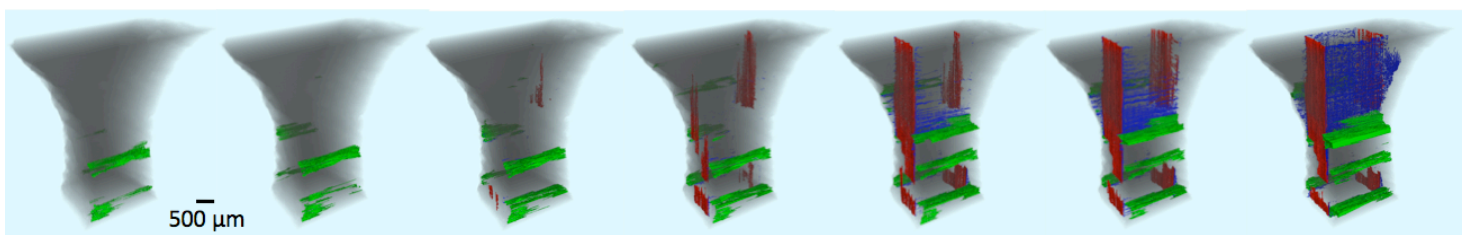


Fig. 1: Damage evolution in near notch region, segmenting transverse ply cracks (green), longitudinal ply cracks (red) and delamination (blue) in uniform loading steps from 30% of nominal UTS to final fracture.

The full field 3D mapping of internal strains is also ongoing, however initial findings can be reported, see Fig. 2. In particular, a combination of digital image correlation and quasi-manual single particle tracking is being used to validate data reduction methods. It is our ultimate intention to make the datasets freely downloadable to the community, providing a unique common resource for composite modelling. One article has been published to date on this experiment, winning the Tsai Prize for graduate student presentation at ICCM17,

Edinburgh, UK, 27-31st July 2009:

"HIGH RESOLUTION COMPUTED TOMOGRAPHY FOR MODELLING LAMINATE DAMAGE"

P. Wright, A.J. Moffat, A. Renault, I. Sinclair, S.M. Spearing

Abstract: *In situ* synchrotron radiation computed tomography has been used during tensile testing of CFRP [90/0]_s laminates to obtain 3D images of initiation and propagation of sub-critical damage. The damage has been quantified to provide exceptionally detailed initialisation and validation of 3D finite element modelling of splitting in 0° plies and transverse ply cracks.

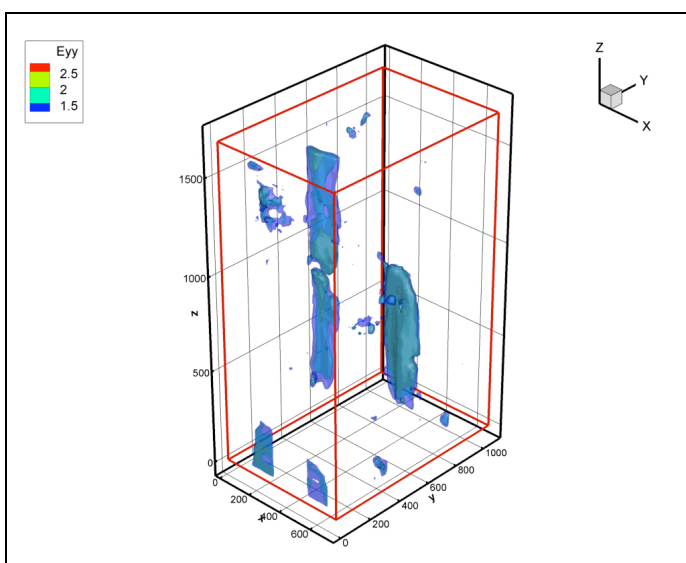


Fig. 2: 3D Local displacement mapping, highlighting longitudinal ply crack locations (running in z direction here).

[1] McLaughlin P.V.D. and Santhanam S., Comp. Structures, **58**: 227, 2002.

[2] Belmonte H.M.S., Ogin S.L., Smith P.A. and Lewin R., Composites A, **35**: 763, 2004.