ESRF	**Experiment title: High resolution X-ray tomography in the study of damages inside microheterogeneous materials**	Experiment number HC 538:
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Shifs:12	Local contact(s): José BARUCHEL	*Received at ESRF:* 29 JUL 1996

Names and affiliations of applicants (* indicates experimentalists):

Daniel Babot	INSA/Lyon CNDRI
Jean-Yves Buffière *	INSA/Lyon GEMPPM
Emmanuelle Cendre *	INSA/Lyon CNDRI
Peter Cloetens *	ESRF Diffraction Topography
J.-F. Gérard	INSA/Lyon Materiaux Macromoleculaires
Gerard Lorrnand	INSA/Lyon GEMPPM
Murielle Pateyron *	ESRF / INSA
Gilles Peix *	INSA/Lyon CNDRI
Françoise Peyrin	INSA/Lyon CREATIS

Report:

At the moment, high resolution X-ray tomography is the only technique which can provide, with a spatial resolution of a few micrometers, non destructive three dimensional (3D) images of damages or of microstructural features within materials. In this experiment, damage resulting from tensile monotonic tests was characterized by X-ray tomography within two aluminium matrix composites. Besides, two undeformed aluminium alloys reinforced by intermetallic precipitates and containing internal porosities were also imaged. Characterization of those porosities is essential for modelling the mechanical behavior (especially fatigue behavior) of these alloys.

Experimental methods

The two studied composites were 1) an aluminium matrix reinforced by an unique silicon carbide (SiC) fibre with a diameter of 140 μm, parallel to the applied stress, and 2) a 6061 aluminium alloy reinforced by.15% of SiC particles with a mean size of 150 pm. For the fibre reinforced composite, no reference state was available and only one strain level has been investigated. For the particle reinforced composite, the initiation and evolution of damages were monitored on the same sample, at three different strain levels and compared to an initial undeformed state. For damage characterization, the sample was removed from the tensile testing device and set up on the beam line. Therefore, all damage observations has been done in an unloaded state.
For each alloy containing porosities, two specimens with different porosity levels were investigated.
The X-ray beam, produced by a bending magnet (beamline D5) or by a wiggler (ID1 9), first encounters a silicon monochromator and then the sample, a rod with a diameter close to 1.5 mm, set on a high accuracy rotating table.
For these kinds of composites, a sufficient contrast between SiC and Al could be attained using low energy X-rays (15 keV), but in this case, the total attenuation throughout the sample was found prohibitive (99% attenuation). Thus an higher energy (23 keV) was used and the detector, an X-ray sensitive camera with 6.5 μm square pixels, was set downstream at a distance of 83 cm. Such a configuration allows the detection of diffraction patterns corresponding to the edges of the different phases, superimposed on the normal attenuation contrast. This method is called “in-line holography”. Reconstruction of the 3D images was carried out using a standard filtered back-projection algorithm.

Results

1) The fibre in the aluminium matrix was broken during the tensile test, as can be seen on figure la which represents one specific plane, parallel to the fibre. In fact, three cracks are observed; the central one seems to have been generated on a matrix porosity. No cracks in the matrix and no debondings along the matrix/fibre interface are observed within the experimental resolution.

2) In the particle composite, the only damage feature detected is the cracking of the matrix (fig. lb). It is interesting to note that internal porosities do not reveal to be potential cracks initiators during monotonic tensile tests for the experimental condition investigated. Instead, cracks are all generated at the sample surface. No particle cracking or particle/matrix debonding are observed, probably because nof the unloaded state of the sample. Thanks to the 3D reconstruction, the cracks interaction with SiC particles can be easily followed within the material as a function of the strain level.

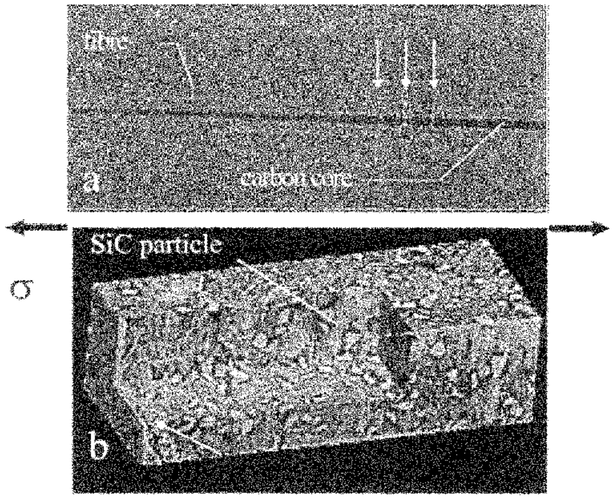

Figure 1: Reconstructed images showing damages induced by tensile test inside aluminium matrix composites a) fibre reinforced, b) particle reinforced. White arrows indicate cracks. For both samples, stress was applied along the direction indicated by black arrows. On image a the carbon core (40 µm diameter) is clearly seen, inside the fibre (140 µm diameter). On image **b** a part of the material was removed to display the inside of the sample.

3) Concerning the Al alloys containing porosities, numerous high contrast features can be seen in the reconstructed images. Their number, within the four different samples, is well correlated with the expected porosity level. Thus, the observed features do not correspond to the reinforcing precipitates.

Future prospects

Great improvements are expected, on beam-line ID19, from the change of the beryllium window, projected for July 1996. This should lead to a better signal/noise ratio. Besides, an in-situ tensile-testing device should be designed, allowing damage observation without unloading the samples.