ESRF	**Experiment title:** In situ observation of fatigue crack propagation in a cast aluminium alloy using high resolution X ray tomography and 3D grain mapping	**Experiment number:** ME287
Beamline: ID19 and ID11	**Date of experiment:** from: 01 Dec 2001(ID11)/ 25 Jan 2002 (ID19) to: 06 Dec 2001 / 29 Jan 2002	**Date of report:** 19/02/03
Shifts: 12 + 12	**Local contact(s):** P.Cloetens (ID19) and L. Margulies (ID11)	*Received at ESRF:*

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Report:
The aim of this experiment was to visualise by high resolution X ray tomography the initiation and the first propagation stages of fatigue cracks in an aluminium alloy. The experiment was twofold: one part was carried out on ID11 where five Al samples were observed using the 3DXRD microscope developed by Poulsen *et al.* in order to map the orientation of internal grains in the material (Tracking technique). Then the observed samples were taken to ID19 for in situ observations of the crack development during fatigue by X ray tomography.
Five samples could be observed on ID11. The tracking technique being quite time consuming, it was decided to scan only a restricted region along the central part of the fatigue samples. In that central part, indeed, the probability of initiating a fatigue crack was assumed to be higher because of the hour glass shape of the samples. The tracking had to be done before mechanical cycling because it was feared that any plastic deformation accompanying the fatigue deformation of the samples would render impossible the indexing of the patterns obtained with the tracking technique.
A portable pneumatic fatigue device was designed at INSA Lyon in order to observe the *in situ* crack development by high resolution X ray tomography. This machine was used for the first time and turned out to be very successful. The cycling frequency was 5Hz and thanks to the low vibration level during cycling, the machine could be permanently installed on the rotation stage. This allowed, in a first step, to monitor damage in the samples with mere two dimensional radiographs.

The specimen/detector distance was increased during that step in order to underline the presence of the cracks by phase contrast effects. When a crack was detected on the radios, the first tomographic scan was performed and then the sample was cycled again. Four of the five samples scanned on ID11 have been observed with this procedure. Five thousand fatigue cycles were performed between two successive tomographic scans. The detector used was a 2048*2048 CCD camera and the voxel size in the reconstructed images was 0.7 μm.

All the cycled samples exhibited at least one crack which development was followed *in situ*. Figure 1 shows a sequence of reconstructed images of one such crack emanating from a pore which acts a stress raiser in this kind of material. To the authors knowledge it was the first time that the initiation of such cracks could be directly imaged *in situ*. The reconstructed images of the growing cracks brought some very useful data in the field of short fatigue cracks. It was shown for the first time that the initiation of a crack from a natural defect (a porosity in the present case) is a progressive process involving first the initiation at the intersection of the pore and the surface and second the progressive surrounding of the pore until a full crack is formed. This process can represent a non negligible fraction of the fatigue life [1]. This is not in agreement with the commonly accepted assumption that pre-existing defects represent initial flaws from which the classical Paris laws can be integrated to estimate fatigue lives.

In spite of the rather high load level investigated, it was possible to show that the above mentioned surrounding process is altered by the presence of grain boundaries which retard the crack propagation. This was shown by using the gallium penetration technique [2] where Ga is used as a marker for visualising the grain boundaries in the material. Unfortunately all the observed cracks have appeared in regions different from the ones scanned by tracking on ID11. Thus we have not been able to use the crystallographic data in relation with the crack path/growth rate, so far.

[1] J.-Y. Buffière Mémoire d'habilitation à diriger des recherches. INSA Lyon 23 Décembre 2002.

[2] W. Ludwig, J-Y Buffière, S. Savelli, P. Cloetens Study of the interaction of a short fatigue crack with grain boundaries in a cast Al alloy using X-Ray micro-tomography Acta Mater. 51 (2003), 585-598

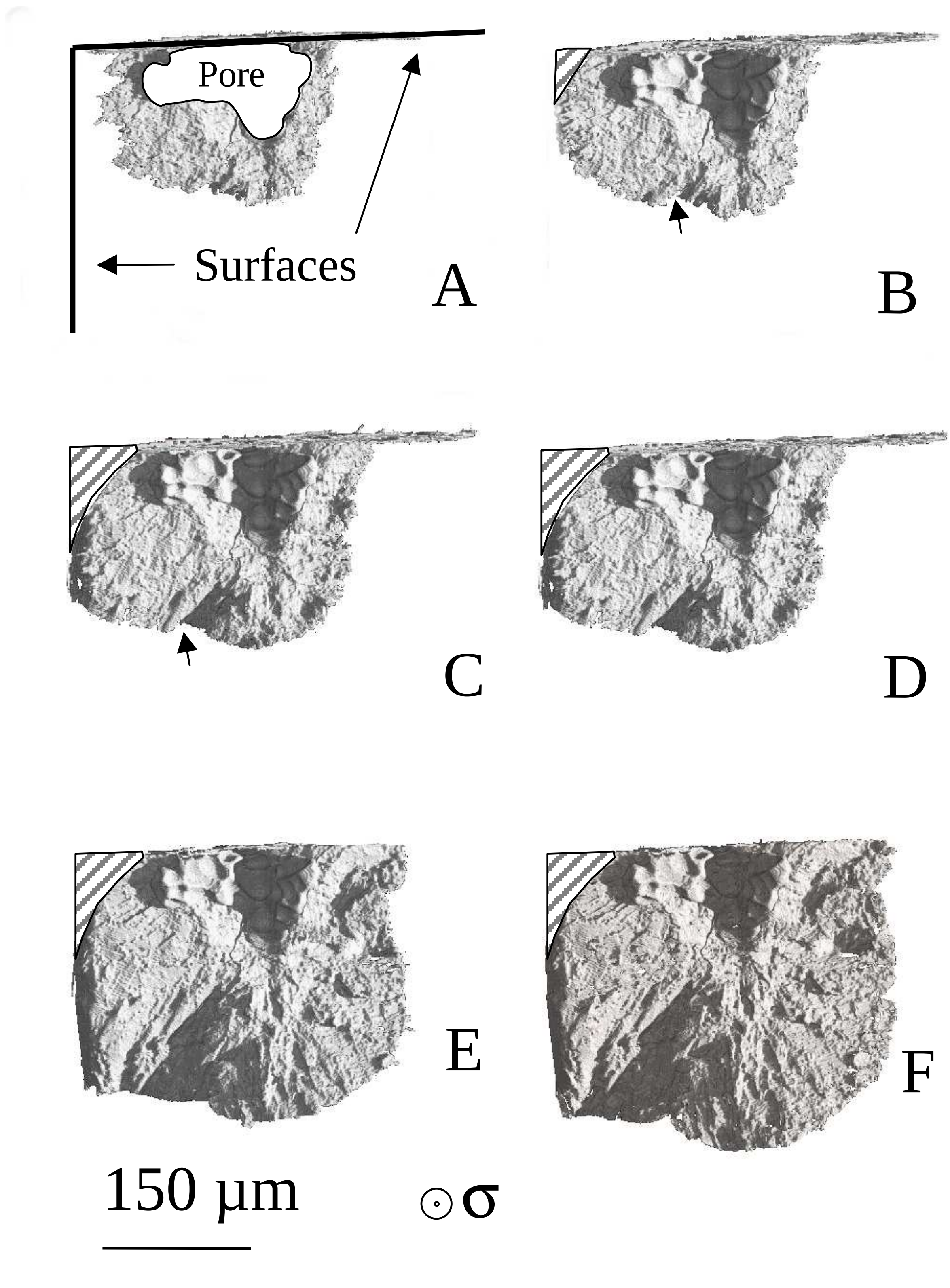

Figure 1: 3D rendering showing the propagation of a fatigue crack initiated at a porosity in a cast AS7G03 aluminium alloy after 59850 fatigue cycles with a constant stress amplitude $\Delta\sigma = 190$ MPa. A) 59850 cycles B) 64850 cycles C) 69450 cycles D) 79450 cycles E) 84450 cycles F) 86950 cycles. The arrows on B and C indicate a local deviation of the crack path induced by the presence of a grain boundary. The dashed area in the upper left corner correspond to a non reconstructed part of the sample which projection did not fit entirely on the detector during the 180 degrees rotation