ESRF	**Experiment title:** FATIGUE CRACK - MICROSTRUCTURE INTERACTIONS IN TITANIUM ALLOYS	**Experiment number**: MA-303
Beam line: ID15b	**Date of experiment**: from: 21.11.2007 to: 25.11.2007	**Date of report**: 12-07-2009
Shifts: 12	**Local contact(s)**: Greg Johnson	*Received at ESRF:*

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Report:

The study of fatigue crack growth in titanium alloys has received considerable interest because of their extensive use in aerospace (due to their high specific strength) and biomedical applications (additionally due to their superior corrosion properties). The fatigue crack growth behaviour in these alloys, however, is dictated by the changes in the microstructures which can range from an equiaxed grain structure to a lamellar microstructure with large lamellar colonies (100-400μm) and an intermediary bimodal distribution combining both equiaxed and lamellar structures. Contemporary investigations on high-cycle fatigue (HCF) properties of the high-strength a+β and β titanium alloys are motivated by an increasing interest in replacing the conventional Ti-6Al-4V (α+β) titanium alloys with Ti-6246 and β titanium for highly-stressed airframe and engine components. Most importantly, the short cracks under fatigue loading conditions have been known to grow at lower stress intensity factor than long cracks, and propagate faster than long cracks at a given stress intensity factor. Therefore, understanding the effects of microstructure on short crack growth behaviour of titanium alloys is critical.

To date, studies have been restricted to surface observations of the crack and post mortem analysis, which excludes any direct observations of how the crack front interacts with the microstructure. A major breakthrough in understanding the microstructure-fatigue property correlations could therefore be expected with the recent capability of directly observing microstructure and damage development in 3D using the ID19 micro-tomography beamline.

The present experiment of characterising the interaction of fatigue cracks with the microstructure in Ti-6246 was carried out on beam line ID19. The fatigue experiment was carried out in-situ using a fatigue rig designed by INSA for the use on tomography beam lines. One of the microstructures studied in MA-303 is presented in Figure 1a. In order to initiate the crack in a specific location, a notch was fibbed into the dogbone shaped sample (Figure 1b)

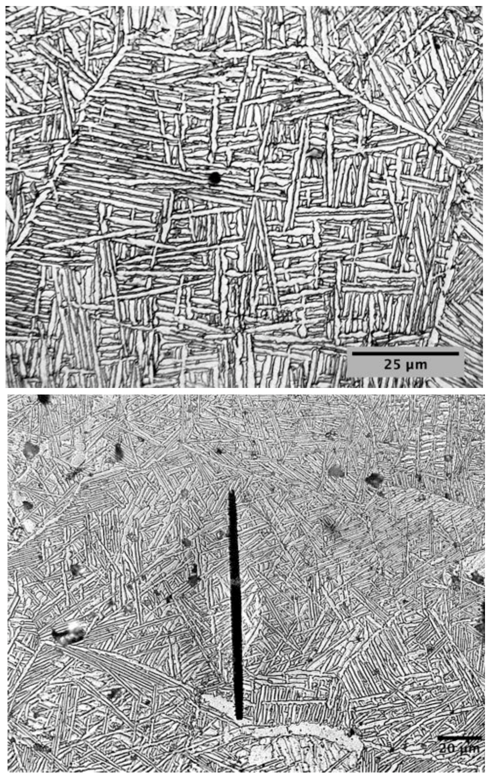
a)
b)


Figure 1: a) showing the microstructure of the investigated Ti-6246 and b) the notch position of the fatigue sample

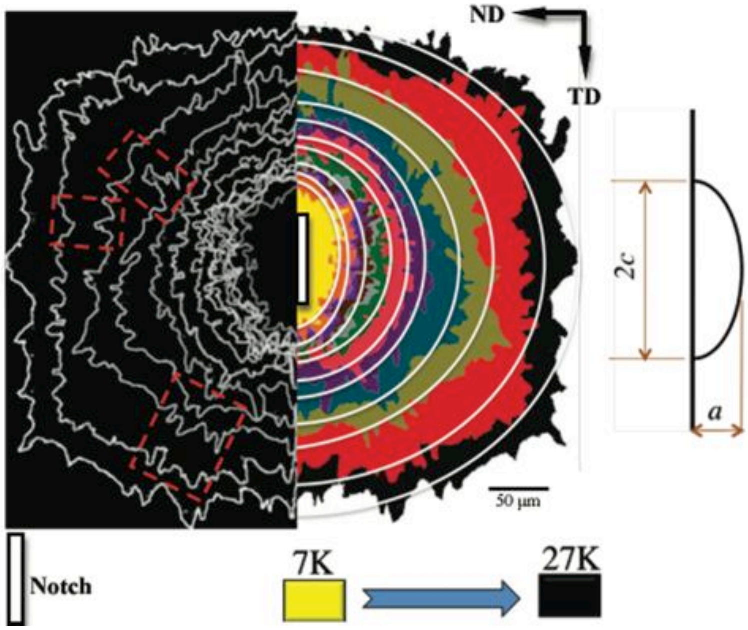


Figure 2: Representation of short crack propagation in Ti-6246 indicating first and second order crack front undulation.

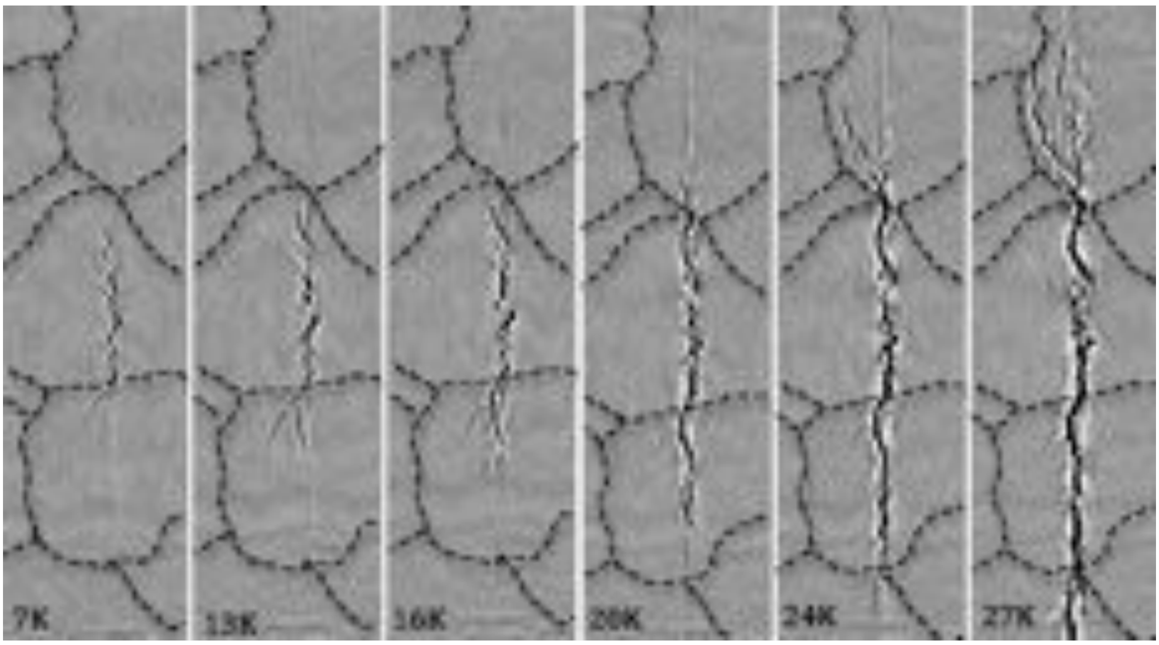


Figure 2. Observation of the role of β grain boundaries on crack bifurcation in the near surface region during short crack propagation studies.

The experiment allowed to follow the short crack propagation in three different microstructures of Ti-6246. Figure 2 shows the crack front evolution between 7,000 and 27,000 cycles. It can be seen that the crack is not perfectly elliptical resulting in a first order crack front undulation. In addition, the crack front appears very ruggid, at a scale similar to the fine lath strcuture of the material, which was termed second order crack undultion. Due to the tomography experiment it was possible to relate the first order crack undulation to crack bifurcation observed near the surface of the material, which is related to β grain boundaries (see Figrue 3). The second order undulation was related to the crystallography of the microstructure, whci was observed by relating the crack front observed by tomography with electron microscopy studies. To date, MA-303 has lead to 2 conference papers and one high quality journal submission. A second journal publication is currently under preparation. We expect to publish both journal papers in Acta Materialia.