ESRF	**Experiment title:** Effect of Residual Stress on Microcracking & Tensile Performance of Intermetallic Ti-44Al-8Nb-1B	**Experiment number:** Me 517
Beamline: ID31	**Date of experiment:** from: 21.09.2002 to: 24.09.2002	**Date of report:** 27.02.2003
Shifts: 9	**Local contact(s):** **François Fauth**	*Received at ESRF:*

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Report:

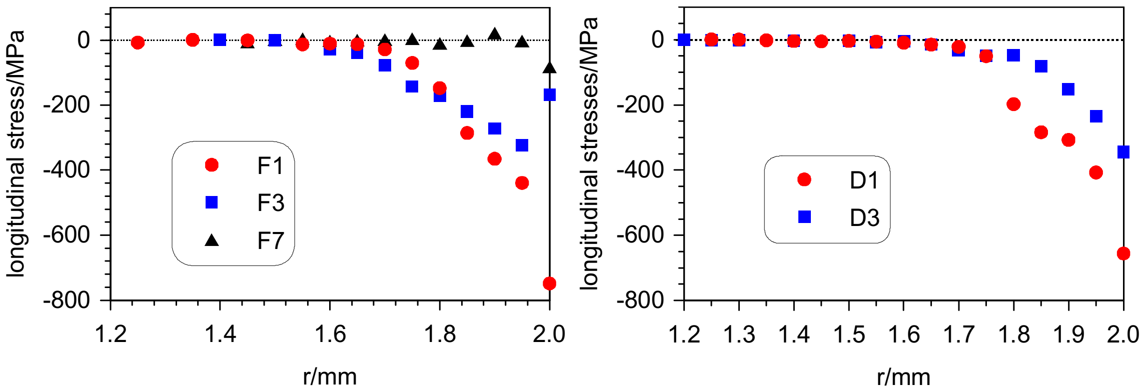
Residual stress measurements in the near surface of intermetallic TiAl-based alloys were successfully carried out on cylindrical tensile samples on beam line ID31. The measured samples were subsequently tensile tested and it was possible to relate the occurrence of pre-yield cracking to the observed surface stresses and the microstructure of the samples.

The intensive research and development which has been carried out over the last ten to twenty years on TiAl-based alloys has led to the development of alloys which appear to offer significant advantages in terms of their strength to weight ratios for operating temperatures of about 750°C. These alloys might replace some of the high temperature Titanium and Nickel-base Superalloys in future aero engines. Recent work [1, 2] using acoustic emission has shown that pre-yield cracking can be observed in samples with lamellar microstructure but not in samples with duplex microstructure of Ti44AlNb1B during testing in tension. The cracks in the lameallar microstructure are very critical since the presence of such cracks can degrade the fatigue performance. The aim of the present work has been to correlate the onset of pre-yield cracking with the nature of the surface preparation and with the level of internal stresses on samples. Both fully lamellar and duplex samples have been investigated although most work has focused on the fully lamellar samples. Test-pieces were prepared in as-machined, shot-peened and various annealed conditions after machining or shot-peening. In addition, test-pieces were electro or hand polished after machining in order to (partly) remove the machine-affected surface region.

The energy applied for this experiment was 60keV, which corresponds to a wavelength of about 0.207Å. Since the detector on ID31 is equipped with an analyzer crystal, any pseudostrains due to a not fully immersed diffraction gauge volume could be kept to a minimum. In order to maximise the number of diffracting grains, the samples were rotated around the longitudinal axes while strain scanning experiments were carried out. Residual strains in the near surface regions were profiled with a spatial resolution of 50 µm at the centre of the gauge length of the tensile sample. Measurements were carried out in the out-of-plane and longitudinal directions with respect to the loading axis of the tensile samples. Assuming that the out-of-plane stresses are zero ($\sigma_z = 0$), the in-plane stresses can be calculated from the measurement of the two strain directions using a Young modulus of 170 GPa and a Poisson ratio of 0.2 [3].

The residual stress measurements revealed essentially three categories of samples (Figure 1). The largest compressive stresses in the surface region were measured in as-machined and as-peened samples (-800 to -600 MPa). Medium compressive stresses in the surface region (about -300MPa) were observed in annealed (700°C) samples and in samples which had been electropolished to a depth of 50-100 µm. The third category of samples did not show any significant surface stresses. Those samples were either hand or electropolished to a depth of 200 µm. The depth of the compressive stress field in samples of category 1 and 2 were usually in the range of about 300 µm (see Figure 1).
After characterising the level of residual stresses in the surface region of the tensile test-pieces, they were fitted with acoustic detectors to record the occurrence of surface damages during tensile loading (carried out back in Birmingham). The studies show that the major factor which influences the presence of pre-yield cracking is the microstructure. However, the level of applied stress at which the first pre-yield cracks occur is strongly influenced by the level of compressive stresses in the surface regions of the machined or shot-peened tensile samples. Thus lamellar samples with large compressive surface stresses showed cracking only fairly near the yield point of the material whereas samples with no compressive stresses near the surface exhibited very premature cracking during tensile loading. Samples with duplex microructure displayed no pre-yield cracking, even when machined-annealed samples were tested (with moderate compressive stresses), whereas all fully lamellar samples cracked below the 0.2% proof stress.

As a result of this experiment, currently 2 papers (1 conference and one journal paper) are in preparation [4, 5].



a) b)
Fig.1: Typical longitudinal stress profiles for samples with a fully lamellar (F) and duplex (D) microstructure. F1, D1 = as-machined, F3, D3 = annealed, F7 = electropolished).

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[1]: Botten, R., Wu, X., Hu, D and Loretto M. H. Acta Materialia, 2001, **49**, 1687.
[2]: Wu, X., Hu, D., Botten, R., and Loretto, M.H., ibid 2001, **49,** 1693.
[3]: private communication Rolls-Royce plc.
[4]: Xinhua Wu, D. Hu, M Preuss, P.J. Withers and M H Loretto: The role of surface condition, residual stress and microstructure on pre-yield cracking in Ti44Al8Nb1B, to be submitted to Acta Materialia, March 2003.
[5]: Xinhua. Wu, N. M. Solis, D Hu, M H Loretto, W. Voice, M Preuss and P.J. Withers: The influence of microstructure on pre-yield cracking in TiAl-based alloys, abstract submitted to Thermec Madrid July 7 – 11 2003.