| ESRF | **Experiment title:** **Optimisation of Mechanical Pre-Treatments for Enhanced Fatigue Life in Hard Ceramic Coated Aluminium Alloys** | **Experiment number**: MA 243 |
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| **Beamline**: ID31 | **Date of experiment**: from: 14/02/07 to: 17/02/07 | **Date of report**: 19 September 2007 |
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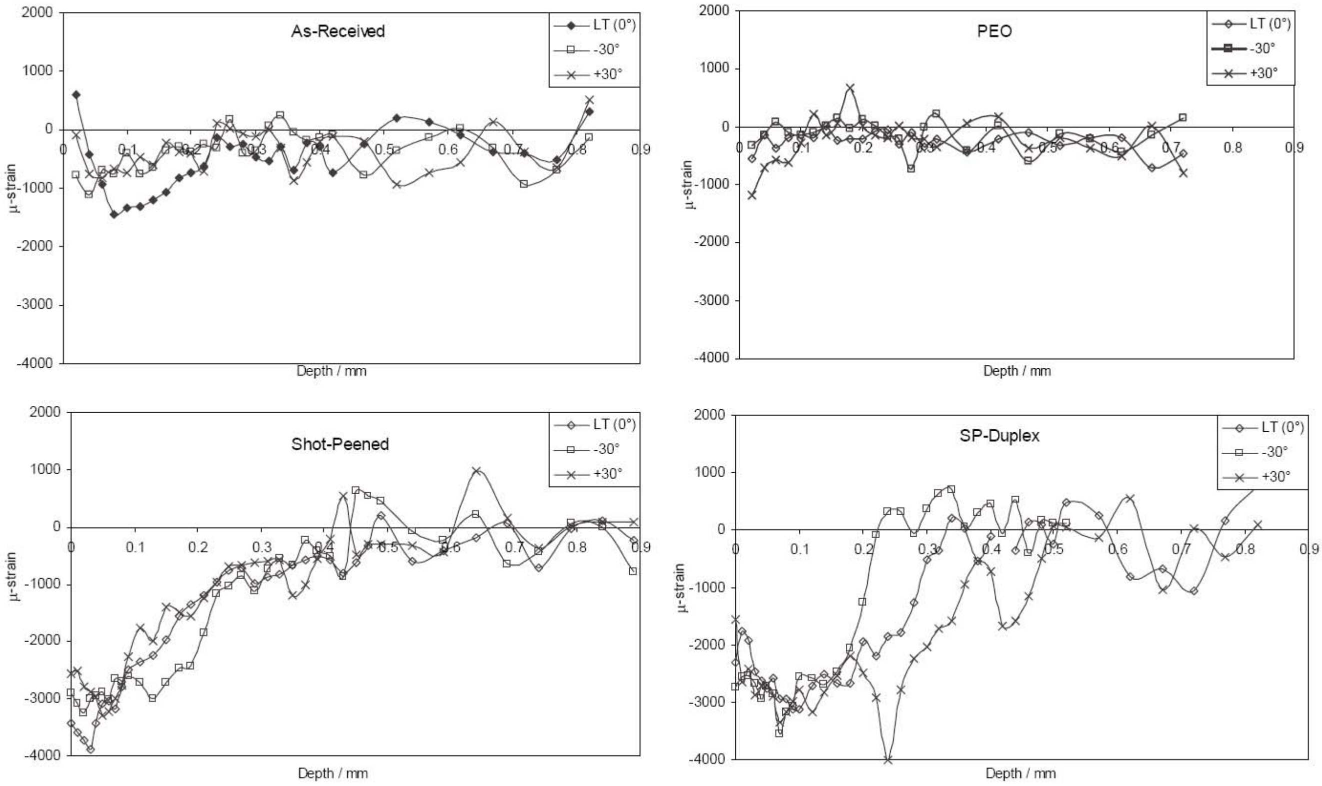
## Report:

This project aimed to characterise the residual strain state present in aluminium specimens subjected to both cold-work treatment and oxide-ceramic coating. Mechanical cold-work treatments such as shot-peening have previously been shown to introduce a compressive residual stress in the surface of metallic materials which is beneficial for the fatigue life. Conversely, oxide ceramic treatments such as plasma-electrolytic oxidation are known to reduce the fatigue performance of aluminium alloys. Preliminary work demonstrated that combined treatments produced better fatigue performance than an untreated benchmark and therefore substantially improved performance over PEO treatment alone. A significant difference in interfacial residual stress was also identified as a possible source for accelerated crack growth in specimens treated with PEO alone. By evaluating the nature of interfacial and substrate strain in a range of specimens treated with a combination of the two processes an understanding of the failure mechanisms through cyclic loading could be developed; this in turn can be used to improve the applied cold-work and PEO treatment to produce optimised systems.

Specimens machined from the aerospace grade aluminium alloy 2024-T351 were prepared in six different treatment conditions. A single surface was shot-peened to 20AlmenC with a coverage of 200% prior to PEO treatment. In addition to shot-peening, a second cold-work process was used to introduce compressive residual stress; a controlled plasticity burnishing system has been developed at the University of Sheffield and shown to produce comparable fatigue performance to the 200% shot-peened condition. The benefits of CPB are that the surface roughness is substantially reduced when compared to shot-peening and a greater degree of control over the operating parameters can also be achieved. PEO treatment was carried out in an aqueous alkali electrolyte containing additions of 2-3g.l$^{-1}$ of $Na_2SiO_3$ and $Na_3P_2O_7$. A pulsed bipolar current supply was used with frequency set at 2 kHz and current ≈ 30A.dm$^{-2}$. This produced dense layers of polycrystalline alumina of 25μm thickness with a nominal peak hardness of 1600Hk.

Strains were evaluated in the specimens using the same spatially resolved three dimensional technique developed previously in ME748. This involves measuring strain relative to depth from the specimen surface in four different directions, from which the principal strains can be evaluated. Surface location assisted by the theodolite and roof cameras on ID31 improved the set-up times over ME748 and meant that all six specimens could be evaluated in the allotted nine shifts. For each different direction 40 individual measurements were made at intervals of 10μm for 10 steps, 20μm for 20 steps and 50μm for ten steps, giving a total evaluated depth of 1mm; the staggered increase in step size gives a valuable insight into the surface strain state with emphasis on the important interfacial region. The ability to penetrate the alumina layer for strain evaluation in this important zone non-destructively is possible only with a high energy source and the valuable information obtained is currently unique in its field. The following figures contrast in-plane strains for shot-peened vs. shot-peened duplex and as-received vs. PEO; typical of the data obtained in this experiment.




The further evaluation of all the data obtained has been the subject of a PhD thesis [1], forming the primary contribution of experimental work. It is also anticipated that the analysed data will be published following the acceptance of the PhD thesis. One shortcoming of this experiment, due mainly to time constraints, was the inability to evaluate the strain state in the alumina layer; though it is perfectly feasible to apply the same strain scanning technique to alumina to obtain depth resolution in such thin films requires the development of a further technique. An application for beam-time to develop this has been made and if successful would enable a complete evaluation of the residual strain with these surface treatments.

[1] DT Asquith, "Residual stresses and fatigue in a hard-coated aluminium alloy", PhD thesis, University of Sheffield, September 2007.