ESRF	**Experiment title:** “Engineering residual stress distributions by laser peening process control”	**Experiment number:** MA 1187
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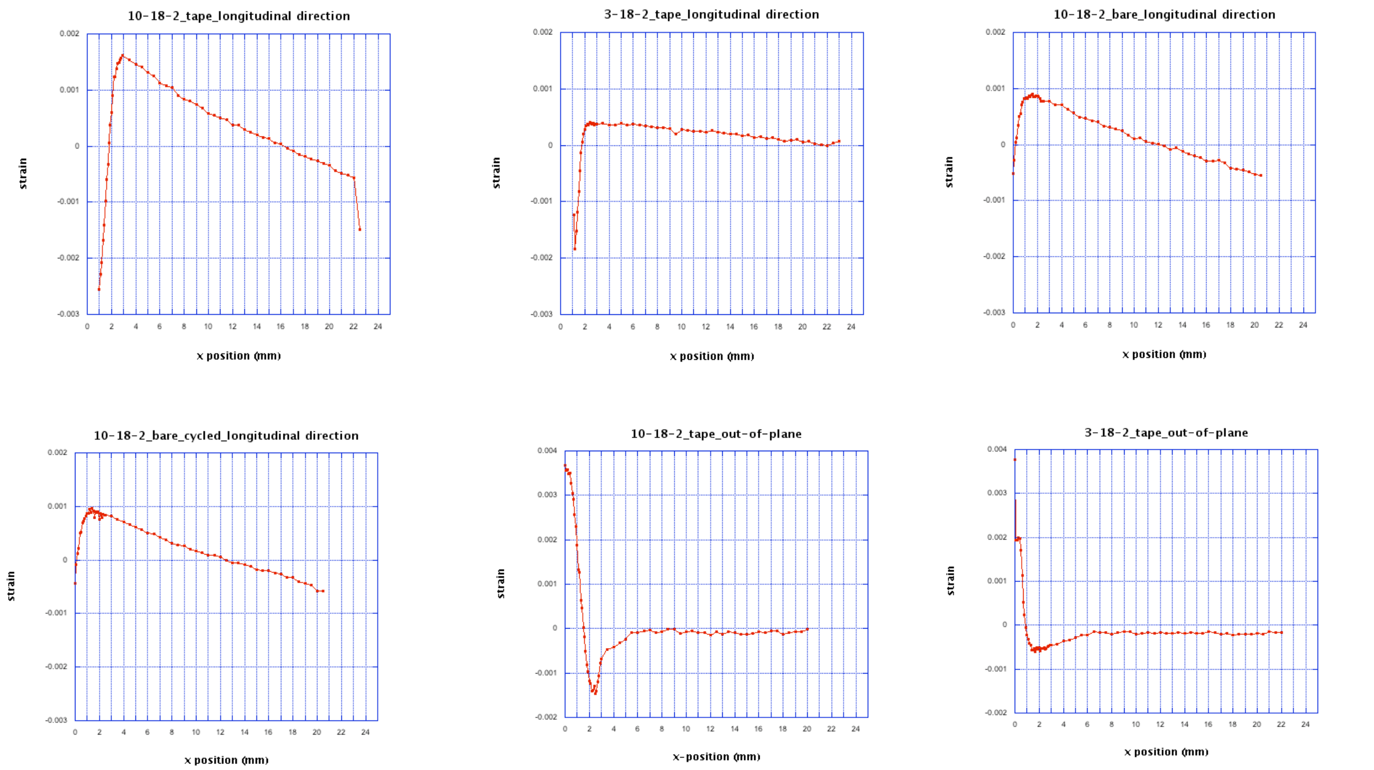
Introduction:
Laser shock peening (LSP) is capable of introducing life enhancing compressive residual stresses to ten times the depth of conventional shot peening (~2mm) [1]. Indeed recent results on stainless steel suggest that even greater depths (5-10mm) can be achieved with process optimisation. Remarkable improvements in foreign object damage (FOD) tolerance and fretting fatigue have been observed. However, significant improvements in life are not always achieved. In real components, sub-surface initiation can be enhanced, due to compensatory tension, the location of which can be very different for thick, thin, and irregular geometries. The purpose of this experiment was to form one part of an investigation into laser shock peening residual stresses as a function of fatigue. The experimental samples comprised five laser peened four point bend samples that had been produced under differing laser irradience and spot size conditions. The material studied is Ti-6Al-4V, which is currently used for compressor blades. The specimens were laser shock peened in the notch, with coverage extending to ~ 5mm beyond the notched regions onto the specimen shoulders.

Residual elastic strains were mapped through the 22mm thicknesses of each of the four point bend samples at the midpoint of the notch. A monochromatic synchrotron x-ray beam was used (57keV, 0.1907Å) on ID31. One line scan on each sample was performed in 2 or 3 directions; the in-plane longitudinal, in-plane transverse, and the out-of-plane strains were measured at each point along the line scanned. Step sizes of 0.1mm from the peened surface up to 2.5mm depth were used, 0.5mm step sizes from 2.5mm to 3.5mm depth, 1mm steps from 3.5mm up to 5mm depth, 2mm steps from 6mm up to 8mm and 5mm steps were applied thereafter up to the back face of the sample. Strains were computed from the shift of the (1012) diffraction peak. Data analysis was performed using the Large array manipulation program (LAMP).

Experimental results:
The following figures represent strain results from part of an investigation into how LSP affects the residual stress fields in samples of differing geometries, with emphasis given also to fatigue performance as a function of the LSP parameters applied.
Figures 1-4 are examples of the measured residual strains in the longitudinal in-plane direction (parallel to the long edges of the samples) for two of the four point bend samples laser shock peened using the same laser spot sizes, but with different laser irradience settings having been applied. A particular point of interest is the comparison of maximum value of strain measured in the as-received sample and the sample that had been fatigued cycled. Importantly, no significant differences between these corresponding values was observed, implying that shakedown of residual stresses as a result of the fatigue had not occurred.

Figures 5 & 6 feature the strains measured in the same samples in the out-of-plane direction. The non-zero strains measured from the surfaces up to a location up to 2mm into the samples' depths suggest an effect relating to near-surface intergranular strains. This effect is believed to be associated with anisotropic plastic behaviour [2,3] where slip has occurred preferentially within grains with a certain orientation, meaning that the load applied by the LSP process will have been distributed across those grains which are less favourably orientated for slip. In turn, this will translate into the highest strains being recorded nearest to the samples surfaces, where there is minimal material constraint. In accordance with the ISO/VAMAS standard for diffraction experiments, the choice of plane for this material (HCP titanium) was a pyramidal plane (10-12) for the lowest intergranular strains.



Figures 1 & 2: Through-depth residual strain profiles of as-received, LSP'd 4 point bend samples. Irradience settings are 10 and $3GWcm^{-1}$ respectively. Figure 3: Through-depth residual strain profile of a similar sample as in figure 1, but no ablative tape was applied to the peened region beforehand. Figure 4: As figure 3 but fatigued to 13,716,525 cycles. Figures 5 & 6: As figures 1 & 2 but with strains measured in the out-of-plane direction.

Implications of the results:

These results will be compared against predicted data from finite element modelling performed by Oxford university. Ultimately, this will enable models capable of predicting compressive and tensile stresses and their locations for complex test pieces as a function of laser process parameters to be made available. This data will also be used as a basis for the interpretation of fatigue crack growth measurements made by the Swansea team on fatigue cycled samples.

References:

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