ESRF	**Experiment title:** Near surface and sub-surface stresses in wide chord fan blades – Part 1	**Experiment number**: ME379
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Report:

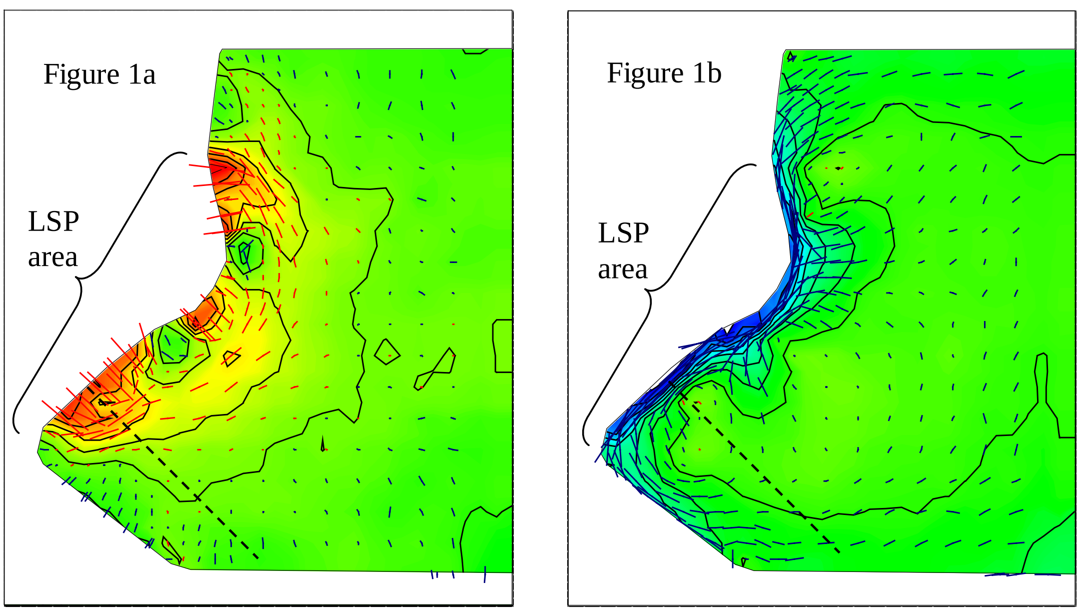
Residual stress measurements have been carried out on three Ti-6Al-4V Wide Chord Fan Blade root specimens. The fan blade is the first compression stage of a turbofan engine. The root of the blade is attached to the fan disc by means of a dovetail joint. The root supports the centripetal load generated by the spinning blades and must withstand fatigue from vibrations. The contact surfaces of the joint also experience fretting fatigue. Laser Shock Peening (LSP) is an advanced mechanical surface treatment, which has been used to introduce protective compressive residual surface stresses to the root. For accurate life predictions it is important to quantify the residual stress distribution introduced by this treatment. The three conditions of the measured samples were a) LSP, b) LSP + fatigued and c) prefatigued +LSP + fatigued.

During the strain scanning experiment, three diffraction peaks of the hexagonal Ti phase, the (002), (100), and (101) were measured. This enabled us to determine not only the type I residual strains but also study any apparent intergranular stain development in the LSP zone. The energy used during the experiment was 60KeV, allowing measurements to be made in transmission through 15mm specimens. Residual strains were measured in three different in-plane directions in the root specimens. The data were used to calculate the magnitude and direction of the principal strains and stresses.

Advanced strain mapping techniques were developed and used for this experiment. Prior to the experiment the contour shape of the samples were measured in Manchester with an accuracy of 2µm using a Coordinate Measuring Machine (CMM). The same type of CMM is now also available through FaME38 at the ESRF/ILL. A Matlab routine (specgenerator.m) was written, which reads in the output file of the CMM and automatically generates SPEC macros to strain scan the sample according to its shape. During the experiment a number of improvements were implemented in the Matlab routine. For instance, the distance of the first measurement point close to the edge had to be specified. This is important when steep strain gradients are observed at the edge of the sample. Measurement time was saved by using a high density of points in areas of interest, but fewer elsewhere. Without these innovations it would not have been possible to make the stress maps in the time available. The Matlab routine is now available through FaME38 and we will use future experiments to further improve the routine.

The measurements of strain in three in-plane directions allowed he calculation of principal stresses. These were plotted as contour maps revealing the distribution of stresses introduced by LSP in the complex root section. Examples are shown in Figures 1a and b. It can be seen that the greatest residual stresses are found at the LSP surface. The magnitude of the near surface compressive stresses (Figure 1b) reached -400MPa in the as-LSP sample. Balancing tensile residual stresses are seen further beneath the surface. Both the depth and the magnitude of these tensile stresses vary depending on the local geometry of the component. Where the component section is thicker, the magnitude of the tensile stresses is less, and the tensile stresses are further from the surface. Balancing tensile stresses varied in magnitude from 60-140MPa. The maps also reveal the stress distribution at the edge of a LSP region. Peak Full Width at Half Maximum height data indicate that LSP causes plastic deformation to a depth of about 3mm.

Figure 2 shows the compressive stresses from simple line scans measured in the contact region of the roots (as indicated in Figure 1). The comparison of the unfatigued LSP sample (a), with the LSP+fatigue sample (b), reveals the effect of service fatigue on the LSP stresses. It was observed that the near surface compressive stresses relaxed from -400MPa to -200MPa. The sub-surface balancing tensile stresses were also reduced, and became less localised. The depth of the protective compressive stresses was reduced by fatigue. Stress relaxation effects were most pronounced in the part of the root that experiences fretting fatigue. Comparing sample (c) (prefatigued + LSP + fatigued) with sample (b) revealed that the prefatigue loading had a beneficial effect on the compressive stress field of the sample. After fatigue testing, sample (c) revealed slightly larger compressive stresses in the near surface region than the fatigued sample, which was not exposed to prefatigue loading. It is planned that future experiments will further study the effect of prefatigue on the effectiveness of LSP.



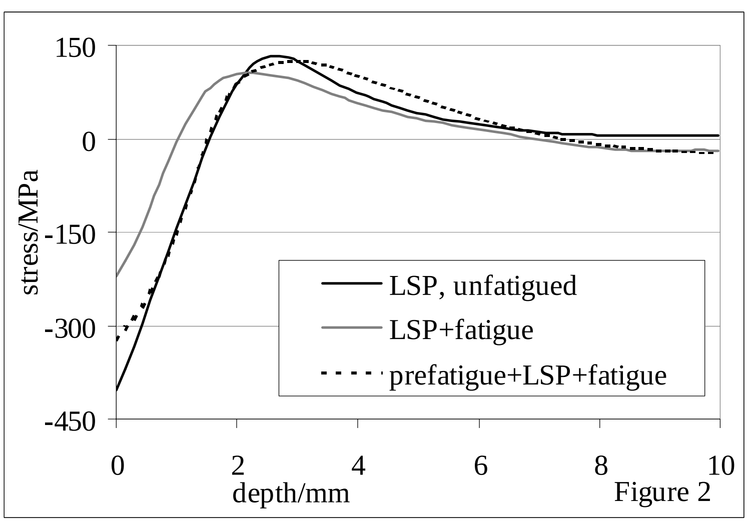


Figure 1a. Maximum (tensile) principal stresses in a fan blade root.
Figure 1b. Minimum (compressive) principal stresses.
Direction of stress is indicated by the lines. Dashed line indicates location of line scans.

Figure 2. Line graph showing stresses in LSP roots after different fatigue cycles.