ESRF	**Experiment title:** Synchrotron diffraction investigation of residual stresses in lasershock peened turbine blade steels as a life enhancement technology	**Experiment number**: ME1440
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Shifts: 9	**Local contact(s)**: Dr Thomas Buslaps	*Received at ESRF:*

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Report:

Aim of the experiment:

The aim of the experiment is to characterise the residual stresses introduced into low-pressure steam turbine blade steels by Laser Shock Peening (LSP) in order to enhance the service life of these highly stressed components. Fine spatial resolution quantification of residual stresses combined with penetration capability is critical to the development of the LSP process for new industrial applications in the power generation sector. To this end, only energy-dispersive X-ray diffraction available on ID15A at the ESRF facility are required to obtain in depth measurements in order to distinguish between LSP parameter sets.

The Experiment:

Samples were extracted from an ex-service turbine blade by removing slices from the fir tree attachment region as depicted in Figure 1. A stress relieving cycle of 660°C for 20 minutes was performed on the coupons. The samples were wire EDM cut to dimensions of 20x20x15mm which were also surface ground. Electro-polishing was applied to remove the surface grinding effects, and hardness was checked to ensure that the stress relieving did not alter the mechanical properties. Laboratory XRD measurements were performed on each sample before and after LSP processing for repeatability verification of sample preparation and LSP processing.

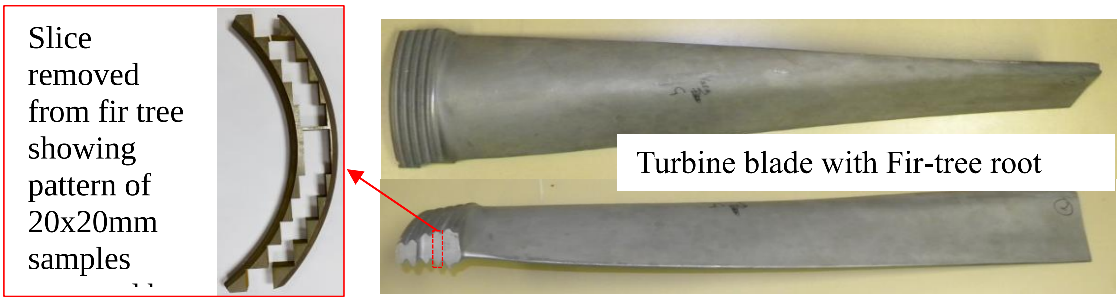
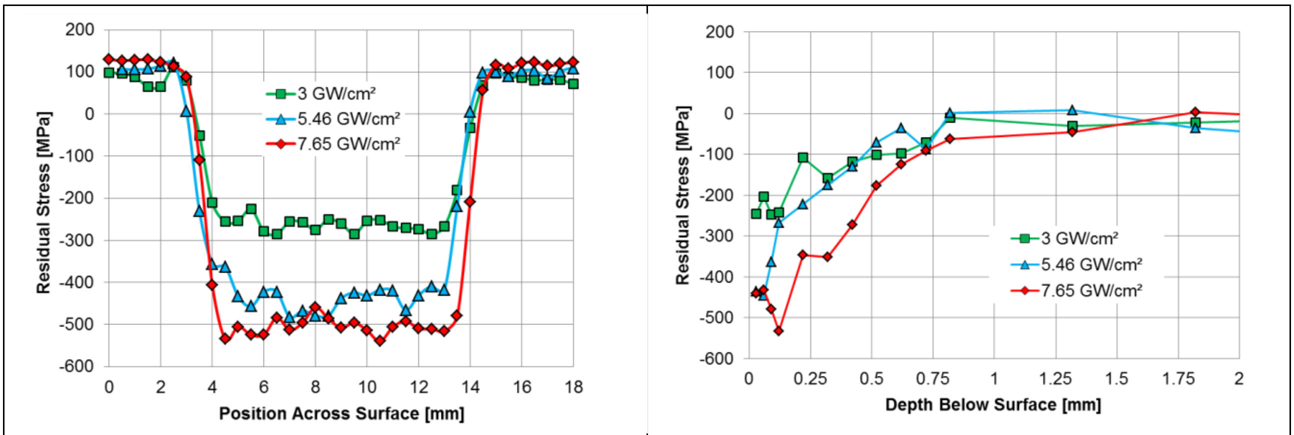


Figure 1: Turbine blade configuration

The application of laser peening was performed at the PIMM Laboratory (ENSAM-CNRS-CNAM) using a Thales GAIA laser system operating at 532nm with the sample immersed in a water tank. For the LSP work, a sacrificial thermo-protective overlay in the form of a black PVC tape was used (around 100µm thick with a 30µm adhesive). In order to ensure coating integrity, the spot-to-spot overlap was kept low at around 21.5%. A spot size of 2.0mm was selected, as this is approximately the largest diameter spot that would be practical to process within the turbine blade fir tree as depicted in Figure 1. A preliminary phase was first conducted in order to determine an appropriate power intensity whereby a constant spot size and overlap were used with varying power intensity from 1 to 8GW/cm^2. Surface XRD measurements were made to identify 5GW/cm^2 as a conservative power intensity operating below the saturation limit of the process due to dielectric breakdown before the target. The LSP processing was performed on the 20x20mm sample face with a 10x10mm LSP patch. The LSPwC processing used two different spot sizes, 0.6 and 0.8mm with coverage parameters of Np = 16.55 and 33.75, (Np = the number of pulses per mm^2).

Figure 2 shows the XRD surface and SXRD through thickness residual stress results for three different power intensities with one layer of tape. Previous work has shown that the depth profiles become more consistent and deeper with the second tape layer and this is reflected in the data variation of up to 100MPa peak to peak (pk-pk) shown in the plots. There is good correlation between the XRD and SXRD data at the surface of the samples, and a clear indication of the improved depth profile with increasing power intensity.



XRD surface residual stress line scans, 1mm aperture, 0.5mm spatial resolution

SXRD residual stress depth profiles

Figure 2: Power intensity comparison for LSP with one tape layer

LSP and LSPwC both show a significant improvement over SP with the depth of residual stress at the zero crossing point increasing from 0.25 to 1.5mm, see Figure 3. LSPwC has a better depth profile than LSP, but the process is slower due to the smaller spot size and the higher overlap. In industrial applications the time required to treat a component will be one of the deciding parameters. The next phase of the project will be treatment of 2D and 3D surfaces.

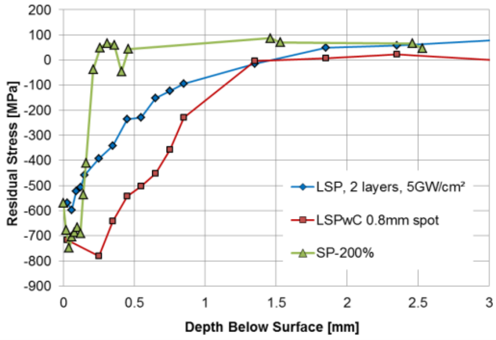


Figure 3: Comparison of techniques

Conclusions

The LSP and LSPwC treatment proceses are both producing the desired results on 12Cr steel flat samples, with significantly improved residual stress profiles when compared to SP.

Residual stresses induced from LSP (2mm spot, 21.4% overlap, 5GW/cm^2 and one tape layer) vary periodically by approximately ±220MPa across the treated area.

The depth profile on a sample improves after two layers with treatment and the surface stress shows less variation. This is important when considering the time required for application on industrial components.

The residual stress transition from the treated to un-treated regions was very smooth and did not exhibit a sharp tensile peak.