Experiment Report Form

The double page inside this form is to be filled in by all users or groups of users who have had access to beam time for measurements at the ESRF.

Once completed, the report should be submitted electronically to the User Office using the **Electronic Report Submission Application:**

http://193.49.43.2:8080/smis/servlet/UserUtils?start

Reports supporting requests for additional beam time

Reports can now be submitted independently of new proposals – it is necessary simply to indicate the number of the report(s) supporting a new proposal on the proposal form.

The Review Committees reserve the right to reject new proposals from groups who have not reported on the use of beam time allocated previously.

Reports on experiments relating to long term projects

Proposers awarded beam time for a long term project are required to submit an interim report at the end of each year, irrespective of the number of shifts of beam time they have used.

Published papers

All users must give proper credit to ESRF staff members and proper mention to ESRF facilities which were essential for the results described in any ensuing publication. Further, they are obliged to send to the Joint ESRF/ ILL library the complete reference and the abstract of all papers appearing in print, and resulting from the use of the ESRF.

Should you wish to make more general comments on the experiment, please note them on the User Evaluation Form, and send both the Report and the Evaluation Form to the User Office.

Deadlines for submission of Experimental Reports

- 1st March for experiments carried out up until June of the previous year;
- 1st September for experiments carried out up until January of the same year.

Instructions for preparing your Report

- fill in a separate form for each project or series of measurements.
- type your report, in English.
- include the reference number of the proposal to which the report refers.
- make sure that the text, tables and figures fit into the space available.
- if your work is published or is in press, you may prefer to paste in the abstract, and add full reference details. If the abstract is in a language other than English, please include an English translation.

ESRF	**Experiment title:** *High resolution mapping of residual strains generated by Laser Shock Peening.*	**Experiment number**: **ME-747**
Beamline: ID31	**Date of experiment**: from: 06-FEB-04 to:10-FEB-04	**Date of report**: 12/01/06
Shifts: 12	**Local contact(s)**: Dr A Fitch	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

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Laser shock peening is a mechanical surface treatement which generates a near surface compressive residual stress field in response to the plastic deformation caused by a mechanical shock wave[1]. The plastically defomed region and resulting residual stresses have been found to significantly increase the fatigue resistance and damage tolerance of aerospace components[2]. These compressive residual stress field are balanced by potentially deleterious tensile residual stresses which can act as crack initiating sites. Hence is is necessary to characterise these residual stress fields. The objective was to measure the residual strain distribution in an aluminium alloy disc sample which had been laser shock peened on the two opposite faces. The aim of the experiment was to spatially resolve the compressive and tensile residually stresses regions. This was achieved by measuring the residual strain depth profile and 2D mapping of the highly residually stressed regions.

The studied sample was a laser shock peened 7075-T7351 disc shaped sample provided by Dr Patrice Peyre at the French CNRS laboratory for laser science LALP. The disc was 30mm in diameter and 12.85mm thick as shown schematically in Figure 1. The sample was laser shock peened at the centre on both the circular faces of the disc. One side was laser shock peened repetitively twice in the same position while the other face was peened four times. The laser impact footprint was 8 mm in diameter.

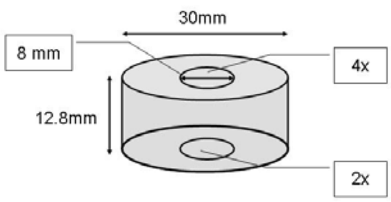

Figure 1. Schematic of the 7075 disc sample treated with 4 times and 2 times repetitive laser impacts at the same position.

Measurements were made on the high resolution powder diffractometer ID31. The energy of the monochromatic synchrotron beam was 60KeV. The (311) diffraction plane was measured giving a scattering angle (2θ) of ~ 9.7º. The incident beam size was 0.2 x 0.2 mm, defined by automated slits. The secondary slits were also set to 0.2 mm, giving a gauge length of ~2.4mm. An analyser crystal is used to define the diffracted beam which eliminates the pseudostrain arising from partially filled gauge volumes.

The full thickness residual strain depth profile through the 4 times impacted side to the 2 times impacted side is shown in Figure 2. The residual strain profile shown in Figure 2 reveals that the side peened 4 times repetitively, exhibits compressive residual strains to 2mm in depth. Peak balancing tensile residual strain occurs around 2.5mm in depth, decreasing to near zero strain 5mm beneath the surface. The side peened 2 times exhibits the transition from compression to tension at around 1mm beneath the surface.
The balancing tensile residual strain exhibits a peaked shape, but has a rather flat profile at ~150με through to the centre of the sample. The greater scatter in the shape of the profile may suggest that the grain size increases in this undeformed region, hence measurements are recorded from individual grains or a few grains

with similar residual strain. This is confirmed by the scatter from point to point in the peak width profile shown in Figure 3. The general trend of the peak width shows significant broadening of the diffraction peaks on both treated surfaces, indicating increased plastic strain in these regions.

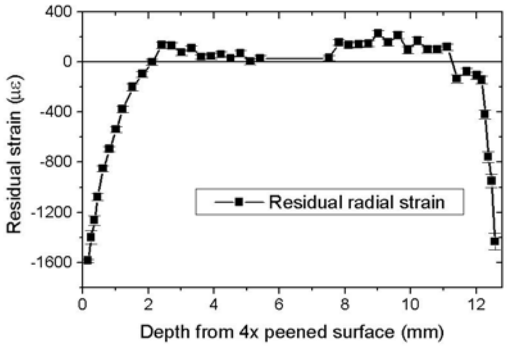

Figure 2. Radial residual strain depth profile from 4X peened surface

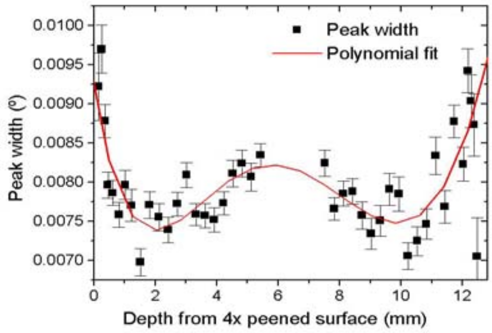

Figure 3. Peak width depth profile from 4X peened surface

The 2D map of residual strain of from the centre of the circular impact of the surface peened four times repetitively to a radius of 8mm is shown in Figure 4. The compressive residual strain of the peening impacts is clearly seen extending from the centre along the radial direction (X) to around 7mm, beyond the edge of the impact at 4mm. In depth along direction Y (axial), the stress state becomes nominal around 2mm in depth and becomes slightly tensile at ~3mm. The particularly striking aspect of the map is that the bulk of balancing tensile residual strain located not beneath the compressive region, but laterally of this position, towards the edge of the disc. The largest tensile strains are found between 2-3mm beneath the surface, although the tensile region extends close to the surface.

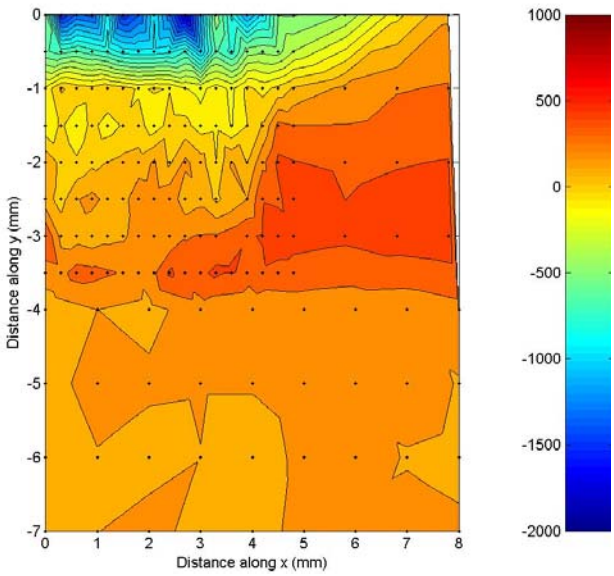

Figure 4. 2D residual strain map of radial strain component given by scale in strain x10^{-6}

Conclusions

The synchrotron diffraction measurements revealed the deep case of compressive residual stress generated by the laser shock peening treatment. Peak width analysis revealed significant broadening to depths corresponding to the compressive residual stress regime,indicating the depth of plastic work generated by laser peening. 2D area maps of the laser peened region and surrounding elastically deformed region revealed the position and magnitude of the deleterious balancing tensile residual stresses. Such stresses can assist in fatigue crack initiation and propagation and hence there is necessity to characterise these regions. This work has shown that high energy monochromatic synchrotron radiation is very suitible for the study of mechanical surface treatments such as laser shock peening. This work is the first non-destructive characterisation of spatially resolved residual strain distribution created by laser shock peening, which clearly demonstrates that depth profiling using conventional laboratory X-ray alone does not reveal the extent of tensile residual stresses in certain sample geometries. The fast acquisition times allowed very high spatially resolved maps of residual strain to be made. The results have been presented at MECASENS 2006 conference, Santa Fe, USA and used to refine Finite Element models of the laser shock peening process [3] and 2 papers are in preparation.

[1]Peyre, P., Fabbro, R., Merrien, P. and Lieurade, H. P. (1996). "Laser shock processing of aluminium alloys. Application to high cycle fatigue behaviour." Materials Science and Engineering A 210(1-2): 102-113
[2]Ruschau, J. J., John, R., Thompson, S. R. and Nicholas, T. (1999). "Fatigue crack nucleation and growth rate behavior of laser shock peened titanium." International Journal of Fatigue **21**(Supplement 1): 199-209
[3]K. Akita, M. Kuroda, A.D.Evans and P.J.Withers, Dynamic Finite Element Analysis and Measurement Using High Energy Synchrotron X-ray of Residual Stress Induced by Pulse Laser Irradiation, The 41th Symposium on X-ray Studies of Mechanical Behaviour of Materials 13-14/07/2006,Kyoto, Japan