ESRF	**Experiment title:** Residual stresses in aluminium alloy	**Experiment number:** HS -35
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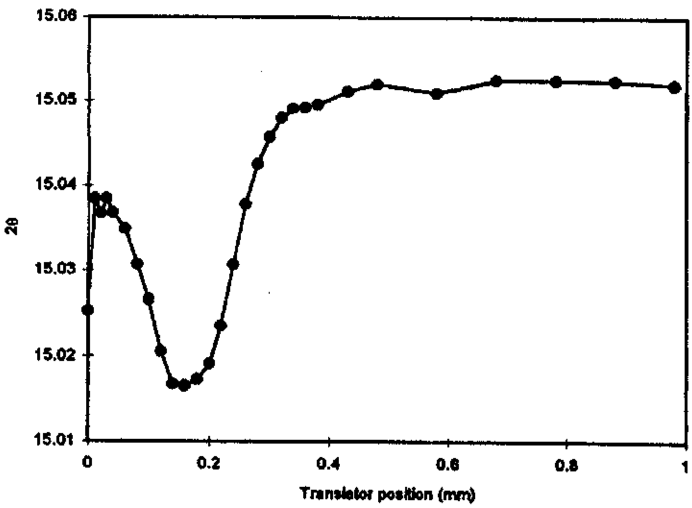
Report:

The experiment was designed to measure, and to compare with equivalent neutron data, the steep in-surface and normal residual stress depth profiles through a heavily shot-peened, 75 mm square by 10.6 mm thick, plate of aluminium 7071 alloy, containing 4.5% zinc and 2.5% magnesium. The alloy is of generic aeromechanical engineering interest and is used extensively in the aerospace industry, particularly for airframe components where lightness and strength are crucial. Shot-peening is a cold working process, used in the finishing of critical metal components, in which the surface is plastically deformed by bombardment with small round shot leaving it finely dimpled where the shot has impacted. A thin surface layer is left in in-plane compression which is balanced by in-plane tension in the interior. The compressive layer inhibits the initiation and growth of surface cracks by fatigue, but if it is too thin and the balancing tension is localised too near the surface the advantages can be offset by the increased risk of failure from sub-surface defects in a tensile stress field. By varying shot-peening parameters; material, size, speed and duration, the magnitude and depth of the peening effect can be varied.

Neutron measurements of the (311) reflection, using a 'gauge volume' 0.5 mm wide and a wavelength 1.9 Å, had revealed features of the internal residual stress field but the data were limited due to the relatively low neutron scattering length and inherent instrumental insensitivity near the surface.

In this investigation measurements were made in normal and in-surface orientations using the (1 11), (200), (220) and (311) reflections at an X-ray wavelength of 0.32 Å at detector angles between 7.8° and 15°. The 'gauge volume' was defined by slits in the incident and diffracted beams 0.1 mm wide and 5 mm long. The measurements were made in linear scans from one surface to the other in incremental steps varying from 10 μm near the surface where strain gradients are high, to 500 μm near the centre where gradients are low. An additional set of measurements was made on a parallel sided 'stress-free' aluminium powder plate sample to evaluate any near-surface instrumental effects.

The data were collected at a rate between 10 and 100 times faster than was possible with the highest flux neutron sources and with up to 5 times better spatial resolution. An example of the results obtained is shown in the figure, as a peak position versus depth graph. Residual strain is inversely proportional to the peak shift. The graph reveals four significant features. At the greater depths the normal strain gradient is low. As the surface is approached the curve drops steeply as anticipated for a normal Poisson's ratio strain response to in-plane compressive stress. Nearer the surface there is an upturn, a feature which is only predicted when a sample has been 'over-peened'. Very close to the surface there is a small downturn. This downturn was shown by the stress-free powder investigation to bean instrumental effect rather than due to peening.



Normal direction strain and instrument related (311) peak shifts versus depth for heavily peened aluminium 7071 alloy.

The results show clearly that the technique is not only viable but can be, for aluminium samples up to at least 10 mm thick, vastly superior to both neutron and traditional laboratory X-ray methods. It is intended that a technique and instrument development programme will now be initiated at the ESRF to enable more sophisticated and efficient measurements to be made on a wide range of engineering samples, particularly of light element materials of generic interest to aerospace engineering.