ESRF

Experiment title:

Residual stresses in peened Ti-6Al-4V alloy

Experiment number:

HC -326

Beamline: BM 16

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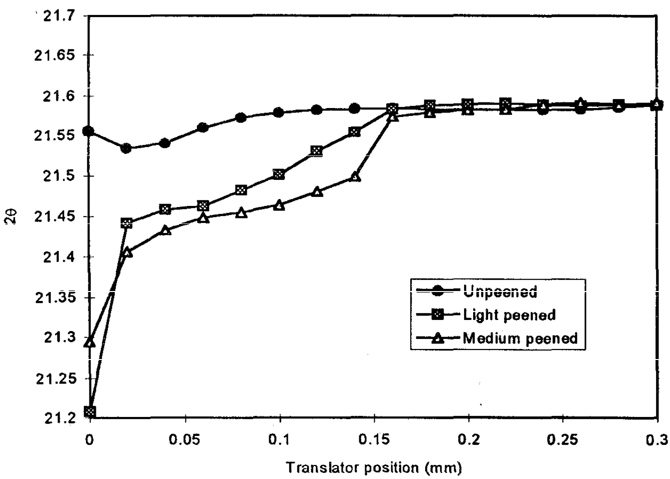
Report:

Ti-6Al-4V is a material of generic mechanical engineering interest widely employed for aerospace applications. The material is relatively light, fracture-tough and fatigue resistant, with the necessary strength to withstand very high cyclic stresses and ambient and low temperatures. It is the alloy used to make the large fan blades seen at the air intake of aeroengines. Thermally stable nickel superalloys are used in the hotter regions of the engine. It is important that fan blades, and even more so the discs that hold each set of blades, do not fail in service.

One potential failure mode is fatigue cracking. Fatigue cracks may propagate as a result of cyclic fatigue, from defects such as scratches that may be present at the surface. To increase the fatigue resistance fan blades and discs are routinely shot-peened. 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 compression which is balanced by 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.

The proposal was designed to evaluate the potential of synchrotrons radiation for non-destructive internal and through-surface strain scanning and, if possible, to measure the through-thickness residual strain distributions in the in-plane and normal directions of three plates of Ti-6Al-4V material that had been peened to three different calibrated intensities.

Measurements were made successfully, using a beam of 35 keV (0.35 Å) X-rays, through sections of the three peened plates, which were each 1.6 mm thick, and through one unpeened reference plate. The incident beam cross-section was reduced to 0.1 x 5 mm, with 0.1 mm slits in front of the detector, to define the small 'gauge volume' used to scan the sample. Measurements were made at increments varying from 20 to 400 μm through the thickness depending upon the steepness of the strain gradient. Examples of the results obtained are shown in the figure, as (211) peak position versus depth profiles, for strain effects in the direction normal to the surface, for three representative unpeened, lightly peened and medium peened samples. The unpeened sample shows a small peak shift at the surface which is most probably due a combination of residual stresses introduced when the surface was machined and a small near-surface instrumental effect that will be the subject of further study as part of a development programme. The lightly peened sample shows a significant residual stress effect to an apparent depth of about 130 pm. The medium peening shows a larger effect to a depth of about 180 pm. The data when processed to account for the diamond shaped 100 μm wide gauge cross-section and for exponential attenuation will show that the actual peening effects penetrate to depths of about 50 μm for the lightly peened and 100 μm for the medium peened sample,



Strain related (211) peak shifts versus depth for unpeened, lightly peened and medium peened samples of Ti-6Al-4V alloy

As these measurements, the first of this type at the ESRF, have been successful it is intended that a technique and instrument development programme will be started 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.