Dependence of microtextural orientation on applied fatigue loading in shot-peened aluminium

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Extended Abstract It is well known that cold-work induced residual stresses can be used to influence the fatigue life of strain-hardening metals. The effect of load cycles on stress fields in such materials is less well understood; reports of stress relaxation at various proportions of fatigue life can be found in the literature but little correlation is found between experiments. The phenomenon of strain re-orientation was noted in [1] as a function of orientation of maximum principal strain with applied loading. Residual strains evaluated over a short range (of the order of a few grains) are significantly influenced by the order and orientation of those grains, described as microtexture. To accurately describe the cyclic behaviour of aluminium treated with shot peening it is necessary to develop an understanding of the relationship between residual stress, microtextural orientation and applied loading.

Previously, a re-orientation in principal strain direction was observed in specimens loaded in this manner, key data from the author's previous work is shown in Figure 1, the graphs show the angle of maximum principal strain in the plane of the specimen surface with increasing depth from the surface. Strains were measured with synchrotron diffraction on ID31 at the ESRF as part of ME748. The maximum strain is seen to lie near 0 degrees (rolling direction, axis of applied stress in fatigue) in the near surface and shift towards 90 degrees with depth. With applied loading the depth at which the strain changes direction becomes deeper in the specimen, more so with greater applied loading; this is attributed to a change in microtexture in the examined layers.

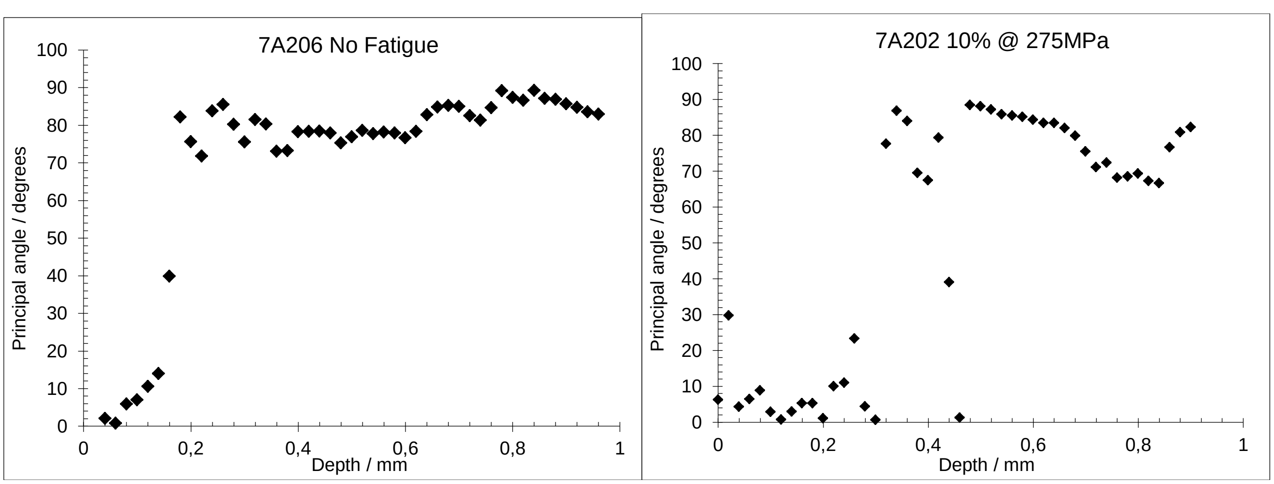

Figure 1 Change in strain angle with applied fatigue loading [1]

Shot-peening is known to increase dislocation density in the plastically deformed region at the specimen surface and has been shown to increase grain boundary mis-orientation in steel specimens in the same layer [2]. Furthermore, plastic strain has been shown to alter the grain boundary mis-orientation in AA7050-T7451, in particular small pre-strains causing increasing mis-orientation and subsequent thermal compression allowing a degree of recrystallization and thereby decreasing mis-orientation [3]. It is hypothesised here that the initial shot-peening introduces an increased level of boundary mis-orientation along with the well documented refinement of surface structure; the application of fatigue loading enables a textural re-orientation which drives the previously observed phenomenon of strain re-orientation. By capturing the changes in texture through applied loading it may be possible to specify a slip mechanism facilitating the changes and thereby further our understanding of the fatigue process.

To enable this study specimens of aluminium alloy 7050-T7451 were prepared for four-point bending fatigue measuring 20x20x150mm. Shot-peening in accordance with MIL-S-13165C (20AlmenA, 200%) was applied to a single surface of the specimens to introduce compressive residual stresses in the near surface for study. The specimens were then loaded cyclically using a servo-hydraulic test frame in a four point bending configuration at a stress ratio of R=0.1 such that the peened surface was subject to maximum stress. The loading and number of cycles for each specimen was determined from previous stress-life data with an adjusted Basquin curve fitted to 10% of cycles to failure shown in Figure 2. Actual number of cycles and corresponding maximum stresses are shown in Table 1.

Specimen	σ_{max} (MPa)	Cycles applied
7-F-2-09	0	0
7-F-2-10	0	200,000
7-F-2-13	0	178,500
7-F-2-14	0	30,000

Table 1 Specimen numbers, applied stress at R=0.1 and number of cycles applied

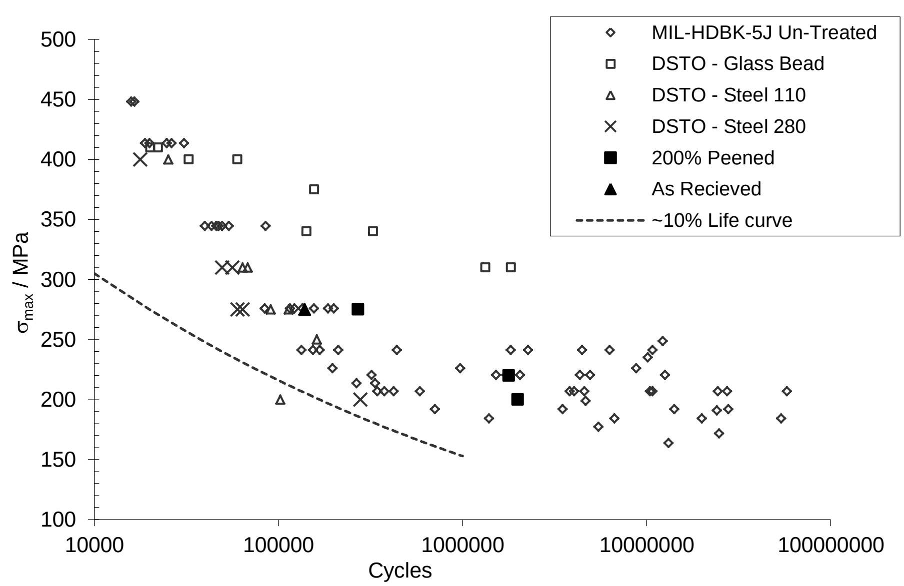

Figure 2 Fatigue data from literature and authors for 7050-T7451 with curve fitted at 10% total life

To investigate this phenomenon in a microtextural context samples were taken from the fatigued specimens to enable examination with XRD and EBSD. The samples were as 10x10mm cross sections retaining the surface layer and viewing onto the long-transverse plane of the specimen. These samples were then ground with silicon carbide paper to 1200grit and then polished with diamond suspension to 1µm grit and finally vibratory polished with colloidal silica at 0.04µm. Following mechanical polishing the specimens were electro-polished in an automated bath with a solution of phosphoric acid (200ml), industrial methylated spirit (400ml) and de-ionised water (600ml). A current density of ~35A.dm^{-2} was applied for 90s, a stainless steel cathode was used. Texture maps of the surface regions through to approximately 600µm are to be made using x-ray diffraction and electron back-scatter diffraction and a subsequent analysis of the variation in microtexture will be made.

References

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