

# 202 Residual stress, preferential orientation, and cyclic loading in shot-peened aluminium

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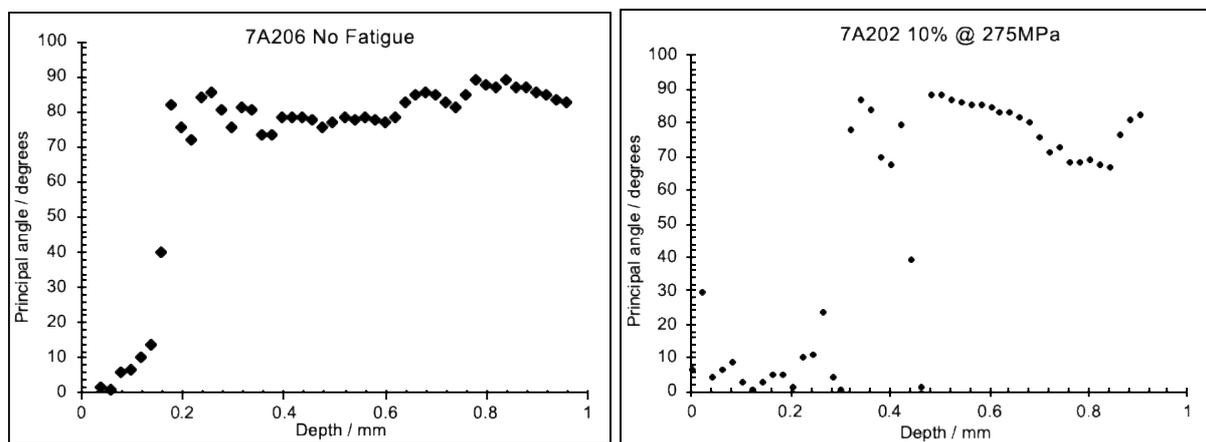
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**Abstract.** Cold work induced compressive residual stresses are frequently used to influence the fatigue life of strain-hardening metals. The effect of load cycles on stress fields in such materials is less well understood; reports of stress relaxation 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 orientation of those grains, described as microtexture; alignment in preferred directions may influence the effect of applied strains. To accurately describe the cyclic behaviour of aluminium treated with processes such as shot peening it is necessary to develop an understanding of the relationship between residual stress, microtextural orientation and applied loading.

## Introduction

Previously, a re-orientation of principal strain direction was observed in specimens loaded in this manner, data from previous work is shown in Figure 1, the graphs show the measured angle of maximum principal strain in the surface plane of the specimen with increasing depth from this 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.



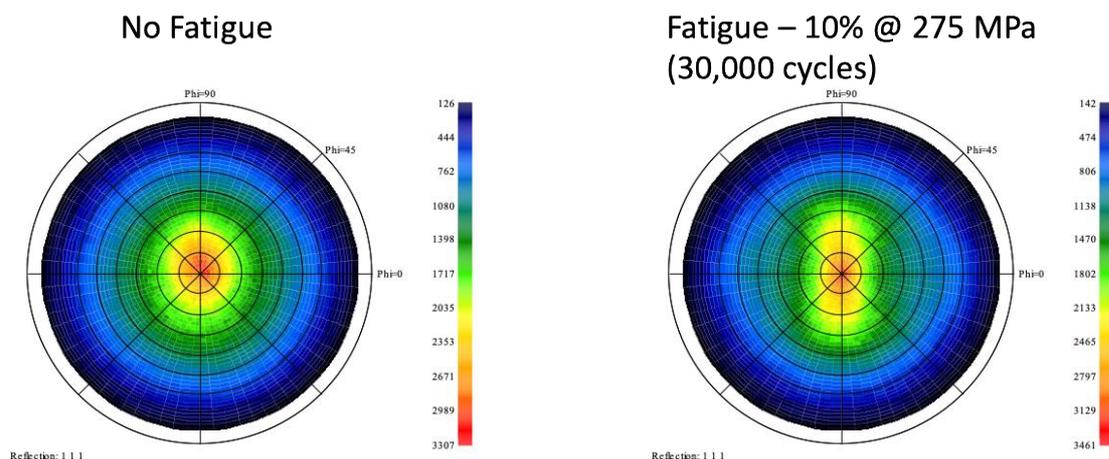
**Figure 1** Change in strain angle with applied fatigue loading [1]

A similar study conducted on AA2024-T351 showed no consistency of principal strain angle either prior to fatigue loading or afterwards. Stress relaxation in this alloy system has been reported previously and some similar effects would be expected. It is important to note that the development of texture within these two different alloys is different with a tendency towards a more ordered system in 7050 and more random orientation in 2024. Studying both will help to develop a general understanding, since, if applied loading causes some consistent re-orientation in 7050 then a degree of textural alignment in 2024 may be anticipated.

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 facilitates 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.

In a preliminary study, specimens of shot peened aluminium alloy 7050-T7451 were cycled at the same stress levels as in the specimens shown in Figure 1, to the same number of cycles (corresponding to 10% of life) and subjected to a texture analysis. Orientation distribution was measured on the [111] plane and

referenced to the rolling direction for the plate. The pole figures shown in Figure 2 at the surface of specimens with loading and without. The narrowing of the central contour to a strip rather than a circle suggests that the primary slip plane is aligning with the applied loads. Subsequent analysis of these specimens with mechanical depth profiling was inconclusive, different textures were observed but not with any clear conclusion.



**Figure 2 Microtexture at the surface of shot-peened AA7050-T7451 specimens with no applied loading (left) and 30,000 cycles at 275 MPa (right), narrowing of the contours can be seen in the fatigued specimen.**

This paper will present an extended study of the texture in shot peened aluminium alloys with applied fatigue loading. Specimens from both 7050-T7451 and 2024-T351 have been prepared in a similar configuration to those in previous studies and loaded cyclically to approximately 10% of their total life. Results from both textural analysis and strain orientation in both alloys will be evaluated.

## References

1. Asquith DT, Hattingh DG, James M,N., Yates JR. 'Re-orientation of residual strains under cyclic loading' Fatigue 2007, Queens' College, Cambridge, 2007.
2. Oxford Instruments Application Note, 'Evolution of EBSD patterns during sample preparation', [online], Last accessed 4<sup>th</sup> June 2012 at [www.oxford-instruments.com](http://www.oxford-instruments.com)
3. Hu, H, Yang, L, Zhen, L, 'Relationship between boundary misorientation angle and true strain during high temperature deformation of 7050 aluminum alloy', Trans. Nonferrous Met. Soc. China, **18** (2008), 795-798