Effect of Shot Peening on High Cycling Fatigue of Al 2024-T4

Y. Fouad and Mostafa M. El Metwally
Faculty of Engineering and Materials Science, German University in Egypt.

Abstract: The present work was aimed at evaluating the effects of shot peening on the high cycle fatigue performance of the age hardening aircraft alloy Al 2024 at different almen intensities. Shot peening to full coverage (100%) was performed using spherically conditioned cut wire (SCCW 14) with an average shot size of 0.36 mm and at almen intensities of 0.1 mmA, 0.2 mmA and 0.3 mmA. After applying the various mechanical surface treatments, the changes in the surface and near surface layer properties such as micro-hardness, residual stress-depth profiles and surface roughness were determined. The microhardness, surface roughness and the residual stresses increased proportionally with the almen intensity. Electropolitically polished conditions were used as reference in the mechanically surface treated specimens. A significant improvement was seen in the fatigue performance of the 0.1 mmA.

Keywords: Fatigue, shot peening, Aluminum 2024, surface treatment.

1. Introduction

Mechanical properties such as shot peening and ball burnishing are often applied to light alloys based on aluminum mostly to improve their high cycle fatigue strengths [1] It is said that 100% coverage in shot peening is required to achieve full benefit in terms of near surface high dislocation densities, residual compressive stresses and fatigue performance [1-2] This increase in dislocation densities led to higher resistances to fatigue crack nucleation while the compressive residual stresses were found to stop micro-crack growth [3-5]. In this research study, the effect of shot peening on fatigue performance and microhardness was studied on Al2024 T4 condition for different almen intensities. Shot peening is surface treatment frequently subjected to aluminum alloys surface. It has receive extensive attention in research due it increase the component’s fatigue life [6-8]. In many industries, where components often experience repetitive loading, materials are commonly treated with cold working processes to increase their fatigue performance. In particular aluminum alloys are shot-peened to improve these characteristics. The process of shot-peening involves bombarding a surface with hard spherical particles propelled by compressed air or a centrifugal effect. These properties inhibit short crack growth and increase the fatigue life [9]. Shot-peening tends to increase the surface roughness which can be detrimental to fatigue performance [10]. It can also increase the susceptibility to corrosion, but it does not usually affect the tribological performance of aluminum. The early stages of fatigue crack development are not of course restricted to the growth of small mode I crack under a tensile cyclic loading. It is in these early stages that faceted and locally divergent crack paths are often present. Moreover, a compressive loading component is a feature of many service environments and crack paths are often encountered that are markedly inclined to the loading direction.

Very little experimental work has been reported on this wider area of the influences of compressive loading and pronounced mixed-mode loading on small crack closure. Even for long cracks, experimental measurements of closure under mixed-mode loading are relatively unreported [11-13], although mode I crack closure in the presence of a wide range of loading profiles has received much attention. Despite additional input from modeling work [14-15], the influence of crack closure on fatigue crack growth during mixed-mode loading is not well understood. The present work addresses the areas of influence of different almen intensities on the mechanisms of fatigue life of Al 2024-T4. It describes observations and measurements of the surface and near surface layer properties such as micro-hardness, residual stress-depth profiles and surface.
2. Experimental Work

The age hardening alloy Al 2024 were received as raw rods specimens (11 x 11 x 70) cut specimens were taken with the long axis parallel to the extrusion direction and were solution heat treated at 495°C for 1 h followed by water- quenching and naturally aged for 5 days at room temperature (condition T4). Shot peening was conducted using a gravity induction shot peening machine type OSK-kiefer GmbH. Shot peening was carried out for 40 seconds using spherically conditioned cut wire (SCCW 14) each at a constant distance between the nozzle and the specimen of 9 cm. The specimen is rotating continuously during peening to ensure 100% coverage. Different almen intensities were used to compare the fatigue improvement. Table (1) indicates the various almen intensities, time and pressure used.

Table 1: Various almen intensities, time and pressure for Al 2024-T4 alloy.

<table>
<thead>
<tr>
<th>Peening pressure</th>
<th>Almen intensity</th>
<th>Peening medium</th>
<th>Distance from nozzle</th>
<th>Coverage</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5 bar</td>
<td>0.1 mmA</td>
<td>SCCW 14</td>
<td>9 cm</td>
<td>100 %</td>
<td>40 s</td>
</tr>
<tr>
<td>2 bar</td>
<td>0.19 mmA</td>
<td>SCCW 14</td>
<td>9 cm</td>
<td>100 %</td>
<td>40 s</td>
</tr>
<tr>
<td>5 bar</td>
<td>0.3 mmA</td>
<td>SCCW 14</td>
<td>9 cm</td>
<td>100 %</td>
<td>40 s</td>
</tr>
</tbody>
</table>

The surface roughness was measured by a profilometer. The residual stress were investigated using the incremental hole drilling method technique where the residual strains are calculated first using a 1.9 mm diameter drill. The induced strains are measured every 10 μm. These strains are then converted to stresses by a series of equations using the macroscopic Young’s modulus of E=70 GPa and a Poisson’s ratio of 0.34. The microhardness depth profile was measured using a Struers Duramin Härteprüfer with a Vickers hardness pyramidal diamond indenter for a dwell time of 15 seconds. Fatigue tests were performed on hour glass shaped specimens with a gage diameter of 6 mm in rotating beam loading (R= -1) in air at frequency 50HZ. Specimens were electropolished and taken as reference. Roughly 100 μm were removed from the as machined and mechanically pre-polished to remove any machining effect that can affect the results while the rest of the specimens were mechanically polished before shot peening.

3. Results and Discussion.

As observed in the microstructure investigation, the microhardness was increasing proportionally with the almen intensity of shot peening. Because of the amount of cold working and plastic deformation the microhardness was increased.

Table 2: Roughness values for Al 2024-T4 at different Almen intensities.

<table>
<thead>
<tr>
<th>Condition</th>
<th>RA</th>
</tr>
</thead>
<tbody>
<tr>
<td>EP</td>
<td>0.08</td>
</tr>
<tr>
<td>SP 0.1 mmA</td>
<td>1.51</td>
</tr>
<tr>
<td>SP 0.2 mmA</td>
<td>2.76</td>
</tr>
<tr>
<td>SP 0.3 mmA</td>
<td>3.42</td>
</tr>
</tbody>
</table>

As expected, the roughness increases gradually with increasing the almen intensity of the shot peening process as in Table (2). The high roughness of the 0.3mmA has a great influence on the fatigue performance.
Fig. 1: Microstructure and section topographies of peened AL 2024 at different Almen intensities (A, B near surface) SP 0.1 mmA, (C, D near surface) SP 0.2 mmA and (E, F near surface) SP 0.3 mmA.
As expected the higher almen intensity gave us the higher residual stress profiles which will increase the fatigue performance Fig. 2.

In Fig. 3 After shot peening the fatigue performance was increased clearly in the 0.1 mmA almen intensity (250 MPA) and then the 0.2 mmA but no further improvement in the fatigue performance was observed in the 0.3 mmA(300 MPA) Fig. 4 although the amount of residual stress was higher but this can be
interpreted from the high roughness so that the crack nucleation will be easier or may it is because of some surface damage before testing.

![Fig. 4: S-N curves of Al 2024-T4 alloy after shot peening](image)

### 4. Conclusions

In this study, the effect of shot peening on fatigue performance was studied on Al2024 T4 and the following results were obtained:

1. A significant improvement was seen in the fatigue performance of the 0.1 mmA almen intensity, while improvement in the fatigue performance of the 0.2 and 0.3 mmA almen intensities were equally because of the high surface roughness of the 0.3 mmA.
2. The microhardness, surface roughness and the residual stresses increased proportionally with the almen intensity.

### 5. References


