# Influence of Shot Peening on the Fatigue Resistance of Sulfuric Anodized AA 7175-T74

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**Abstract.**
This study evaluates sulfuric anodizing influence on the axial fatigue strength of Al 7175-T74 aluminum alloy, applied on landing gears. Anodizing decreases fatigue resistance by inducing tensile residual stresses on the material surface and by cracks generated during anodizing process. Axial fatigue SxN curves were performed at stress ratio R= 0.1, with and without sulfuric anodizing. The shot peening process was used to increase fatigue resistance.

**Keywords:** Al 7175-T74 aluminum alloy, fatigue, sulphuric anodizing, residual stress, shot peening.

## Introduction

Structural component failures due to cyclic loading are associated with materials surface damage and its interaction with environment. This type of failure occurs with stresses below the yield strength of each material and is responsible for 90% of mechanical failures [1]. Therefore, fatigue is an important parameter regarding the mechanical behavior of components subjected to constant and variable amplitude loadings [2]. High strength Al 7175-T74 (Al-Zn-Mg-Cu) aluminum alloy has a low specific weight, excellent relationship weight/resistance, chemically inert due to a nature passive film, and provides good surface finish in final product. These characteristics establish aluminum as an important material for aeronautical structural components, where improved formability and toughness are desired [2, 3]. Aircraft structures are subjected to aggressive environments during flight and the most common types of corrosion found are surface corrosion, pitting, intergranular corrosion, metal corrosion and stress corrosion cracking. In aluminum alloys, corrosion occurs as pitting, reducing component fatigue life. The corrosion resistance control is conducted through the use of anodic films, which produce a significant reduction in materials fatigue strength [2, 3, 4, 5]. One of the known ways to improve fatigue resistance is by using shot peening process to induce a compressive residual stress field on material surface layers, delaying fatigue crack nucleation and propagation processes [2]. This research evaluates the influence of the sulfuric anodizing and shot peening process on the axial fatigue performance of Al 7175-T74 aluminum alloy with stress ratio R= 0.1.

## Materials and Methods

This investigation was performed with cylindrical specimens of Al 7175-T74 aluminum alloy. The aluminum alloy chemical composition is (in wt%): 92.37% Al, 3.13% Zn, 1.94% Cu, 2.08% Mg, 0.020% Mn, 0.038% Si, 0.38% Fe, 0.036% Ti. The average mechanical properties obtained from tensile tests, performed according to ASTM E8/E8M are: yield strength of 466 MPa, ultimate tensile strength of 522 MPa, and elongation of 12.1%. These properties were obtained by means of solubilization at 743K followed by a first aging at 380K for 8 h and a second aging at 450K for 5h. The axial fatigue strength was obtained for base material, base material with sulfuric anodizing, shot peened base material and shot peened and anodized base material, according to the following parameters. The anodizing process was performed with sulfuric acid 98%, electrolyte concentration 225 to 235 g/L, the tank volume of 7,200 L, colorless sulfuric anodizing, temperature 290K and layer thickness 12 to 15 μm. The sealing to prevent pores was performed by immersing the specimen in an aqueous solution of nickel acetate, at a temperature between 363 and 371K for 40 minutes. For the shot peening process Almen intensity was equal to 0.013N (30 psi), glass shot (0.3 – 0.43 mm) with coverage 120% and impact angle of 90°. Shot peening was carried out on an air-blast machine according to standard MIL-13165. Measurements of absolute value of residual stresses were performed by X-ray diffraction, by the principle of Bragg's law. The equipment Xstress3000, which operates by method of sen$^2\psi$, with radiation CrK$\alpha$, diffraction the plane {222} of aluminum was used. Incidence angles of X-ray equipment were set at 0°, 20°, 30°, 40° and 45°, with time 10 seconds for each angle through a collimator of 1 mm diameter. To obtain the residual stresses profile in depth, layers were removed by electrolytic polishing using sodium chloride electrolyte, with voltage parameters of 30V and 15A and layer thickness measured by digital comparator clock.

**Fatigue Tests**

Axial fatigue tests were performed with test specimens, according to ASTM E-466 and Figure 1, using equipment Instron 8801 with constant amplitude sinusoidal loading, stress ratio R= 0.1 and frequency of 10 Hz at room temperature.

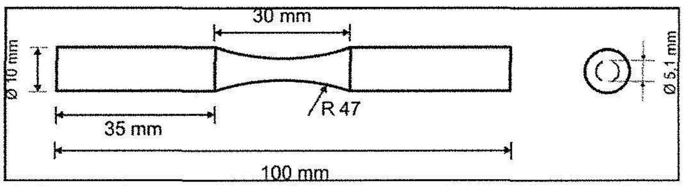


Figure 1.Typical dimensions of axial fatigue specimens, according to ASTM E-466

Specimens were tested in four conditions:

- Base material (Al 7175-T74 aluminum alloy), load ratio R= 0.1;
- Base material (Al7175-T74 aluminum alloy), shot peened, load ratio R= 0.1;
- Base material (Al7175-T74 aluminum alloy) with sulfuric anodizing treatment, load ratio R= 0.1;
- Base material (Al 7175-T74 aluminum alloy) with shot peened and sulfuric anodized, R= 0.1.

**Results and Discussions**

**Residual Stress**

Residual stresses are detailed in Table 1. Experimental values were obtained from surface to 500 (μm) depth. From Table 1 it is possible to observe compressive residual stress from surface until 200μm depth for base material, due to the polishing treatment after machining. Increasing tensile stresses from 300μm, 400μm and 500μm usually observed for aluminum alloy were found [2]. For shot peened base material, higher compressive residual stresses from surface to 400μm depth were obtained, as a result of the mechanical process. According to table 1, tensile residual stress (+90MPa) resulted on specimen surface after sulfuric anodizing, as result of microstructural changes during formation of the anodic film [7]. For the shot peened base material with sulfuric anodizing, tensile residual stress was -71 MPa. The shot peening treatment created a compressive residual stress field that override tensile stresses induced by the coating. This behavior retards or even avoids crack nucleation and delay propagation generated by the anodizing process and results in better fatigue performance. The influence of the shot peening process on anodized base material is also indicated in Figure 2.

Table 1. Residual Stresses [MPa].

| | Depth [μm] | | | | | |
|---|---|---|---|---|---|---|
| Specimen | 0 | 100 | 200 | 300 | 400 | 500 |
| Base Material (7175-T74) | -105 | -100 | -60 | +149 | +180 | +210 |
| BM + Shot Peening (SP) | -300 | -200 | -210 | -105 | -115 | +60 |
| BM + Sulfuric Anodizing (SA) | +90 | - | - | - | - | - |
| BM + SA + SP | -71 | - | - | - | - | - |

### Fatigue

Results from axial fatigue tests for base material, base material with sulfuric anodizing, base material shot peened, and base material shot peened and sulfuric anodized with constant sinusoidal loading and ratio R= 0.1 are shown in Figure 2. Each point represents the average of results from specimens.

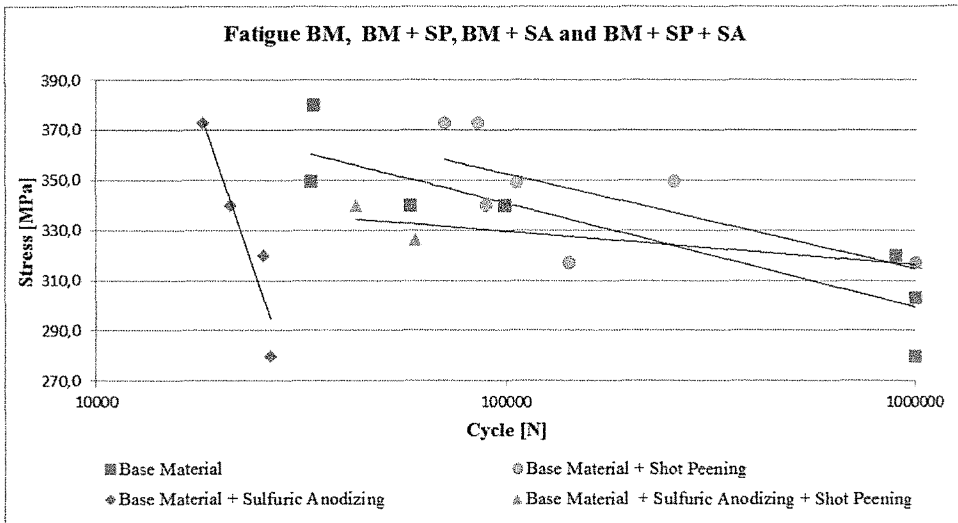


Figure 2. Axial S-N curves.

From Figure 2 it is possible to observe the influence of shot peening process on the fatigue strength of Al 7175-T74 aluminum alloy. Table 1 shows compressive residual stresses from surface to 400µm depths which, as mentioned before, are responsible for the increase in fatigue life. Significant decrease in axial fatigue strength after sulfuric anodizing is indicated in Figure 2. It is also possible to observe in Figure 2, that the fatigue life of anodized Al 7175-T74 aluminum alloy increased after the shot peening pre-treatment.

### Fracture Surface Analyses

The Al 7175-T74 aluminum alloy fracture surfaces are indicated in Figure 3, tested at maximum stress 372.8 MPa. Figures 3a and 3b indicate fatigue crack nucleation at polished specimen surface and propagation inside material. Fatigue striations from stable crack propagation may be seen in Figure 3c. Figure 3d shows dimples associated to final fracture. Fracture surfaces of anodized Al 7175-T74 aluminum alloy are indicated in Figure 4 for maximum stress 372.8 MPa. Figure 4a indicates fatigue crack nucleation at anodized surface and propagation inside base material. In Figure 4b cracks generated due to the anodizing process are indicated, which may accelerate nucleation and further propagation of cracks, reducing fatigue strength [6].
Fracture surface in Figure 5 shows the effect of shot peening pre-treatment on anodized specimens, with respect to fatigue crack nucleation and propagation. Despite the presence of pre cracks associated to the anodizing processes, compressive residual stress generated by plastic deformation from impact balls neutralize the negative effect of anodizing through hardening. The shot peening process will not prevent surface pre-cracks appearance. However, plastic deformation was induced, then, dislocations are blocked and cracks propagated parallel to subsurface layers until to overcome the compressive residual stress field and to propagate into substrate material. Shot peening used aims to increase fatigue life of anodized base material [6].

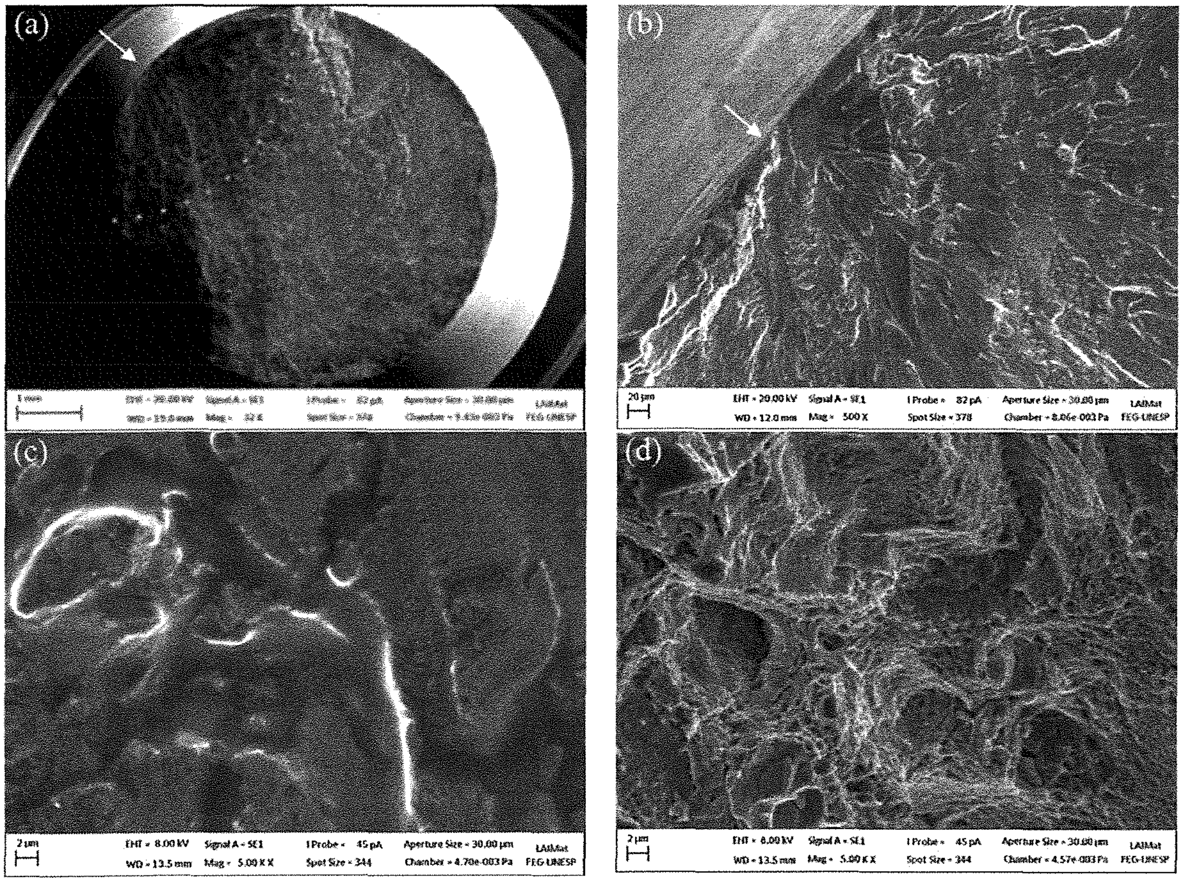


Figure 3. Base material fracture surfaces. R= 0.1. Maximum stress 372.8 MPa

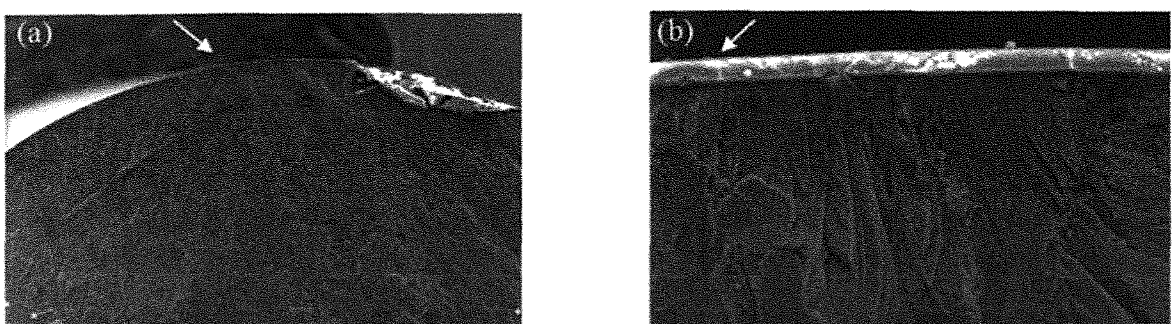


Figure 4. Anodized base material fracture surfaces, R= 0.1. Maximum stress 372.8 MPa.

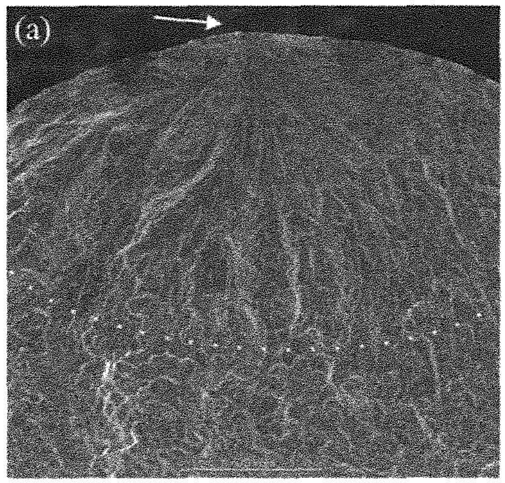

Figure 5. Shot peened and anodized base material. R= 0.1 Maximum stress 372.8 MPa

**Conclusions**

1- The sulfuric anodizing process induced tensile residual stresses on specimen surface (+90 MPa).
2- High compressive residual stresses from surface (-300 MPa) until 400 μm depth (-115 MPa) resulted from the shot peening process.
3- Compressive residual stress (-71 MPa) was obtained in shot peened and anodized Al 7175-T74 aluminum alloy.
4- Sulfuric anodizing reduced axial fatigue strength of Al 7175-T74 aluminum alloy.
5- The shot peening process increased the axial fatigue strength of anodized Al 7175-T74 aluminum alloy.

**Acknowledgments**

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