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INFLUENCE OF SHOT PEENING ON THE FATIGUE RESISTANCE OF ALUMINUM ALLOY AA 7175-T74

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ABSTRACT

This study evaluates the influence of shot peening on the fatigue life of aluminum alloy AA 7175-T74 applied in landing gears. Shot peening increases fatigue resistance by inducing compressive residual stresses on material surface slowing nucleation and propagation of cracks. Axial Fatigue SxN curves were performed at stress ratios R=-1,0, and R= 0,1, with and without the shot peening process. Residual stresses obtained through diffractometry x-ray method indicated that shot peened AA 7175-T74 aluminum alloy showed increase in fatigue life as a result of compressive stresses of the surface on the specimens.

Keywords: aluminum 7175-T74, fatigue, shot peening, residual stress.

INTRODUCTION

Structural component failures due to the cyclic loading are associated to surface damage of materials 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 (Gao, Wu, 2011). Therefore, fatigue is an important parameter regarding to mechanical behavior of components subjected to constant and variable amplitude loadings (Camargo, Voorwald, Cioffi, Costa, 2007).

Metallurgical, mechanical and environmental factors may influence adversely fatigue resistance of structural components; for example, corrosion accelerates failures process. In aeronautical aluminum alloys, corrosion resistance control is conducted through the use of anodic films. Anodic films influence on the fatigue strength occurs in order to produces a significant reduction in the materials resistance (Torres, Voorwald, 2001).
One of the known ways to improve fatigue resistance is by using the shot peening process to induce a compressive residual stress field on material surface layers, delaying the fatigue crack nucleation and propagation processes (Camargo, Voorwald, Cioffi, Costa, 2007).

This research evaluates the influence of the shot peening process on the axial fatigue performance of AA 7175-T74 aluminum alloy with stress ratios R= -1,0 and R= 0,1.

MATERIALS AND METHODS

In this study, cylindrical samples of aircraft AA 7175-T74 aluminum alloy were used. 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 12.13%.

These properties were obtained by means of solubilization at 470°C followed by a first aging at 107°C for 8 h and a second aging at 177°C for 5 h.

AA 7175-T74 aluminum alloy axial fatigue strength was obtained for base material and shot peened base material, according to the following parameters: Almen intensity equal to 0,013N (30 psi), glass shot (0,3 – 0,43 mm) with coverage 120% and impact angle of 90°. 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 CrKα, 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.

- Base material (alloy AA 7175-T74) with shot peening surface treatment and loading ratio 0,1;
- Base material (alloy AA 7175-T74) with shot peening surface treatment and loading ratio -1,0;

FATIGUE

Axial fatigue tests were performed with test specimens (Figure 1), according to ASTM E-466, using equipment Instron 8801 with constant amplitude sinusoidal loading, stress ratio R= -1,0 and 0,1, a frequency of 10 Hz at room temperature.

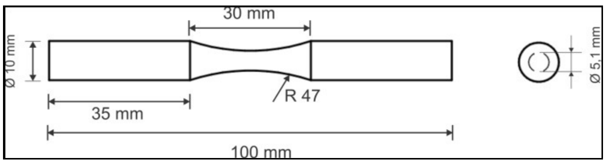


Figure 1 Typical dimensions of axial fatigue specimens, according to ASTM E-466

Specimens were tested in four conditions:

- Base material (alloy AA 7175-T74) with load ratio 0,1;
- Base material (alloy AA 7175-T74) with load ratio -1,0;
- Base material (alloy AA 7175-T74) with shot peening surface treatment and load ratio 0,1;
- Base material (alloy AA 7175-T74) with shot peening surface treatment and load ratio -1,0.

RESULTS AND CONCLUSIONS

RESIDUAL STRESS

Table 1 and Figure 2 present of residual stresses introduced by the shot peening process, from surface to 500 µm depth.

Table 1 Residual Stresses.

Specimens	Specimen Condition	Depth (µm)	Stress (MPa)
1	Base Material	0	- 105
2		100	- 100
3		200	- 60
4		300	149
5		400	180
6		500	210
1	Base Material With Shot Peening	0	- 300
2		100	- 200
3		200	- 210
4		300	- 105
5		400	- 115
6		500	60

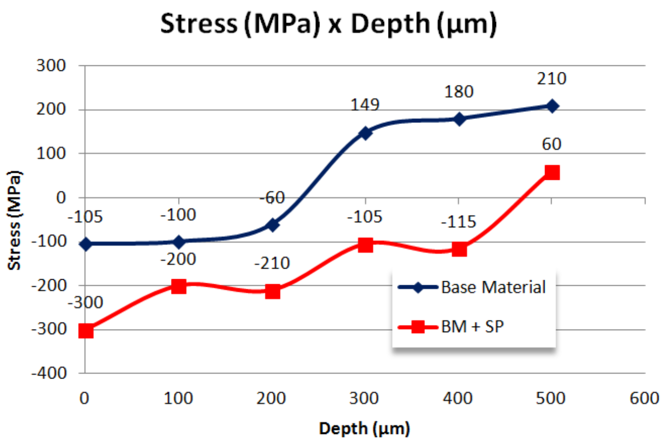


Figure 2 Residual Stress versus depth: base material and base material shot peened

In order to reduce the surface roughness avoiding stress concentrators, the base material specimens were polished.

Table 1 presents compressive residual stresses for AA 7175-T74 aluminum alloy from surface until 200 µm depth. Increasing tensile values were obtained from 300 µm until 500 µm depth.

For shot peened base material, compressive residual stresses are present from surface to 400 µm depth and +60 MPa for 500 µm depth.

It´s important to observe that, despite the higher compressive residual stresses for the shot peened specimens, differences are not so significant.

From Figure 2, higher compressive residual stresses result from shot peening process.

FATIGUE

Results from axial fatigue tests for base material specimens and shot peening surface treatment specimens, with constant sinusoidal loading and ratio 0,1 and -1,0 can be seen in Figures 3, 4 and 5.

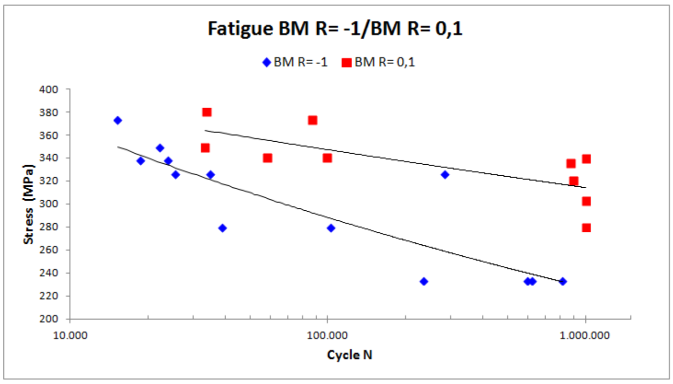


Figure 3 Results of fatigue tests for base material and shot peened AA 7175-T74 R=-1,0; R=0,1.

From Figure 3, it is possible to observe higher AA 7175-T74 aluminum alloy axial fatigue strength for R=0,1 in comparison to R=-1,0. For example, an ultimate tensile strength of 279,6 MPa results in the average number of cycles equal to 70589 for R=-1,0, and 10^6 for R=0,1.

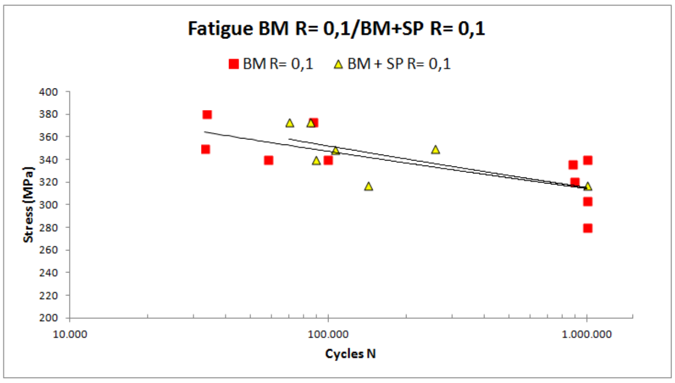


Figure 4 Results of fatigue tests to base material and base material with superficial treatment of shot peening to loading R=0,1.

The influence of shot peening process for R=-1,0 is indicated in Figure 5. It´s possible to observe that specimens with superficial treatment have higher fatigue resistance than the base material, with increasing influence with decreasing maximum applied stress.

From Figure 4, for R=0,1, axial fatigue values for base material and shot peened AA 7175-T74 aluminum alloy are very similar, which means almost no influence of the shot peening process on the fatigue strength.

Residual stresses shown in Table 1 for AA 7175-T74 aluminum alloy and shot peened base material, are associated to the SxN curves behavior in Figure 4.

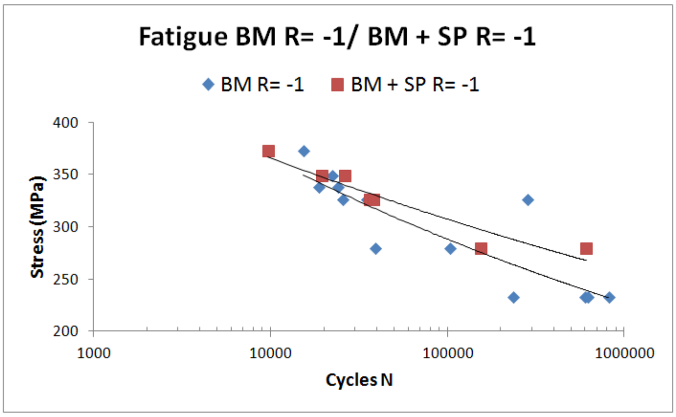
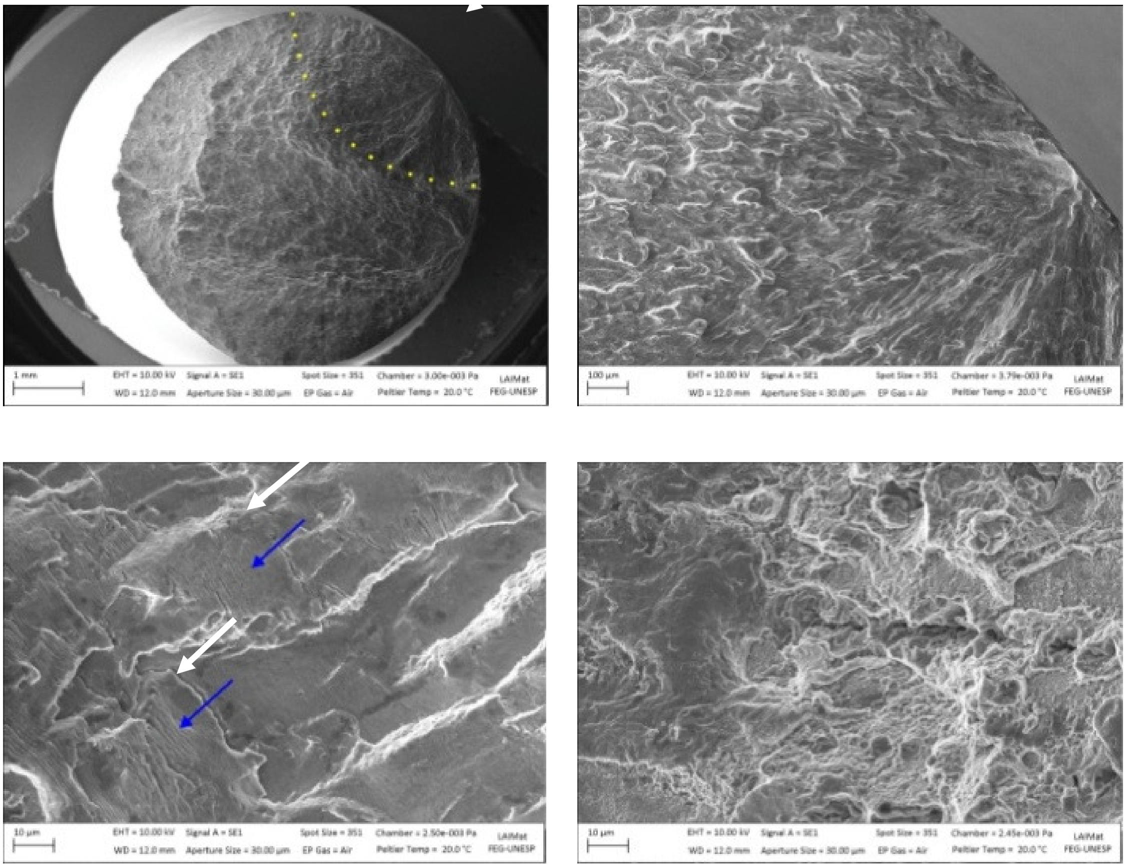


Figure 5 Results of fatigue tests to base material and base material with shot peening to loading R=-1,0.

The increase in fatigue resistance for these parameters of the shot peening process used in the research cannot be adopted as a method to gain strength due to the little difference between the curves for R=0,1 and R=-1,0.

The almost insignificant influence of the shot peening process on the AA 7175-T74 aluminum alloy axial fatigue strength for R=0,1 and R=-1,0 may be associated to the peening parameters.

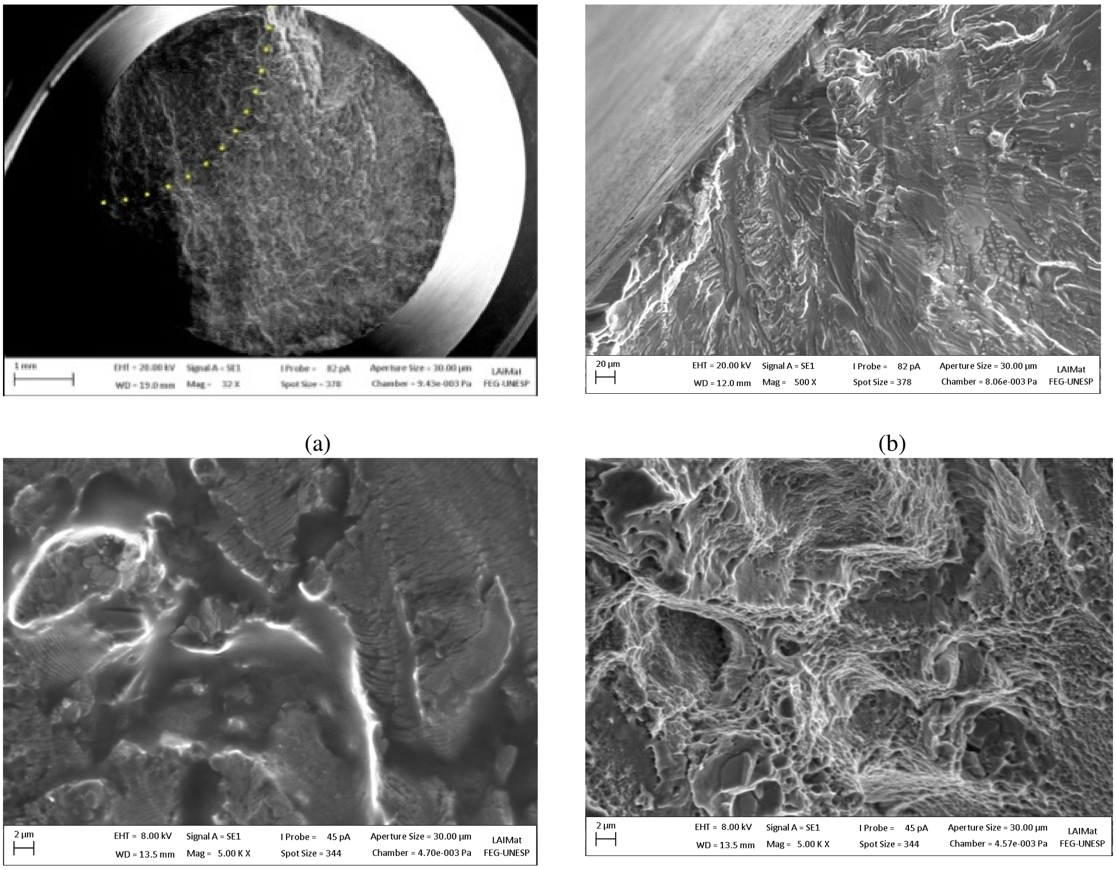
FRACTURE SURFACE ANALYSES



(c) (d)

Figure 6 Microscopic analysis to the fractured region, specimen of base material, ratio R= -1,0 and test stress 326,2 MPa.

From Figure 6(a), it is possible to observe the fractured region of tested AA 7175-T74 aluminum alloy specimen with 326,2 MPa, and 25,556 cycles to failure and R= -1,0. Figures 6a and 6b show fatigue crack initiation it specimen surface and propagation through base material in figure 6c, striation represent fatigue crack growth face and in 6d, dimples are associated to ductile fracture.

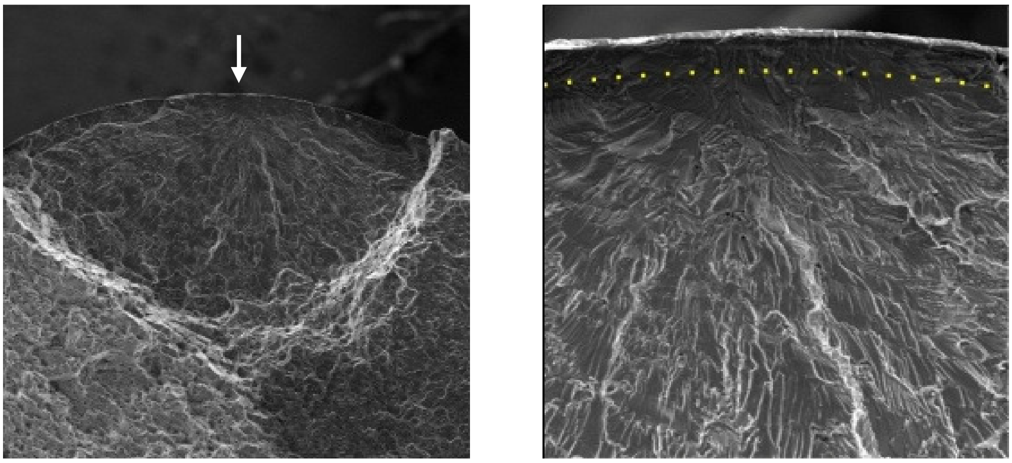


(a) (b)

(c) (d)

Figure 7 Microscopic analysis to the fractured region, specimen of base material, ratio R= 0,1 and test stress 372,8 MPa.

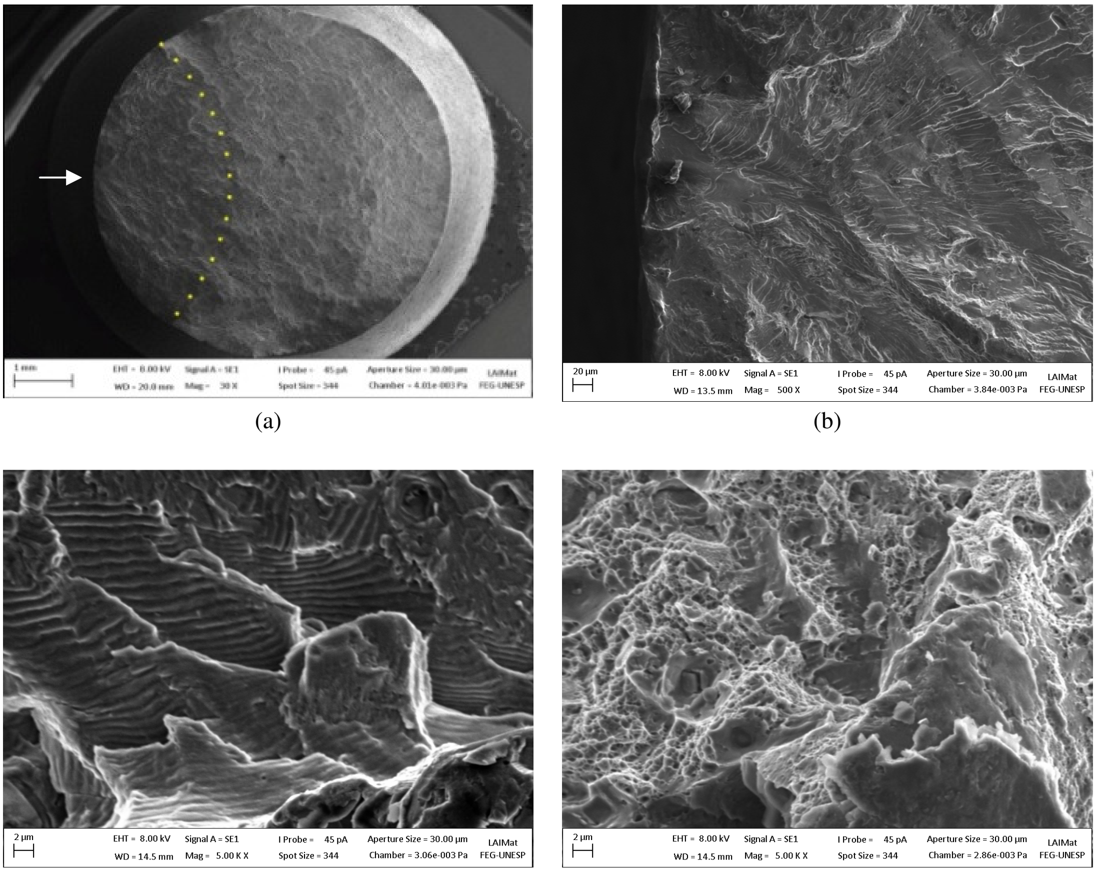
Fracture surfaces for AA 7175-T74 aluminum alloy, are indicated in Figure 7 with ratio load R= 0,1 and maximum stress 372,8 MPa. Figures 7a and 7b indicate fatigue crack nucleation at polished specimen surface and propagation inside material. Fatigue striations and dimples may be seen in figures 7c and 7d respectively.



(a) (b)

Figure 8: Microscopic analysis to the fractured region, specimen of base material with shot peening, ratio R= -1,0 and test stress 279,6 MPa.

Figure 8a and b represent fracture surfaces for shot peened AA 7175-T74 aluminum alloy tested at 279,6 MPa maximum stress, load ratio R=-1,0 with 154721 cycles to failure. The influence of compressive residual stresses on the fatigue process is easily observed in figures (a) and (b).



(a) (b)

(c) (d)

Figure 9: Microscopic analysis of the fractured region, sample base material with shot peening, R = 0.1 and 349.5 MPa stress test.

Fracture surfaces for shot peened AA 7175-T74 aluminum alloy, tested at 349,5 MPa maximum stress and R= 0,1, are represented in Figure 9. Influence of the shot peening process on the fatigue initiation and propagation are shown in figures a and b. Striation and dimples, associated to the fatigue propagation and ductile fracture respectively, are observed in figure c and d.

CONCLUSION

1- Higher axial fatigue strength was obtained for AA 7175-T74 aluminum alloy at R= 0,1 in comparison to R= -1,0.

2- The shot peening processes resulted in higher compressive residual stresses at surface and maintained compressive at increasing depth.

3- Despite the higher compressive residual stresses for the shot peened specimens in comparison to base material, very little difference in the SxN curves were observed for R= 0,1 and R= -1,0.

4- From fracture surfaces it is possible to identify the influence of the compressive residual stress in fatigue initiation and propagation.

ACKNOWLEDGMENTS

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