SHOT PEENING ON THE FATIGUE STRENGTH OF Al7050-T7451 COATED BY HVOF

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The recent tendency of aircraft industry is enhance customer value by improving performance and reducing environmental impact. In view of availability, modern aluminum alloys have a historically tendency to faster insertion due to their lower manufacturing and operated production infrastructure. For landing gear applications there is a very aggressive environment in service, which demand a substract covering to avoid corrosion and fatigue corrosion. High Velocity Oxygen Fuel (HVOF) process has been extensively used in airplane components coating because of an excellent combination of wear and corrosion resistance. Fatigue resistance of Al7050-T7451 coated with WC-17%Co by HVOF and the influence of shot peening pre-treatment in fatigue performance of coated subtract were analyzed. Three groups of specimens were prepared and tested in axial fatigue to obtain SxN curves: base material (Al7050-T7451), base material coated by HVOF and base material shot peened and coated. Fracture surface analysis by SEM was performed. It was observed a reduction in the fatigue strength life of Al7050-T7451 shot peened and coated.

Keywords: Fatigue, Aluminum alloy, HVOF, Shot peening

1. Introduction

In the last century, the advance of materials technology improved the aircraft industry and provided faster and lighter airplanes with lower fuel consumption. Some new products like fiber reinforced metals and titanium alloys had used its insertion reduced due to its high cost of manufacturing, qualification and perhaps an alteration in the existing production infrastructure (Williams and Starke, 2003; Immarigeon et al., 1995).

Aluminum alloys have been the best choice for commercial aircraft with a much more rapid insertion due lower manufacturing costs, low replacing risk and the use of an existing production infrastructure. The 7XXX series are the predominate alloy when strength is the primary requirement (Williams and Starke, 2003; Starke and Staley, 1996.)

In aircraft design, each component has a group of mechanical properties established on the project due to its application. For landing gear, considering its characteristics of capability to support all structure and cyclic loading during landing, the most important criteria design are high strength and fatigue (Torres and Voorwald, 2002; Nascimento et al., 2001).

Several corrosive environmental and friction forces that are imposed to landing gears usually reduce the service life. To prevent a premature wear or corrosion attack, it is common to make use of surface coatings. Hard Chromium Plating has been the process used due to its good corrosion resistance and lubricity (Trofimov and Molyar, 2002; Franco et al., 2004).

On the other hand, it is known that this process produces hexavalent chromium as residue a carcinogenic substance which will have new standards to control the daily average exposure level. In The United Stades particularly, but also in Europe, the new standards advice a value from 0,1 mg m^{-3} to 0,0005mg m^{-3}. This change will raise production costs and the hard chromium plating process will become environmentally dangerous and economically impracticable (Saharaoui et al., 2004; Fedrizzi et al., 2004).

High Velocity Oxygen Fuel (HVOF) is an alternative process that provides lower residual stress, lower porosity, lower oxide content and higher coating adhesion. Moreover, HVOF process provides a better corrosion resistance and fatigue performance than the chromium-plating (Thorpe et al., 2000; Voorwald et al.,2005).

However, it is know that brittle coatings can reduce the fatigue resistance of high strength-alloys. Shot peening is a common technique used in aircraft industry to enhance fatigue performance in that condition. The method consists in a formation of a high residual stress by plastic deformation of the surface. For aluminum alloys, with a relative softness of the surface, the intensity of peening must be controlled to avoid a poor fatigue life (Sharp et al., 1994;.McGrann et al., 1998).

The behavior of fatigue performance of 7050-T7451 aluminum alloy was researched in three conditions: base material, base material with WC 17% Co, and metal base with a pre-treatment of shot peening coated by HVOF.

2. Experimental Procedure

The vase material used in this work was the Al 7050T7451 alloy widely used in aircraft components. The chemical composition is in accordance to required standards. The fatigue experimental program was performed on axial fatigue test specimens, according to Fig. 1

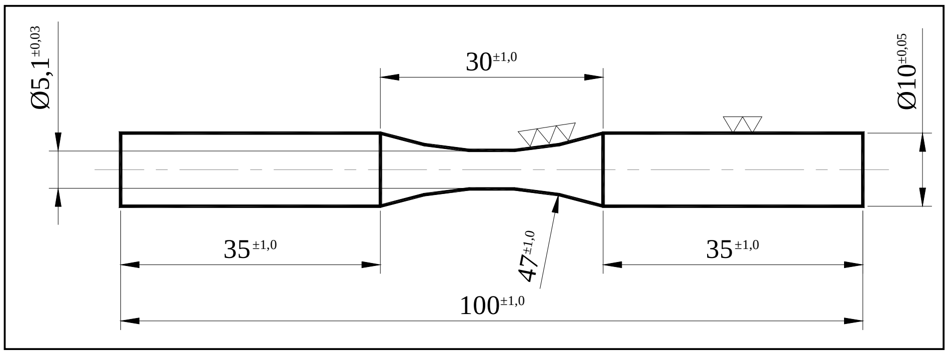

Figure 1. Axial fatigue testing specimen

Mechanical properties of Al 7050T7451 alloy are: 173 Hv. Yield tensile strength 430 MPa, and ultimate tensile strength 503 MPa. For axial fatigue tests, a sinusoidal load of 50 Hz frequency and load ratio of R = 0,1 was applied throughout this study. Three groups of fatigue specimens were prepared to obtain SxN curves for axial fatigue tests.

Tungsten carbide thermal spray coated specimens were blasted with aluminum oxide mesh 90 to enhance adhesion. Axial fatigue test specimens, indicated in table 1, were prepared according to standard ASTM E 466 (Figure 1).

Table 1. Axial fatigue tests

Specimens Number	Materials	Process	Thickness (μm)
12	Base material		
12	Base material/WC-17%Co	HVOF	150
12	Base material/shot peening/WC-17%Co	HVOF	150

The tungsten carbide thermal spray coating applied by HVOF system, used WC powder with 17%Co, resulting in thickness equal to 150 μm.

SxN curves were obtain for base metal and shot peening condition of 0,008 to 0,012N carried out on an air-blast machine according to standard SAE-AMS-S-13165.

Scanning electron microscopy technique (SEM) and optical microscopy were used to observe crack origin sites and the existance of a uniform coverage of nearly all substrate, thickness and adhesion in all the coatings.

3. Results and Discussion

Figure 2 shows axial fatigue SxN data for Al 7050T7451, Al 7050T7451/WC17%Co and Al 7050T7451/shot peening/WC17%Co.

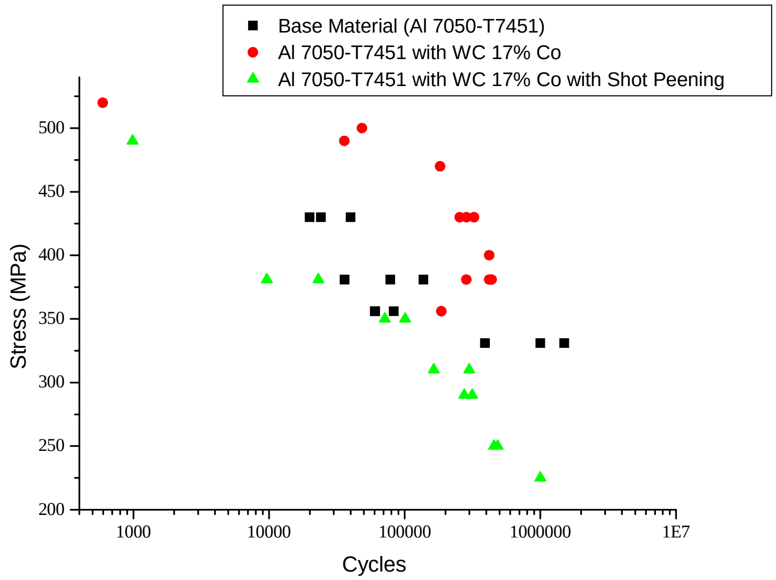

Figure 2. Axial fatigue SxN data. Base material; base material coated with WC17%Co by HVOF process and base material, shot peened and coated with WC 17%Co by HVOF process.

Analysis of the experimental results indicated in Fig. 2 revealed the significant increase in the fatigue strength of Al 7050T7451 associated with the WC17%Co coating. According to the experimental data represented in Fig. 2, a reduction in fatigue life occurred in the condition Al 7050T7451, shot peened and coated with WC 17%Co. The influence of WC17%Co and shot peening pre-treatment on fatigue strength, is more significant in high cycle than in low cycle fatigue tests. For σ_{max} equal 382 MPa average number of cycles to failure for Al7050T7451, Al 7050T7451/WC17%Co and Al 7050T7451/shot peening/WC17%Co were: 84003, 381019 and 16379 cycles, respectively.

The increase in fatigue strength for samples WC17%Co coated by HVOF in comparison to base metal may be associated to residual stresses in coating and substrate, probably tensile near coating surface and compressive around the interface coating/substrate. The base material shot peened and coated with WC17%Co applied by HVOF process presented superposition of residual internal stresses induced by HVOF thermal spray and shot peening process, which may explain reduction in fatigue life.

Figure 3 shows fracture surface of base metal axial fatigue specimens, tested at σmax = 331 MPa (number of cycle to failure N = 391000). One sees fatigue crack initiation at sample surface.

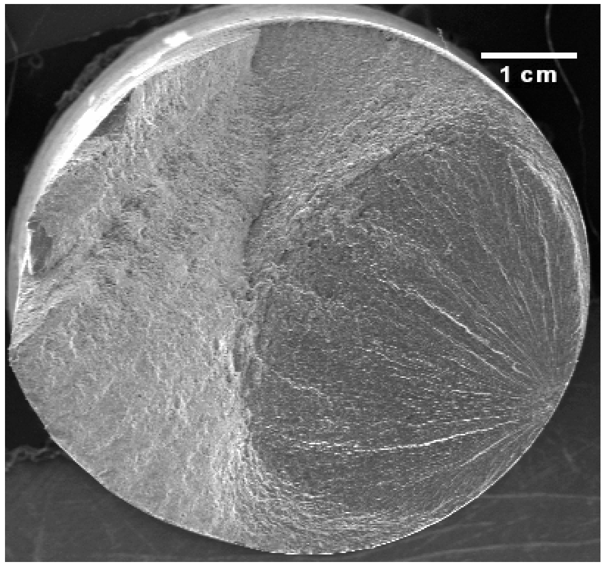

Figure 3. Fracture surface of axial fatigue specimen. Al 7050 T7451.

The fracture surface of axial fatigue specimen, WC17%Co by HVOF, 150 μm thick, is indicated in Figure 4.

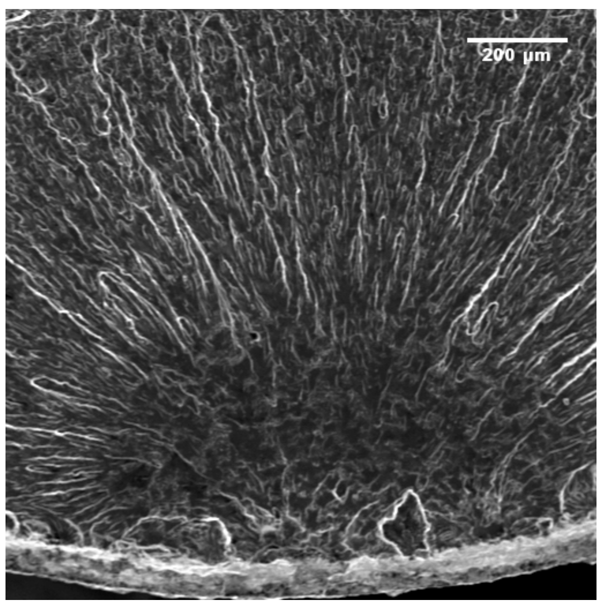

Figure 4 – Fracture surface of axial fatigue specimen. Al 7050 T7451 WC 17 % coated by HVOF process.

Analysis of Fig. 4 indicates coating homogeneity, strong interface substrate/coating and microcrack distributed along thickness in a radial shape.

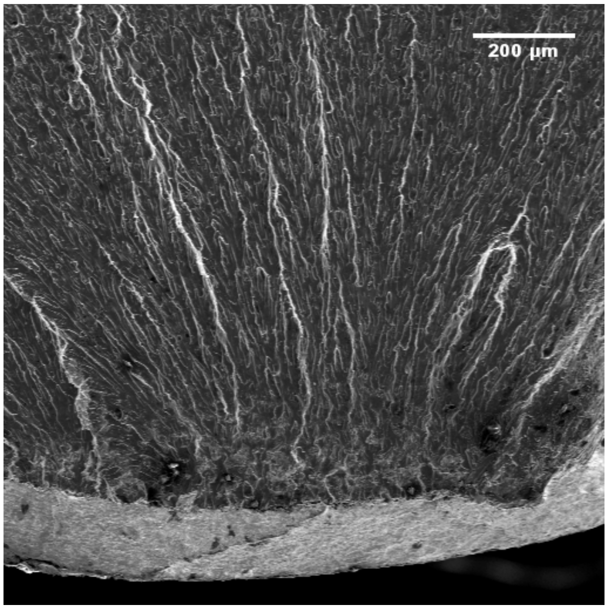

Figure 5 – Fracture surface of axial fatigue specimen. Al 7050 T7451, shot peened and WC 17% Co coated by HVOF process.

Experimental data didn't show recuperation on fatigue strength of the specimens submitted to shot peening pre-treatment. This process induces compressive residual stresses at the surface and subsurface. The depth depends on the intensity, size, material and hardness of the shot and percentage of recovering (Kobayashi et al., 1998). The interaction of compressive residual stresses contained in the WC17%Co layer with are contained at the surface of the base material, originated by the shot peening treatment did not result in an increase in fatigue life. This fact may be attributed to the compressive residual stresses superposition between them. The compressive stresses contained in a layer may generate tensile stresses at the adjacent surface. This implicates that it cannot be appropriated to combine, consecutively, coatings which contain similar residual stresses, but to alternate them through coatings with opposed residual stresses.

4. Conclusions

– WC 17%Co coating provide a significant increase in the Al7050T7451 fatigue strength due to a residual stress induced.

– The influence of WC17%Co and shot peening pre-treatment in fatigue strength is more significant in high cycle.

– The reduction in the fatigue life of base material shot peened and WC 17%Co coated by HP/HVOF process is associated to superposition of residual internal stresses.

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