

**THE EFFECT OF HARD CHROMIUM AND
ANODIZING COATINGS ON FATIGUE
CHARACTERISTICS OF 7075-T6 AL ALLOYS USED IN
AEROSPACE INDUSTRIES**

**M. HAJHASHEMI¹, N. YAZDIAN¹, M. AJABSHIRI²
and M. A. ASADABAD³**

¹Department of Materials Engineering
Isfahan University of Technology (IUT)
Isfahan, 8415683111
Iran
e-mail: m.hajhashemi@ma.iut.ac.ir

²Department of Materials Engineering
Kerman University
Kerman
Iran

³Department of Materials Engineering
Islamic Azad University
Najaf Abad Branch
Iran

Abstract

Undercarriage components encounter some drastic corrosion and abrasion faults. Therefore, to prevent the occurrence of these phenomena, applying hard-chromium coatings for steels and anodized coatings for aluminum alloys is essential. The aim of this study is to investigate the influence of common

Keywords and phrases: fatigue, interfaces, anodizing, A17075 alloy, stress-life curves.

Received October 21, 2015

surface operations in aviation industries on the fatigue behaviour of the most applicable aerospace alloys (including Al 7075-T6 alloys). Therefore, three different anodizing processes in sulphuric acid, chromic acid solutions, and hard-anodizing type were applied on aluminum alloys and their fatigue behaviour were evaluated by drawing stress-life curves. The results obtained from the stress-life curves of aluminum alloys showed that the presence of anodized coating resulted in the reduction of its fatigue life. Presence of tension stresses arising from the anodized coatings is the main reason for this decrement in fatigue strength.

1. Introduction

High tensile strength and superior fatigue resistance are important criteria in the selection of materials for aircraft undercarriage components. In fact, these structures are exposed to cyclic loads in the landing procedure. 7xxx series of aluminum alloys are the best selections for making joints in these fields [1, 2]. It is proved that corrosive environment conditions and friction forces imposed to the aircraft undercarriage lead to a reduction in its operating life. Therefore, in the existence of these deteriorating phenomena, using surface modifying and coating processes are essential to prevent any corrosion and wear in this field [3].

Seamless anodic layers in aluminum alloys act as protective layers against wear and corrosion. However, the presence of microstructural imperfections and ceramic nature of these coatings caused fatigue behaviour of these coated components to be placed in doubts. In addition, the anodic oxide coating is brittle compared to the aluminium substrate, and can easily be cracked under cyclic stresses. Cirik and Genel [4] evaluated the fatigue performance of 7075-T6 alloy for pre-corroded and non-corroded specimens and found that fatigue strength reduction can be primarily ascribed to deep micro-cracks formed during the anodizing process, the brittle nature of oxide layer and irregularities beneath the coating. Rateick et al. [5] showed that hard anodization of AA6061 and C335 aluminum alloys leads to a considerable reduction in fatigue strength and concluded that the presence of cracks in these coatings was responsible for their degradation. But they could not find any reasonable relationship between the coating thickness, residual stress and fatigue life.

With regard to these conditions, shot pining operation is always carried out before the coating process. This process has special importance in industrial components manufacturing and is widely used in order to minimize the loss of fatigue life due to the deposition process of coating. Various researches indicated that compressive residual stresses arising from superficial plastic deformation during the shot pining operation are responsible for the increment in fatigue life of the steel structures by hindering the nucleation and propagation of fatigue crack growth [6].

The aim of this study was to evaluate common coating processes on the fatigue behaviour of the 7075-T6 aluminum alloys in aerial industries. The effect of anodize coating in various electrolytic bathson the aluminum alloys has been investigated on the stress-life curve and residual stress profile in subsurface layers.

2. Experimental Procedure

Al 7075-T6 sheets used in the fatigue test were rolled and prepared according to ASTM E466 standard (Figure 1). Tensile strength and elongation percent of the alloy after the temper treatment T6 are 502MPa and 10%, respectively.

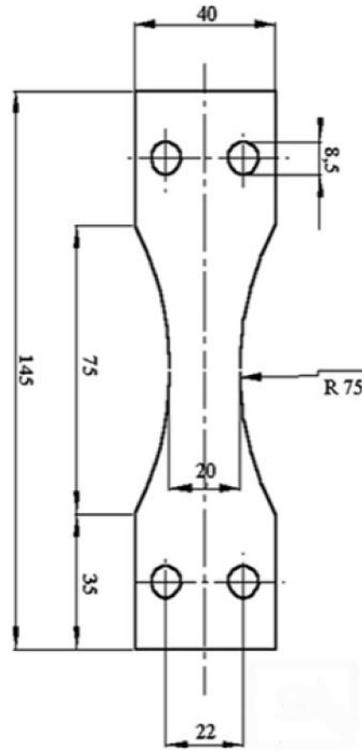


Figure 1. Sketches of the fatigue specimens employed in this study. All the dimensions are in mm.

Anodizing process was carried out on sheets in three different bath conditions. First, anodizing in sulphuric acid solution at 20–22°C and constant current density of 1.4A/dm² (coating thickness 1.4µm); second, anodizing in chromic acid solution at 40°C and constant current density of 0.3–1A/dm² (coating thickness 3.8µm); third, hard anodizing in sulphuric acid solution at –3–3°C and constant current density of 0.3–1A/dm² (coating thickness 65.1µm).

Before the coating treatment was carried out, surface of samples were placed under shot pining treatment according to MIL-13165 standard. All fatigue tests were carried out with loading mode set in the reverse

bending and sinus condition at a frequency of 25Hz and stress rate of $R = -0.1$. In order to draw the stress-life curves for each group of samples, seven fatigue tests in various stress ranges were carried out. To obtain residual stress resulting from the shot pining and anodizing, stress equipment, mounted on the X-ray diffraction system, was used. Accuracy of the measurements was equal to $\Delta\sigma = \pm 20\text{MPa}$. In order to determine the stress distribution in the thickness of the samples, layer removing from the surface was carried out by electrolytic polishing.

3. Results and Discussion

Fatigue test results related to stress-life curves for the base and anodized aluminum alloys in different solutions are shown in Figure 2. According to Figure 2, despite proper performance of anodizing in increasing wear and corrosion resistance [3], reduction in fatigue life is observed in all anodized samples in comparison to non-coated ones. This reduction is considerable in low stress domain levels: *non-plastic fatigue* (high cycle fatigue).

With regard to Figure 2, hard anodizing condition, in spite of its high hardness, stability, strength, and simultaneously good protective and decorative surface properties, has experienced the least number of cycles of fracture in comparison to all coatings. On the other hand, among all anodizing solutions, chromic acid solution has led to a coat which has the least reduction in resistance to fatigue relative to the base metal. Since the oxide coating is brittle compared to the aluminum substrate, it easily cracks under cyclic stress. As mentioned by Lee et al. [7], presence of micro cracks in sulfuric acid anodized specimens may be the main cause of this fatigue strength decrement. But, because the aluminum oxide is somewhat soluble in sulphuric acid, the oxide film is composed of a compact inner layer and a porous outer layer. Because the electrolyte seeps to the pores of the porous layer and the solubility takes place by electric field, the porous layer is thicker compared to the compact layer. The thicker the coat, the more the solubility of the compact inner film

will be. Thus, the increment in the thickness of the anodized coat will be accompanied by a decrement in the inner compact layer which causes easier growth and propagation of the cracks through the cellular structure of this outer layer.

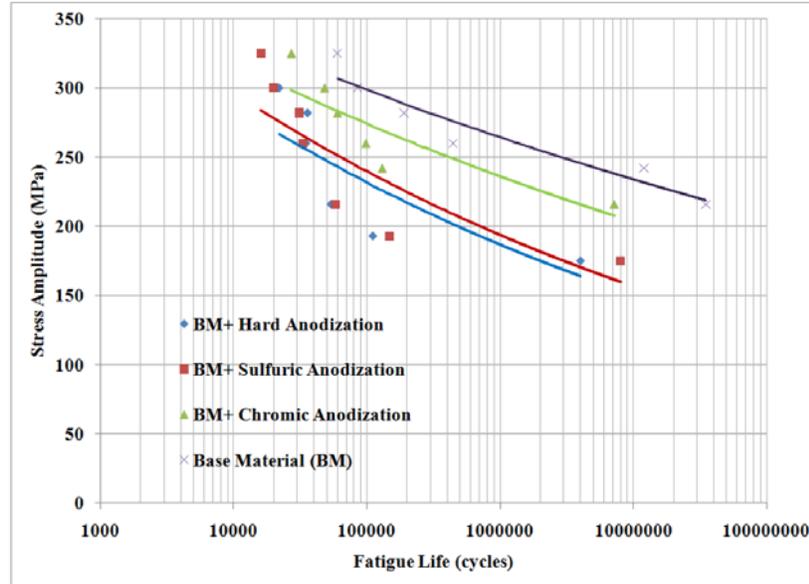


Figure 2. Number of cycles to failure (fatigue life) versus stress amplitude for the tested specimens.

Presence of tensile residual stress in the metal substrate due to the anodic coat is another key factor for the reduction in fatigue strength as was mentioned by Eifert et al. [8]. Figure 3 indicates the residual stress distribution of the samples across their thickness. According to Figure 3, it is obvious that some compressions stresses exist in 0.15mm from the surface of the samples. This can be related to the application of shot pining process before the coating treatment that induces a residual compressive stress field near the surface. However, anodized coatings depend on the solution conditions and the coating process has led to release some compressive stresses and changes in the stress arrangement near the surface in comparison to the non-coated sample. This is

especially obvious in the case of hard anodized coatings that the compressive stress near the surface has released rapidly and completely during the coating process.

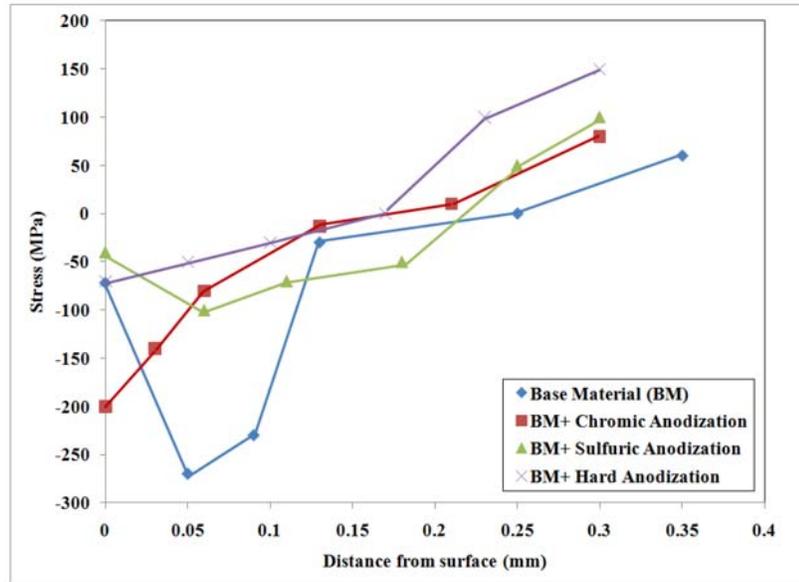


Figure 3. Axial residual stress trend for the tested specimens.

Several researches indicated that residual compressive stresses in undersurface layers are effective to prevent fatigue crack initiation or to stop fatigue crack propagation [9]. In addition, the compressive stress will reduce the tensile stress component of the fatigue test and, therefore, will reduce the rate of early crack propagation. With respect to the fact that fatigue cracks initiate and propagate in surface and subsurface layers and that the main mechanism of failure in high cycle fatigue is initiation and growth of these cracks, the formation of such stress fields in near surface areas can be effective in increasing the high cycle fatigue resistance [10]. This is in accordance with findings in Figure 2 indicating that the maximum fatigue strength was achieved as a result of compressive stress field's existence in the base metal surface. On the other hand, existence of residual tensile stresses in the interface of

coatings accelerated the crack growth in the samples [10]. This fatigue mitigation due to surface treatments like as shot pining has been reported earlier [4, 11], too.

Furthermore, as mentioned above, coating thickness is another key factor in which less degradation is observed with thinner, less porous coatings [8] and here, hard anodized coats with the highest thickness (65 micron) undergo the least fatigue cycles. In fact, ceramic nature of these anodized coatings led to micro-cracks formation in the coatings. Moreover, in metallurgical aspects, interface of the base metal/coat is considered as the weakest zone because of microstructural mismatch. Generally, the more the anodizing thickness, the more the potential of defects and irregular interface between substrate and anodized layer will be. Fatigue cracks initiate from the existing voids in the base metal/coat interface or existing micro-cracks in the brittle anodized coating.

4. Conclusion

In the present work, the effect of solution type of anodize coated specimens in terms of fatigue resistance has been investigated. Three different anodized solutions for the coating treatments were adopted in order to evaluate the influence of solution selecting in terms of fatigue performances. The main conclusions can be summarized as follows:

(1) Applying anodized coating in various electrolytic baths on Al 7075-T6 alloy surface has led to a reduction in the fatigue resistance the samples by releasing of the surface compressive stresses.

(2) Results obtained from stress-life curves showed that hard anodized coatings among other anodized coatings have minimum fatigue endurance limit.

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