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Improvement of the Impact Properties of Aluminum Alloy Through an Anodization

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Abstract: Aluminum alloys are anodized for enhanced resistance to corrosion and for the improvement of dyeing, lubrication and adhesion processes. In this research, an anodization process was carried out on AA 5356 by studying two different parameters (time and concentration of sulfuric acid). Hardness test and impact energy test were adopted to check the effect of anodizing on the alloy. The anodic layer thickness of all the specimens was measured and from the results, it was found that the thickness increased with an increasing time and sulfuric acid concentration. An increase in the time of anodizing more than 15 min and a sulfuric acid concentration of more than 5% increased the toughness of the material by about 40% and decreased the hardness by about 14%. The thickness of the anodic layer increased with an increasing electrolyte concentration more than increasing the anodizing time and this led to more decrease in the hardness.

Key words: Aluminum alloys, anodized, adhesion processes, hardness, toughness, electrolyte

INTRODUCTION

The outer surface of an aluminum component can be converted into a film of aluminum oxide through an anodization process. This process also incorporates all the constituents of an alloy into the aluminum film. An anodization process has always been used to enhance the anti-corrosion and mechanical properties of aluminum (Aryslanova *et al*., 2015; Byeon and Tzeng, 1988; Habib *et al*., 2017). Anodization is an electrochemical process which involves the conversion of aluminum into its oxide through an appropriate selection of the anodizing conditions like the voltage, temperature and current density (Kikuchi, 1985; Abdulhadi *et al*., 2017a, b). During the process, aluminum oxides are deposited on the specimen as an anodic layer such oxides have excellent properties such as good mechanical strength, chemical inertness and high hardness (Bensalah *et al*., 2007, 2008, 2010; Abdulhadi *et al*., 2017a, b). Several researchers have over the years studied the anodization of aluminum. For instance, Bensalah *et al*. (2010) have studied the formation of aluminum oxide coatings on aluminum substrates using oxalic-sulfuric acid bath. From the study they observed that the chemistry of the temperature, the anodizing electrolyte and the current density controls the mechanical properties of the formed anodic oxide layer. Similarly, Konieczny *et al*. (2008) examined the influence of the anodic treatment parameters and the casting method on the thickness, structure and properties of an anodic layer formed on aluminum casting alloys. The outcome of the study showed that the application of an oxide layer shaped the casting process and reproduced the primary surface geometry. The aim of this research is to study the effect of two anodizing parameters (variation of time and sulfuric acid concentration) on the hardness and impact energy of aluminum alloy 5356, this alloy has application in welding filler wire and nail wire.

MATERIALS AND METHODS

Experimental work: The material used in this research is AA5356 with chemical composition and mechanical properties presented in Table 1 (Hull and Abraham, 2002).

Anodizing process: An anodizing process was carried out on the eight specimens of diameter 3.2 mm and length 38 mm using four periods (15, 30, 45 and 60 min) with 10% sulfuric acid concentration. The dimensions of specimens were determined, according to, the manual related to the device. The four specimens and a control specimen (as received) with the same dimension were immersed in different concentration of sulfuric acid (5, 10, 15 and 20%) for 30 min.

Impact test: To estimate the effect of the anodizing process on the toughness of the material, the Charpy impact test was carried out on the specimens using a TE15 TQ device (Fig. 1). The fracture energy for all the specimens was recorded.

Hardness test: Hardness test was carried out on the anodized specimens using a rockwell device. The dimensions of the specimens are shown in Fig. 2.

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Table 1: Chemical composition of AA 5356

Element (%)	Si	Fe	Cu	Mn	Mg	Zn	Ti	Cr
Standard Wt.	0.25	0.4	0.10	0.05-0.2	4.5-5.5	0.10	0.06-0.2	0.05-0.20
Measured Wt.	0.2	0.38	0.88	0.22	5.25	0.12	0.08	0.19

Mechanical properties of AA 5356 Hardness: 62 HRB and tensile strength: 262a

Fig. 1: Impact test device

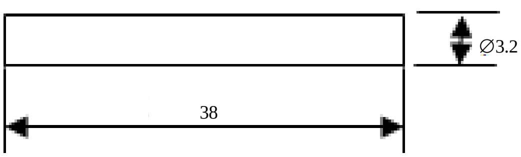

Fig. 2: Impact test specimen (dimension in mm)

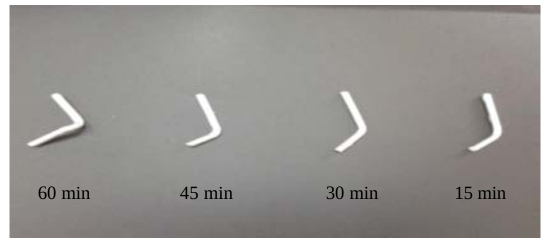

Fig. 3: Specimens treated with 10% sulfuric acid at different times after the impact test

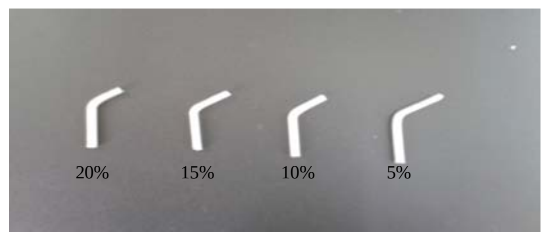

Fig. 4: Specimens treated with different concentrations of sulfuric acid for 30 min after the impact test

RESULTS AND DISCUSSION

Anodic layer thickness measurements: An optical microscope was used to measure the thickness of the formed oxide layer (Fig. 3 and 4) while Fig. 5 and 6 illustrate the oxide layers of the specimens at different sulfuric acid concentration and different anodizing periods, respectively.

Hardiness and impact: The effect of the anodizing process time on the hardness and impact energy was illustrated in Fig. 7. From Fig. 7, it was observed that the hardness and impact energy increased until 15 min anodizing time because of the formation of an oxide layer on the surface of the alloy. However, after 15 min there was a decrease in the hardness.

Figure 8 illustrated the relationship between the time and the thickness of the anodic layer. The thickness of the anodic layer increased with an increase in the time, leading to a decrease in the hardness after 15 min because of the porosity produced by the anodizing process over a prolonged time especially at the surface of the specimen. This means that the toughness of the material increased while the hardness decreased when the time of the anodizing process is prolonged. This is also attributable to the effect of the oxide layer (anodic layer) which represents the substrate's surface shape (Konieczny *et al*., 2008). Another reason could be the effect of Mg atom precipitation on the mechanical characteristics of 5xxx aluminum alloy. A high strength 5xxx aluminum alloy can be achieved through Mg atom interaction with dislocations in a process called solid-solution strengthening (Ali *et al*., 2013; Wen *et al*., 2005). So, the anodizing process can be affected in this interaction and cause a variation in the mechanical properties.

Also, the thickness of the anodic layer increases with an increasing sulfuric acid concentration during the anodizing process as shown in Fig. 9.

The effect of different concentrations of sulfuric acid on the mechanical properties (hardness and impact energy) of the specimen at a constant process time of 30 min was illustrated in Fig. 10.

The effect of sulfuric acid concentration was evidenced in the increasing impact energy and the decreasing hardness by more than 5%, meaning that the

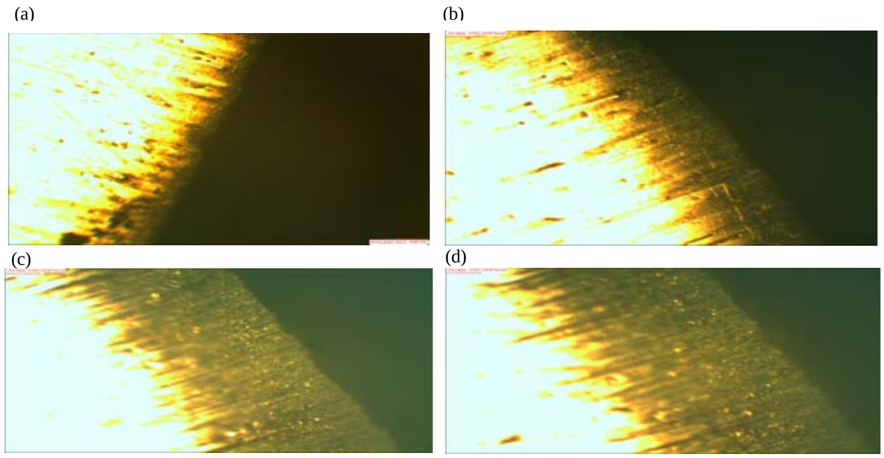

Fig. 5: a-d) Thickness of anodic layer according to, the concentration of sulfuric acid after 30 min (1 = 5, 2 = 10, 3 = 15, 4 = 20%)

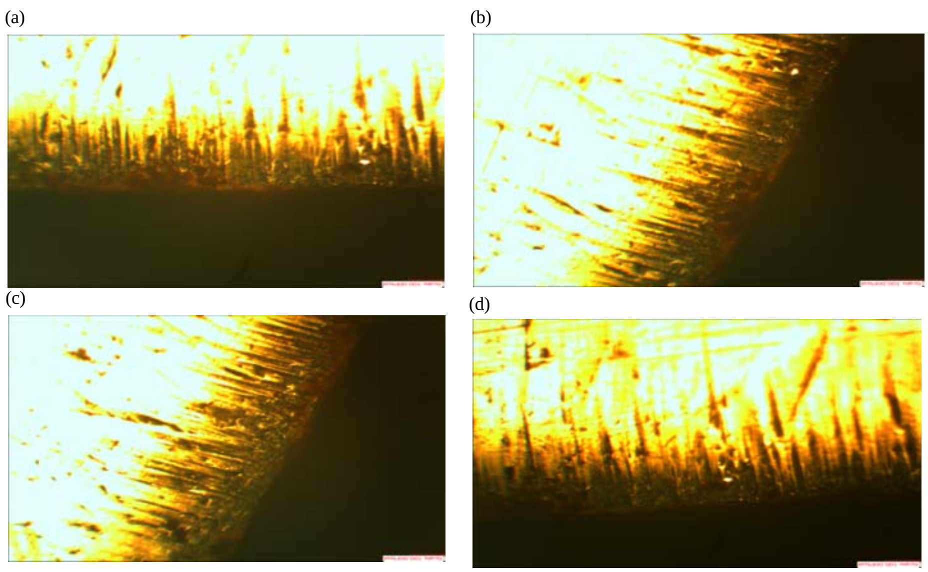

Fig. 6: a-d) Thickness of the anodic layer according to, the time of anodization process using 10% sulfuric acid conc. (1' = 15, 2' = 30, 3' = 45 and 4' = 60 min)

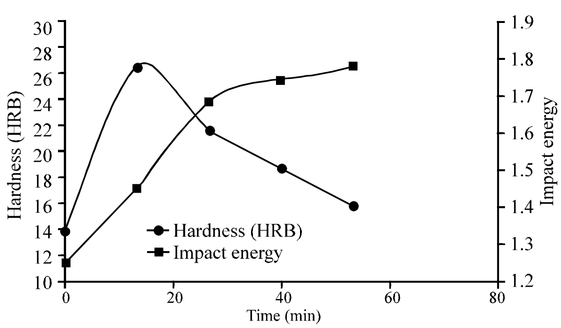

Fig. 7: The variation of hardness and impact energy with time at 10% H_2SO_4 concentration

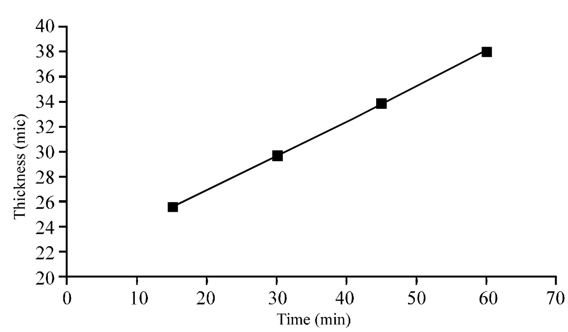

Fig. 8: The relationship between the anodic thickness layer and the process time

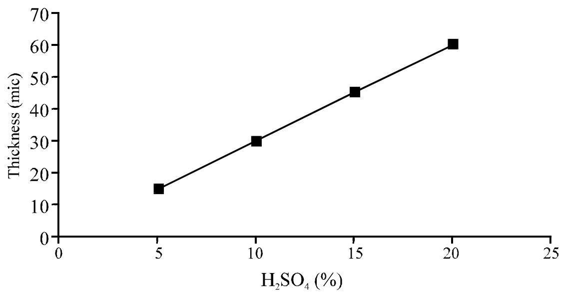

Fig. 9: The relationship between the anodic thickness layer and sulfuric acid concentration

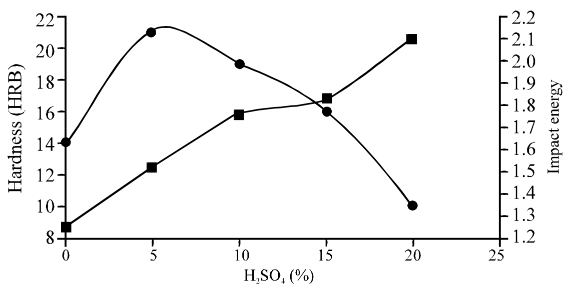

Fig. 10: The variation of hardness and impact resistance of AA 5350 with H_2SO_4 concentration within 30 min of the process time

increase of both the electrolyte acidity and the process time has a similar effect on the specimen. The main difference between the effect of time and the effect of sulfuric acid concentration on this process is the thickness of the anodic layer. The thickness is greater with an increasing sulfuric acid concentration than with increasing the process time (Fig. 8 and 9) because of the surface area which was subjected to the interaction that increases with an increasing electrolyte concentration. A higher anodic layer thickness was observed to be accompanied with a decreasing specimen hardness as shown in Fig. 10.

CONCLUSION

The anodizing process improves the mechanical properties of AA 5356 (toughness and impact strength); however, a prolonged anodizing process time of more than 15 min and a sulfuric acid concentration of more than 5% resulted in an increased toughness of AA5356 by about 40% and a decreased hardness by about 14%. The thickness of the anodic layer increased more with an increasing sulfuric acid concentration compared to an increasing process time, resulting in more decreases in the hardness of AA 5356.

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