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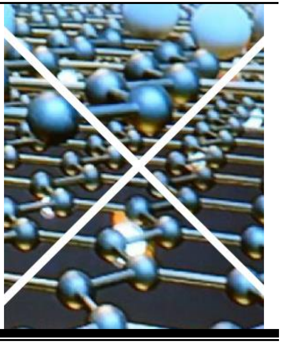

HARD ANODIC OXIDATION OF A356 ALUMINUM ALLOY

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Abstract

ASTM A356 (ISO AlSi7Mg) aluminum alloys are widely used in automotive and aircraft industries but they are selected mainly as automobiles wheel rim materials. They are composed of magnesium and silicon elements for improving corrosion and strength properties. Wheel rim materials are often electroplated by rim paints for decorative views and durability considerations. In this study; aluminum A356 alloy was coated by hard anodic oxidation method. 14 samples are prepared from an automobiles original 14 inch A356 aluminum alloy wheel rim. Samples are machined by 4x20x20 mm in dimensions for hard anodic oxidation. Three different case depths of hard anodic oxidation about 45, 65 and 90µm are applied on samples. Micro-structural investigations, micro-hardness surveys and the case depths of samples are thoroughly studied. The applicability of hard anodic oxidation method on wheel rim material A356 alloy is examined. The micro-structural surveys and micro-hardness tests proved that A356 aluminum alloy samples were hard anodic oxidized up to 90µm in coating thickness.

Keywords: Aluminum alloys, Aluminum A356 alloy, Hard Anodic Oxidation.

1. Introduction

ASTM A356 (ISO; AlSi7Mg) alloy is favorably preferred in wheel rim industries as well as aircrafts, marine, pumps, machine parts, valves, automotive transmission cases, oil pans. These alloys are composed of basically silicon and magnesium alloying elements in order to improve both corrosion and strength properties. This specialty group of premium casting alloys have restricted amounts of impurities and carefully controlled alloying elements for providing

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ductility, toughness, and tensile properties also with difficult castability. They can be heat treated. They are grouped in four types of classes according to their strength values in case of applied heat treatments [1-3].

Whether A356 aluminum alloy is used in wheel rim industries they are casted in moulds. After casting and surface fine machining they are frequently coated by rim paints for nice looking and prolongation of service life.

Wheel rims are often damaged by banquettes or sidewalks by driver faults in automobiles. Paints of commercial wheel rims are not so strong to resist with these types of hard damages.

Some classes of aluminum alloys are strengthened by heat treating techniques like precipitation hardening but they are also surface treated by case coating and hardening applications mainly as anodic oxidation. Anodic oxidation is applied for decorative and hard surface layer needs. Aluminum alloys are protected against oxidation at ambient service conditions by decorative anodic oxidation but they have been hard anodic oxidized for increasing their wear resistance. Hard anodic oxidation is mainly applied approximately within 5 to 18 µm case depths generally in sulfuric acid baths commercially [4].

In this study; main aim is to find out the applicability of hard anodic oxidation on wheel rim material produced from A356 aluminum alloy. Silicon contents more than 7% by weight in aluminum alloys is hard to be hard anodic oxidized as indicated in literature [4]. For this purpose, 14 samples are hard anodic oxidized by three different case depths as 45, 65 and 90 µm in mean values. Hence; the applicability of hard anodic oxidation on A356 alloy is thoroughly investigated.

2. Materials and Methods

The experimental material was prepared from the original 13 inch aluminum wheel rim as given in Figure 1-(a). The wheel rim was machined by band saw with coolant for preparing samples as seen in Figure 1-(b).


(a) (b)

Figure 1. (a) Original wheel rim (b) sample preparation

After samples are cut they were machined to 4x20x20mm in dimensions for hard anodic oxidation operation. 14 samples before hard anodic oxidation are given in Figure 2.

One of the samples representing the aluminum wheel rim material is analyzed for chemical composition by Amatex Spectromax argon spectrometer and the results are given in Table 1.

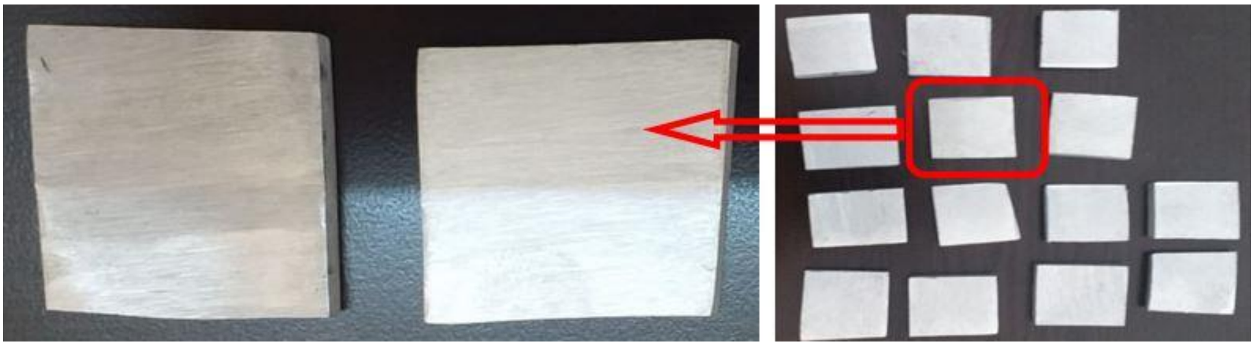


Figure 2. Samples before hard anodic oxidation

The original wheel rim material is consistent with the ASTM A356 (ISO; AlSi7Mg) aluminum alloy specifications [1, 2].

14 samples of A356 aluminum material are treated for hard anodic oxidation. Hard anodic oxidation is applied in 19% sulfuric acid bath and all samples are cleaned by both caustic soda and sand blasting. Samples are immersed in oxidation baths by 3 different holding times (45, 65 and 90 minutes of duration times in sulfuric acid baths respectively) for gaining 3 different case depths of approximately 45, 65 and 90 µm in mean values.

Micro-structural investigations are made by a metallurgical microscope and Scanning Electron Microscope (SEM) after grinding with 240µm up to 800µm emery paper and polished by 6µm diamond paste. Metallographic inspection samples are etched by $HF+HCl+HNO_3$ solution in 15 seconds of duration time via immersion method [5].

Micro-hardness survey is made in each hard anodized sample groups by EMCOTEST Durascan 20 model micro-vickers hardness testing instrument at 22°C ambient temperature under 100g load (HV0.1) [6-9].

Case depths of hard anodic oxidation layers are estimated by micro-vickers hardness surveys and micro-structural inspection methods. The micro-hardness spectrum values confirm the coating thicknesses by comparing with the core hardness.

Table 1. Spectral analysis of wheel rim material

Material	Analysis	Cu	Si	Mn	Mg	Cr	Ni	Zn	Sn	Ti	Fe	Al	Others
Original Rim	1	0.0049	7.0686	0.0073	0.2546	0.0015	0.0021	0.0376	0.0010	0.1156	0.1819	92.04	0.2849
	2	0.0019	7.0428	0.0049	0.1987	0.0013	0.0015	0.0166	0.0010	0.1230	0.1193	92.20	0.2890
A356 Alloy	ASTM ISO	<0.20	6.5-7.5	<0.10	0.25-0.45	---	---	<0.10	---	<0.20	<0.20	91.3-93.2	---

3. Results and Discussion

Samples after hard anodic oxidation treatment are given in Figure 3. The surface views of samples are homogenous and no scratch was observed on surfaces. One of the samples is uncoated.

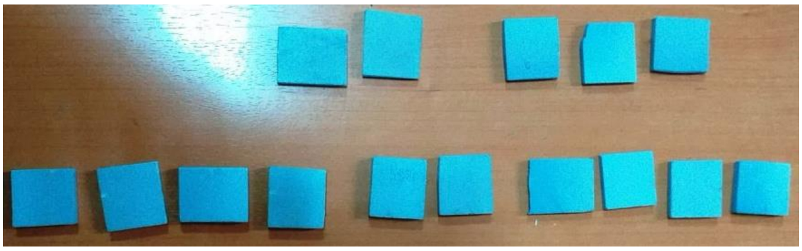
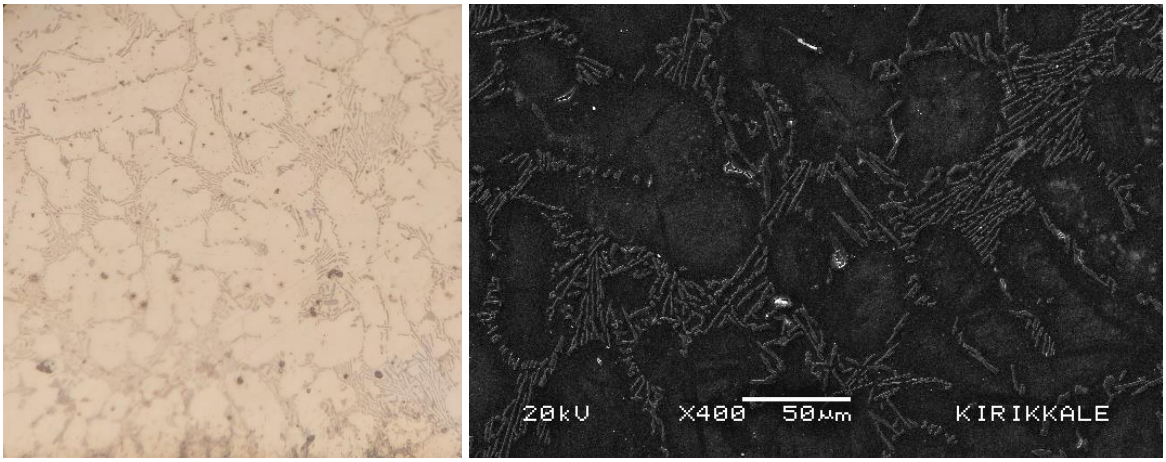


Figure 3. Samples after hard anodic oxidation

3.1. *Micro-structural Investigations*

Microstructures of raw (uncoated) aluminum A356 material are given in Figure 4. Raw material in Figure 4-(a) consists of dominant aluminum based micro-phases in lighter view and darker needle regions represents silicon based micro-precipitates (e.g. Mg_2Si) as also indicated in literature [5].

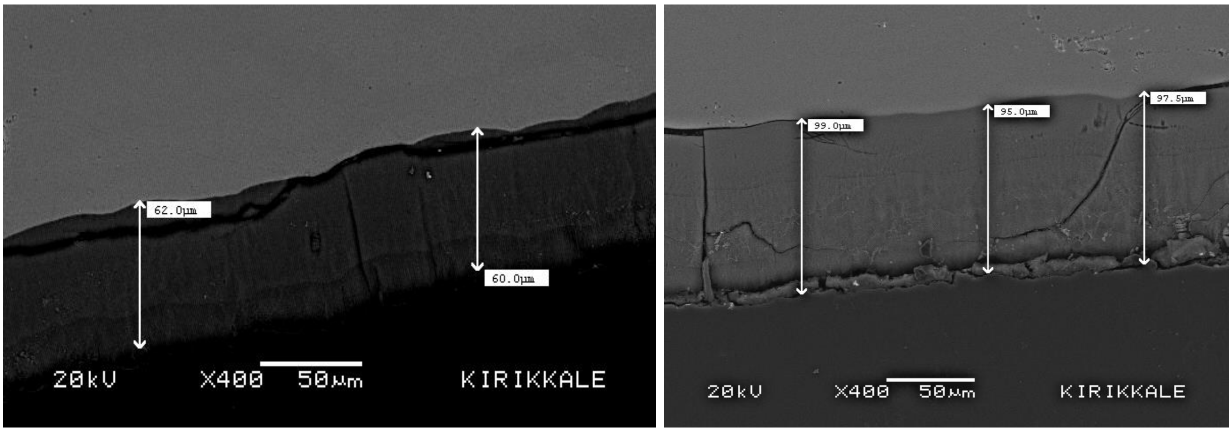
These silicon based needle like precipitates are also clearly visible in SEM images of raw A356 aluminum alloy as given in Figure 4-(b).



(a) (b)

Figure 4. Micrograph of raw A356 alloy, (a) optical microscope (b) SEM view

Microstructures of hard anodized samples are given in Figure 5. The coating layer thickness is also visible in microstructures. The coating layer seems darker than the matrix aluminum microstructure in micrographs. The hard anodic oxidized layer includes sub-surface cracks. However, these cracks are inevitable in hard anodic oxidation especially in thicker coatings [4].



(a) (b)

Figure 5. Micrographs of hard anodic oxidized samples (a) 60µm, (b) 90 µm in mean values

The case depths are estimated by micro-structural views of SEM microscope gauge as seen in Figure 5 and also confirmed from micro-vickers hardness differences of determined values.

3.2. Micro-hardness Test Results and Case Depths of Samples

Micro-vickers screen views of hard anodic oxidized samples are given in Figure 6 as examples.

3 different case depths of approximately 45, 65 and 90µm values are maintained. Case depths are measured according to micro-vickers hardness survey on samples as given in Table 2. The 3 distinct groups of hard anodic oxidized samples have approximately close values of surface micro-vickers hardness values among themselves.

The case depths are determined quite different in consequence of different bath duration times. Increasing the hard anodic oxidation operation of soaking in sulfuric acid bath times increases the coating thickness values.

Base metal core hardness was determined approximately as 60HV. The maximum case depth of samples was recorded as 90µm. The highest surface (case) hardness values are observed as 384 HV0.1 in samples having approximately 90µm coating thicknesses.

269 HV 0.025
Çap 1: 13.1 µm
Çap 2: 13.2 µm

384 HV 0.1
Çap 1: 22.4 µm
Çap 2: 21.5 µm

Figure 6. Micro-vickers screen views of hard anodic oxidized samples

As the period of soaking in sulfuric acid bath increases also the case depth of hard anodic oxidation increases as seen in Table 2. In Table 2, case depths are estimated according to micro-vickers hardness differences by comparing with the core hardness of approximately 60HV. For instance, the first samples group (Sample 1) has exhibited approximately 45µm of case depths. The maximum case hardness value is recorded from 370HV to 228HV in Sample 1. After recording the minimum micro-vickers hardness value of case region by 228 HV, a sharp hardness drop to core hardness value by 60HV is noted. Hence, the case depths of coatings are estimated also by micro-vickers hardness surveys.

There are some studies about hard anodic oxidation on Aluminum alloys [10-12]. There are also studies concerning the abrasion properties and hardening treatment of aluminum based special alloys [13,14]. But hard anodic oxidation of A356 alloys with case depths up to 90µm is not yet studied in literature.

Table 2. Micro-vickers hardness survey of samples (HV0.1)

Sample group/ (Hard Anodic oxidation bath times)	Micro-vickers surface (case) hardness values			Core Harnesses (Mean Values)	Case Depths (Mean Values)
	Test 1	Test 2	Test 3		
1 (45 minutes)	370	369	370	60	≅45µm (370→228HV)
2 (60 minutes)	369	370	371	62	≅65µm(371→227HV)
3 (90 minutes)	384	379	371	61	≅90µm(384→269HV)

4. Conclusions

Aluminum A356 wheel rim material is successfully hard anodic oxidized approximately up to 90µm in case depths in this observation.

In hard anodic oxidation operation, increasing the duration times in sulfuric acid baths increases the coating thickness values of samples. The maximum surface hardness values of 384 HV is obtained on samples with a coating thickness of 90µm by 90 minutes of duration times in sulfuric acid bath.

The raw (uncoated) A356 aluminum alloy has exhibited 60 HV micro-hardness in mean values.

This study ensured the applicability of hard anodic oxidation on A356 aluminum alloy. Since aluminum alloys containing silicon amounts more than 7% by weight is difficult to be coated by hard anodic oxidation technique. Experimental material in this study has silicon element amounts more than 7% by weight. Consequently, prolonging the usage life of wheel rim materials can be safely provided by hard anodic oxidation method.

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