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Research Article

Investigation of atmospheric corrosion of 6063 aluminium alloy in industrial environment

Emre Çankaya*, Alptuğ Tanses, İ. Artunç Sarı, Görkem Özçelik

ASAS Aluminium

*Corresponding author's email: emre.cankaya@asastr.com

Abstract

Demand for aluminium alloys is increasing day by day, especially with the electrification trend of the automotive industry. The reason for this increase lies in the advantages of aluminium such as high specific strength, low density, high recyclability and high corrosion resistance. Especially corrosion behaviour is important for aluminium parts used in structural components. High corrosion resistance in aluminium alloys stem from its natural oxide layer. Although this layer provides a certain level of corrosion resistance, it cannot completely prevent corrosion. Exclusively in industrial environment, aluminium alloys are more corroded due to the high presence of corrosive substances such as moisture, dust, dirt and chemicals. Aluminium specimens were left next to ASAŞ Aluminium anodizing facility which has air containing H_2SO_4, moisture, dust and dirt. Due to high volatile chemicals around anodization facility, this location has been selected to place the samples. To examine and compare the corrosion degrees, 3-, 6- and 12-months exposing times were selected. In this study, corrosion behaviour of the 6063 aluminium profiles placed at same zone with different waiting times in industrial environment was investigated. In order to make comparisons, samples were examined under optical microscope and SEM. At 6 months samples, the corrosion type change has been examined from pitting to IGC. This study is done in order to minimize the scrap amount causing from atmospheric corrosion after anodization of structural automotive profiles.

Keywords

Corrosion, anodised aluminium, 6063 alloy, IGC, pitting

1. Introduction

The atmospheric corrosion behaviour of aluminium alloys is well understood, thanks to decades of observance of old structures. The church of San Gioacchino is one of these observed structures. In addition, long-term corrosion tests performed open air since 1935 (especially in the marine and industrial environment) are also important in determining the corrosion behaviour of aluminium alloys [1].

Performing corrosion tests in a laboratory environment can give an idea about the corrosion behavior of the material, but in order to simulate real life, it is necessary to see its behavior in ambient conditions. Intergranular and pitting corrosion type are most popular for atmospheric environment [2-5].

Atmospheric environment is divided into 4 categories: Rural, Urban, Industrial and Marine [6].

Temperate industrial regions where this study also carried out are characterized as very strong in terms of corrosion aggression [6].

Mostafa Sliem et al. investigated the corrosion behaviour of 6082 and 6063 alloys in the Qatar region. According to the study findings, it has been observed that these alloys tend to inherit intergranular corrosion (IGC) in the industrial environment. In addition, it was stated that the chloride ions in the environment affect the pitting corrosion rate [7].

M. Merajul Haque et al. examined corrosion behaviour of galvanized steel compared with aluminium in %5 NaCl solution Fig. 1 shows the corrosion behaviour of galvanized steel and aluminium. Aluminium has a clear corrosion behaviour advantage over galvanized steel is seen here [8].

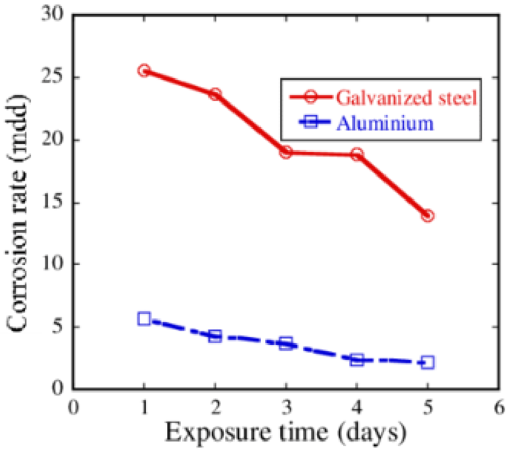

Figure 1. Corrosion behaviour of galvanized steel and aluminium [8].

Aluminium is an amphoteric metal which means it can react with both acids and bases which means it can be corroded by both this is why we have left the samples near anodization facility which contains both acids and bases. Also, Pongsaksawad, Wanida et al. have been conducted 6005A and 6082 alloy corrosion test for 18 months period [9,10].

In this study, atmospheric corrosion behaviour of 6063 alloy in the industrial environment (ASAS Aluminium production plant, Sakarya, Turkey) was investigated for 3 months, 6 months and 12 months of periods.

2. Materials and Methods

2.1. Materials

Since it is one of the most widely used 6xxx series aluminum alloy, 6063 alloy is preferred in this study.

Table 1 shows OES analysis of 6063 aluminium specimen.

Table 1. Chemical composition (wt.%) of 6063-T6 alloy.

Element	Si	Mg	Fe	Cu	Mn	Zn	Al
Weight Fraction (%)	0,50	0,55	0,17	0,01	0,02	0,01	Bal.

2.2. T6 Heat Treatment Procedures

T6 condition include solution treatment and artificial aging steps. Artificial aging temperature is 185°C, time is 5,5 hours for all specimens.

2.3. Method

Aluminium profiles have been studied for periods of 3, 6 and 12 months. The specimens were cut using a saw with oil based cooling system.

Heat treated profiles then left in the corrosive industrial environment. Aluminium specimens were exposed to atmospheric corrosion next to ASAŞ Aluminium anodizing facility. The environment which has been claimed to have has been its air analysed and in conclusion it contained H_2SO_4, and high amounts of humidity throughout the experiment.

Corroded profiles then collected in the predetermined times and after cleaning the surface of the profile, technical anodizing operation was carried out. The thickness of the anodizing layer is approximately 10 μm. In order to determine the corrosive environment's effect on the material, all specimen has been analysed under optical microscopy, Scanning Electron Microscopy (SEM). Energy Dispersive Spectrometer (EDS) analysis has also been done to the corroded spots.

3. Results and Discussion

3.1 Optical Microscope Analysis

Corroded profiles taken from facility area at 3,6 and 12 months investigated via Optical Microscope.

Fig. 2,3 and 4 show that optical microscope images of 3-6-12 months waited profiles respectively.

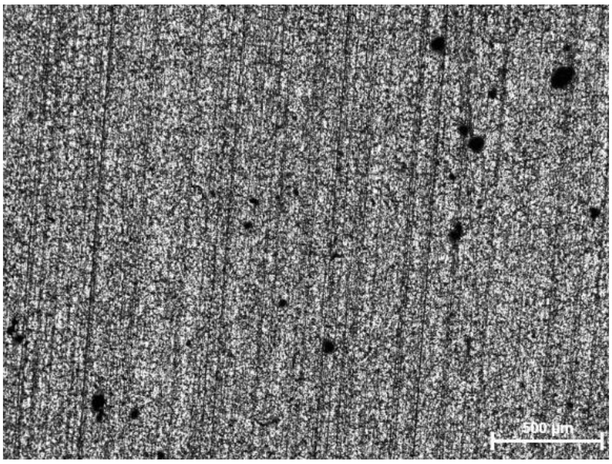

Figure 2. Optical Microscope image of 3 months waited profile (100x).

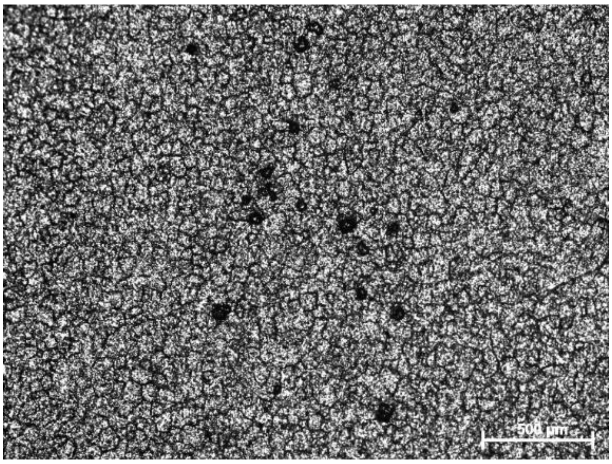

Figure 3. Optical Microscope image of 6 months waited profile (100x).

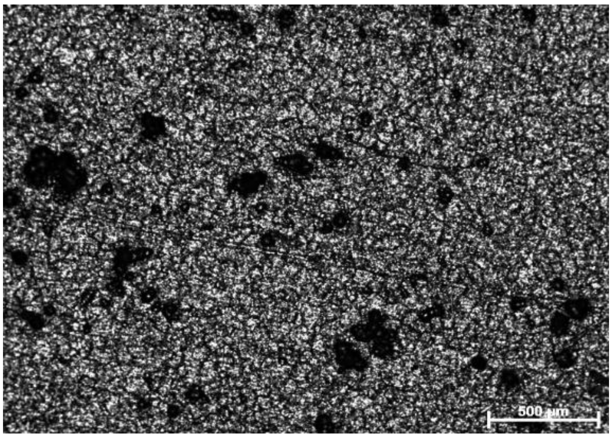

Figure 4. Optical Microscope image of 12 months waited profile (100x).

In Fig. 2 Number of pits are low and dimension are relatively small. The dominant corrosion type is pitting corrosion here. As the time progresses to 6 months, number of pits increased and also intergranular corrosion starts to damage material as seen in Fig. 3.

When the time is increased to 12 months in Fig. 4 size and number of the pits are the highest as expected. It is seen that, IGC has been progressing and weakening the material in the process.

3.2 SEM Analysis

After metallographic preparation, cross section of the sample was investigated in SEM and surface analysis was carried out in order to characterize frequency of corrosion. Fig. 5,6 and 7 show 3-6-12 months waited profiles' surface images under SEM, respectively.

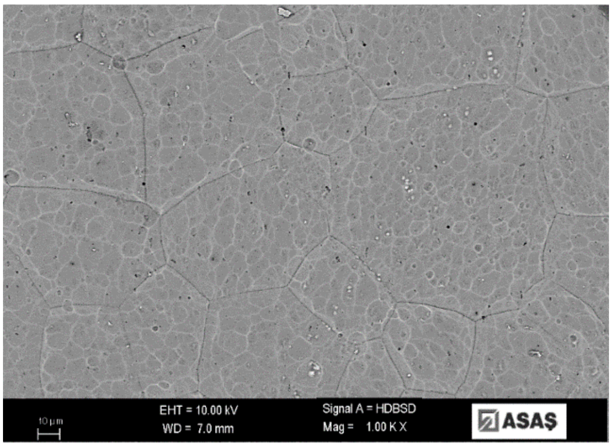

Figure 5. SEM image of 3 months waited profile (1000x).

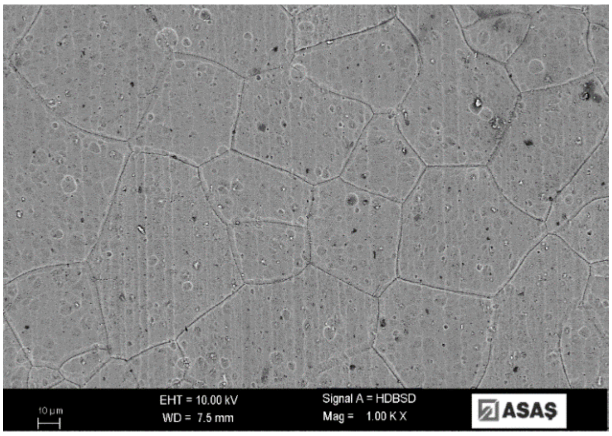

Figure 6. SEM image of 6 months waited profile (1000x).

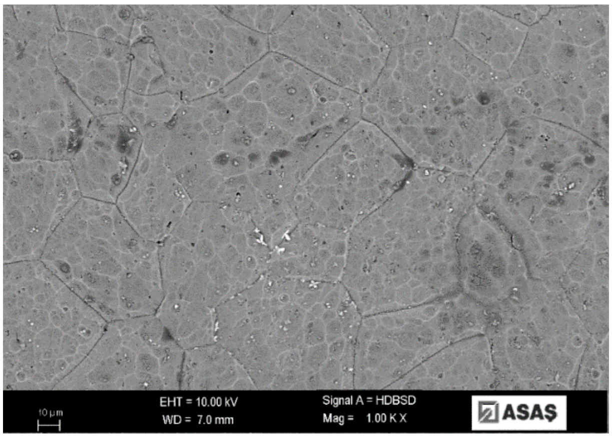

Figure 7. SEM image of 12 months waited profile (1000x).

When examined Fig. 5-7, pits are prominently visible under anodized layer and their number is increased with exposure time. As shown in Fig. 7, longer waiting time increases corrosion degree due to acid, base and humidity factors.

Fig. 8,9 and 10 show 3-6-12 months waited profiles' cross sections images under SEM, respectively.

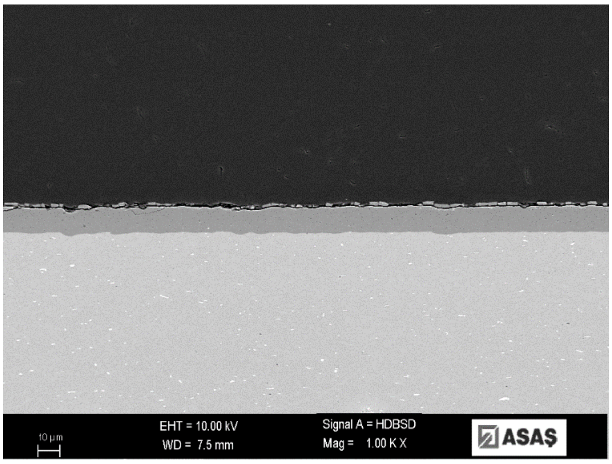

Figure 8. SEM cross section image of 3 months waited profile (1000x).

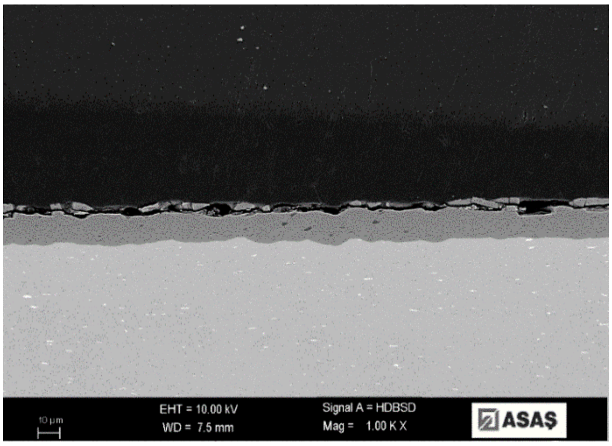

Figure 9. SEM cross section image of 6 months waited profile (1000x).

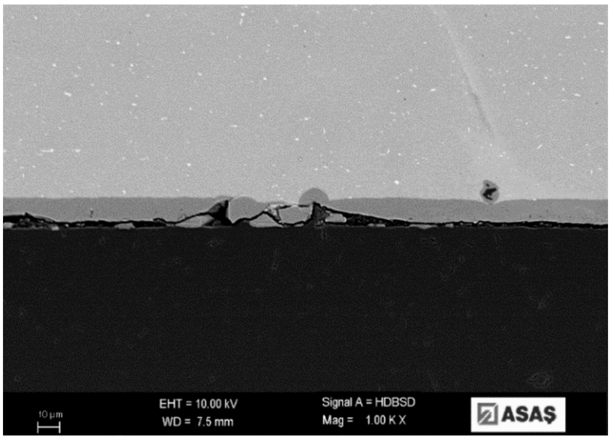

Figure 10. SEM cross section image of 12 months waited profile (1000x).

In Fig. 8-10 damage on the surface caused by pitting corrosion is observed. The deepest damage can be seen in Fig. 10 from the damage under the anodizing layer.

3.3 EDS Analysis

EDS Analysis was performed from the corrosion pit. Analysis result and selected area given in Fig. 11.

Element	Weight %	Atomic %	Error %
O K	8.29	13.49	10.63
AlK	78.85	76.07	2.82
S K	12.85	10.43	8.00

Figure 11. EDS Analysis Selected Area and Elemental Analysis Results.

In the EDS analysis taken from the corrosion pit in Fig. 11, the presence of Oxygen and Sulphur element is thought to be caused by oxidized aluminium and sulfuric acid in the environment during anodization process.

EDS Spectra of the selected zone is given in Fig. 12.

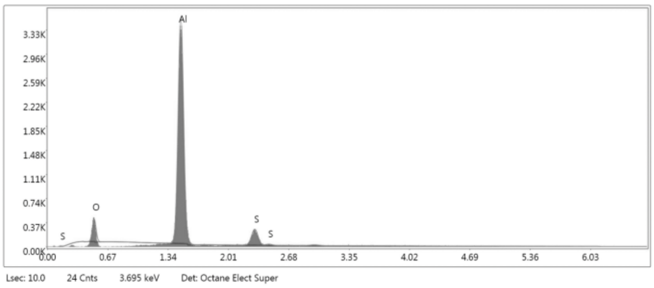

Figure 12. EDS Spectra of Selected Area.

4. Conclusion

Results obtained from this work indicate a significant effect of the atmospheric conditions and waiting time on corrosion performance of aluminium.

(1) Pitting corrosion starts after 3 months exposure to atmosphere.

(2) When exposure time is up to 6 months, pitting and IGC co-existed on the surface due to the presence of weak areas on the natural oxide layer.

(3) After exposure for 12 months, the natural aluminium oxide layer had lost its protective effect completely and IGC and pitting corrosion intensity increased during corrosion period.

Authors' Contributions

Designing and writing: Emre Çankaya; materials preparation, and characterization: Alptuğ Tanses; revision and technical support: İlyas Artunç Sari and Görkem Özçelik.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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