Corrosion behaviour of aluminium alloys EN AW-6026 and EN AW-6082 in a sulphuric acid medium

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Abstract. The corrosion behaviour of aluminium alloys EN AW-6026 and EN AW-6082 in 0.1 M and 1 M sulphuric acid solutions at different temperatures has been investigated by using gravimetric techniques and a digital microscope. The study revealed that the corrosion rate increases with higher temperature and concentration of H$_2$SO$_4$. The surface attack increased with the increasing of the concentration of sulphuric acid and the temperature. Alloys EN AW-6026 and EN AW-6082 have a higher corrosion resistance at 25 °C.

1. Introduction

Corrosion is the destructive attack on a material by reaction with its environment and the serious consequences of the corrosion process have become a problem of worldwide significance [1]. Aluminium and its alloys are widely used in engineering applications and are very reactive metals, predisposed to corrosion. They frequently come in contact with acids, such as sulphuric acid, during pickling, de-scaling or electrochemical etching of aluminium. Dilute sulphuric acid solutions, up to 10% in concentration, cause-some attack on aluminium alloys, but the action is not sufficiently rapid at room temperature in order to prevent them from being used in special applications [2].

The studied aluminium alloys EN AW-6026 and EN AW-6082 refer to the series of 6xxx alloys and magnesium and silicon are the principal alloying elements. Aluminium–magnesium–silicon wrought alloys usually show some susceptibility to intergranular corrosion. With a balanced magnesium–silicon composition that results in the formation of Mg$_2$Si constituent, the intergranular attack is minor. When the 6xxx alloy contains an excessive amount of silicon, the intergranular corrosion increases because of the strong cathodic nature of the insoluble [2]. What makes the Mg$_2$Si phase unique is that it is an ionic compound and is not only anodic to aluminium but also reactive in acidic solutions [3].

The 6xxx alloys offer moderately high strength and a very good resistance to corrosion which make these alloys extremely suitable for various structural, building, marine, machinery, and process equipment applications [3].

Most of the reported studies of corrosion have been conducted on EN AW-6082 in chloride solution [4-6] and under simulated acid rain conditions [7] but there has been little investigation into the reaction of alloy 6026 in different media.

The present work is focused on the corrosion behaviour of aluminium alloys EN AW-6026 and EN AW-6082 in 0.1M and 1M H$_2$SO$_4$ solutions at different temperatures. The study was conducted by using gravimetric techniques and a digital microscope.
2. Experiments
2.1 Gravimetric technique
One of the main methods that was used to express the corrosion rate is the measurement of weight loss per unit area and unit time.

The weight loss experiments were carried out with cylindrical samples of aluminium alloys EN AW-6026 and EN AW-6082 with an exposed area of 8.40 cm². Before immersion in the solution, the experimental samples were initially abraded with fine emery paper, washed in detergent for five minutes and then rinsed with distilled water and dried. The dried samples were weighed with an analytical balance Acculab ATILON to an accuracy of ± 0.0001g and then immersed in test solutions of 0.1 M and 1M H₂SO₄ for 4 hours. The experiments were carried out at temperatures of 25 °C and 50 °C (± 0.5 °C). After 4 hours of total time of exposure, the specimens were taken out, washed with distilled water, dried and weighed accurately.

The corrosion rate (CR), in terms of weight loss measurements, were calculated using the following equation:

\[
CR = \frac{(m_1 - m_2)}{S \cdot t} \quad (1)
\]

where \(m_1\) is the weight of the sample, g; \(m_2\) is the weight of the sample after the corrosion test, g; \(S\) is the area of the sample, m²; and \(t\) is the test time, h.

2.2. Surface analysis
The structures of the corroded and the uncorroded surfaces of EN AW-6026 and EN AW-6082 were examined with a digital microscope (Digi Micro Scope 2.0M Pixels).

3. Results and discussion
3.1. Gravimetric technique
The comparative plots of the corrosion rates versus exposure time in 0.1 M and 1 M H₂SO₄ solutions for EN AW-6026 and EN AW-6082 at 25 °C are shown in figure 1 and figure 2. Observation of the plots shows an initial increase in the corrosion rate with respect to time. During the first two hours of immersion in the solutions, the graphs reach the maximum level followed by a decrease in the corrosion rate of these alloys.

The behaviour of this process can be attributed to the formation of a protective layer on the alloy surface and the increase in the corrosion rate with respect to time. The increase in the corrosion rate ceases with the formation of a protective oxide layer [8]. The results obtained in this work also showed that in the conditions employed in the present study EN AW-6082 at 25 °C has a higher corrosion rate at both concentrations.

The corrosion rates depend strongly on other factors, such as surface state, electrolyte flow rate, geometry and temperature [9].

![Figure 1](image-url)

**Figure 1.** Corrosion rate of EN AW-6026 in 0,1M and 1M H₂SO₄ at 25 °C after 4 hours.
The corrosion rates of these alloys immersed in 0,1M and 1 M H₂SO₄ solutions at 50 °C are presented in figure 3 and figure 4. The results show that the corrosion rate increased with the increase of temperature. The aluminium alloys tested demonstrated different behaviour at 50 °C (± 0.5 °C) after the fourth hour of immersion. With the increase of the temperature in the 0,1 M H₂SO₄ solution, EN AW-6026 had a higher weight loss than EN AW-6082. At the same temperature in the 1 M H₂SO₄ solution, EN AW-6026 demonstrated a higher corrosion resistance and EN AW-6082 had a significantly higher corrosion rate in these conditions.
3.2. Surface analysis
The structures of the uncorroded surfaces of both alloys are shown in figure 5a and figure 6a, respectively.

![Figure 5](image-url) **Figure 5.** Structures of the surface of EN AW-6026: a - before immersion; b - after 4 hours of immersion in 1M H₂SO₄ at 50 °C.

![Figure 6](image-url) **Figure 6.** Structures of the surface of EN AW-6082: a - before immersion; b - after 4 hours of immersion in 1M H₂SO₄ at 50 °C.

The corrosion rate of aluminium alloys depends on the specific ions present in the solution. Furthermore, acidic medium could activate the alloy surface. When exposed to an environment with aggressive sulphate ions, the oxide layer on the alloy surface breaks down at definite places causing corrosion on the aluminium surface. The structure of the surface of both samples was changed in the presence of sulfuric acid solutions and the surface attack increased with the increasing of the temperature and the concentration of H₂SO₄. Large pits were observed on the surface of EN AW-6082 (figure 6b) with corrosion products after 4 hours of immersion in 1M H₂SO₄ at 50 °C.

4. Conclusion
From the investigation of the corrosion behaviour of aluminium–magnesium–silicon alloys can be concluded that EN AW-6082 at 25 °C is more susceptible to corrosion attack in 0.1 M and 1 M H₂SO₄ than EN AW-6026. Comparison of the corrosion rate of these alloys from the weight loss analysis showed that EN AW-6026 and EN AW-6082 both have a higher corrosion resistance at 25 °C.

The structure of the surface of both samples was changed in the presence of sulfuric acid solutions. The surface attack increased with the increasing of the temperature and the concentration of H₂SO₄.
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References
[1] Roberge P R Handbook of Corrosion Engineering (New York: McGraw-Hill Education)
[2] Wisdom J, Kelechi D and Ugochukwu J 2018 IRJET 5 121
[3] Kaufman J G 2005 Corrosion of Aluminum and Aluminum Alloys (Ohio: ASM International)
[4] Panagopoulos C, Georgiou E and Gavras A 2009 Tribology Int. 42 886
[5] Cicolin D, Trueba M and Trasattim S 2013 Electrochim. Acta. 124 27
[6] Xhanari K and Finšgar M 2017 Int. J. Electrochem. Sci. 12 5845
[7] Gerengi H, Slepski P, Ozgan E and Kurtay M 2015 Mater. and Corrosion. 66 233
[8] Tolulope R and Adeleke A 2016 J Fail. Anal. and Preven. 16 874
[9] Bardal E 2003 Corrosion and protection (London: Spring)