Computer Simulation of Electrochemical Studies of Al6061-Al2O3 Metal Matrix Composite: Effect of Heat Treatment

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Abstract. The aim of this work is to investigate the corrosion Studies of Aluminum Oxide (Al2O3) reinforced Aluminum 6061 metal matrix composites in Different Concentrations of HCl & NaCl solutions using weight loss method, Potentio-dynamic & EIS Technique. The composites have been prepared by Die-casting method. Aluminum 6061 / Al2O3 MMCs containing different sizes such as 40, 60, and 100 microns and 0, 4, and 8 weight percentages of Al2O3 particulates are casted. The corrosion characteristics of Aluminum 6061 / Al2O3 composite and the unreinforced alloy were experimentally assessed. The results indicated that corrosion rate of metal matrix composites is lower than that of matrix material Al 6061 under the corrosive atmosphere irrespective of exposure time and concentration of corrodent. Aluminum 6061 / Al2O3 composite become more corrosion resistant as the Al2O3 content is increased. This is because of the formation of stable oxide layer over the specimens. Scanning Electron Microscopy (SEM) shows the degree of attack of HCl & NaCl solution on the surface of the investigated material.

Keywords: Al6061, corrosion, Heat treatment, Metal matrix composites, SEM.

1. Introduction
Pure metals of aluminium have slight strength and we cannot employ with particular purpose wherever tough to distortion and rupture is necessary additional components are fixed to base metals for surge power. The prime mechanical properties of aluminium6061 are attained in alloying trappings and heat treatments. This stimulates the foundation of little heat hastens through line by gesture of displacement and enhance its mechanical properties [1, 2]. Commonly employed aluminium alloy for mechanical application is Al6061 due to its gorgeous wide-ranging properties those are little density, great strength, ductility toughness and conflict to fatigue, it takes stayed widely consumed in aircraft basic components and additional vastly stressed structural application [3]. Al6061 alloy is too vulnerability to stress oxidization furious. It is happening by in homogeneity of the 6061alloy and intrinsic enduring stresses connected by its invention approaches. The aims of the job are
to examine the paraphernalia of heat behaviour on the microstructure, rigidity of aluminium 6061 metal and aluminium 6061/Al2O3 MMC’s. A mixture of Al2O3 adding to aluminium6061 alloy and additional strengthening is assumed by way of imaginable funds of auxiliary progresses the mechanical properties of this 6061 alloy mainly for temperature convention. So, now this investigation the properties of heat treatment is used as a resources of cultivating the mechanical properties of aluminium 8% Al2O3 alloy. Aluminium 6061 are employed in a kind of cast and wrought systems and situation of heat treatment [4, 5].

Corrosion study of aluminium alloy AA6063-T5 was investigated in molybdate-containing NaCl solutions [6]. It was suggested that the inhibition initiation preferentially occurred over Fe-rich cathodic IMPs. The formed layer provided inhibition with an efficiency of ~90% after 4h of exposure. High efficacy of ~70% was achieved even after one week of exposure. A two-step oxidation-reduction mechanism of corrosion inhibition by aqueous molybdates was noticed.

The effect of different precipitates on the corrosion behaviour of an Al-Cu-Li alloy through quasi-in-situ transmission electron microscopy observation was studied [7]. The corrosion mode was directly influenced by the aging time, evolving from IGC to the less detrimental intra-granular corrosion. The maximum and average corrosion depths first increased and then decreased with prolonged aging time. The severe corrosion striations within the grain interior were due to the corrosion of anodic T1 phase, while the corrosion cavities were caused by cubic Al5Cu6Li2 phase.

Al-Cu-Fe alloys in the vicinity of Al6Cu20F12 have been prepared. Among these, one type of particles of a spherical shape was considered as pure cubic β phase in previous reports [8]. Additionally, there are places where the τ phase appears to have out-most layer enriched in Cu. The surface of the particles is faceted and the facets can be classified to three types according to their detailed structures. A close examination and analysis led to the conclusion that these three types are parallel to the atomic planes of {1 1 0}, {1 1 1}, and {1 0 0}, respectively.

Chemical interactions between aqueous vanadium species and aluminium alloy AA6063-T5 were investigated in vanadate-containing NaCl solutions [9]. The study suggests that a two-step mechanism of corrosion inhibition in which V+5 species are first reduced to V+4 or V+3 species above cathodic IMPs, and then oxidized to mixed-valence V+5/V+4 polymerized compounds. 

Corrosion inhibition of aluminum alloy AA6063-T5 by vanadates (NaVO3) in 0.05 M NaCl solution was investigated by electrochemical and weight loss measurements, and associated with microstructure and Volta potential data [10]. Electrochemical potentiodynamic polarization measurements indicated that the vanadates provided mixed corrosion inhibition effects, mitigating both oxygen reduction, occurring on cathodic IMPs, and anodic metal dissolution reaction, occurring on anodic sites, such as Mg5Si and interphase boundary regions. The weight loss measurements show that the inhibition efficiency decreases after long term exposure.

Cu-MoO3/g-C3N4 hybrid nano composite was developed by two step strategy of one-pot pyrolysis followed by impregnation method. The structural, phase, morphology and electronic environment of MoO3, g-C3N4 and Cu in the composite has been determined by various characterization methods [11]. The remarkably enhanced photo catalytic performance was attributed to the combined effect of the double Z-scheme mechanism and defective MoO3. In situ formation process of MoO3/g-C3N4 hybrid follows a direct Z-scheme charge transfer by generating a great number of defects at the solid-solid interface, similar to that of a conductor and offer low electric resistance.

In the present investigation focused on the corrosion properties of Alumina reinforced Al6061 alloy.

2. Methodology

2.1 Specimen Preparation

Al 6061 samples for electrochemical analysis were prepared with the dimension of 2 cm × 1 cm. The surfaces of the samples are thoroughly polished by different grade of emery papers. After getting smooth surface, samples should wash with distilled water and then with acetone and allowed to dry in air for further use. Solution preparation Solutions of hydrochloric acid medium was prepared by using...
analytical grade hydrochloric acid and double distilled water. It was standardized by potentiometric method. Hydrochloric acid of concentrations 1N was prepared by appropriate dilution.

2.2 Die Casting

Die casting method, the stable die and it is constructed with steel. The molten metal pouring into mould cavity with high pressure and high speed. It takes duplet upright platens on which boosts are located which add the die shares. In duel platen, one die platen is fixed and additional die platen is employed for released and locked die. Inserted the necessary metal into the shot sleeve and then presented into the casting die by a hydraulically-driven piston. When the metal has hardened, the mould cavity is opened, and removes the casted metal. Thus, composite materials with numerous different compositions (0, 4, and 8wt %) were attained rectangular solid shaped bars with dimension of 25mm and a length of 150mm.

3. Result and Discussion

3.1 Corrosion Test (without Heat Treatment)

| Microns | Reinforcement | Corrosion current | Corrosion Rate in mpy |
|---------|---------------|-------------------|-----------------------|
| 0       | 1.462×10⁻³   | 2.912             |
| 40      | 2.152×10⁻³   | 2.413             |
| 60      | 1.854×10⁻³   | 2.523             |
| 8       | 2.325×10⁻³   | 1.961             |
| 100     | 2.123×10⁻³   | 2.124             |

Figure 1. Difference of Corrosion Current for Al6061 with Different Particle of A₂O₃ (Without Heat Treatment)
Figure 2. Difference of Corrosion Rate for Al6061 with Different Particle of A2O3 (Without Heat Treatment)

Figure 3. Potential/V v/s Log (Current/A) (Without Heat Treatment)

Figure 4. Potential/V v/s Log (Current/A) (Without Heat Treatment)
The influence of hydrochloric acid standard taking place the corrosion amount of Al6061/Al₂O₃ alloy was deliberate by technique of tafel polarization. Potentio-dynamic division curvatures of Al6061/Al₂O₃ aluminium alloy now dissimilar deliberation of HCl standard at laboratory temperature. Corrosion constraints such by way of corrosion potential ($E_{corr}$), density of corrosion current ($i_{corr}$), slope of anodic and cathodic are gained since curves of tafel polarization technique. Outcomes are listed in table 1. The corrosion amount sprightly attained since CH software. The outcome shows the diminution in the corrosion amount with a cut in the concentration of HCl standard. The Figure 1 and 2 displays the dissimilarity of corrosion current and corrosion rate. In above graph says reinforcement increases corrosion current is increases and corrosion rate decreases. From result we can conclude 8% of 40 microns particle has a good wear properties compare to other two particles such as 60 and 100. Here we can select 8% of 40 microns particles aircraft and automobile application.

3.2. Corrosion Test (without Heat Treatment)

| Microns | reinforcement | Corrosion current | Corrosion Rate in mpy |
|---------|---------------|-------------------|-----------------------|
| 40      | 0             | $1.912 \times 10^{-3}$ | 3.162                 |
|         | 4             | $2.578 \times 10^{-3}$ | 2.762                 |
|         | 8             | $3.323 \times 10^{-3}$ | 2.562                 |
| 60      | 4             | $2.345 \times 10^{-3}$ | 2.962                 |
|         | 8             | $3.023 \times 10^{-3}$ | 2.753                 |
| 100     | 4             | $2.162 \times 10^{-3}$ | 3.155                 |
|         | 8             | $2.872 \times 10^{-3}$ | 3.012                 |
Figure 6. Difference of Corrosion Current for Al6061 with Different Particle of A$_2$O$_3$ (With Heat Treatment)

Figure 7. Difference of Corrosion Rate for Al6061 with Different Particle of A2O3 (With Heat Treatment)

Figure 8. Potential/V v/s Log (Current/A) (With Heat Treatment)
After heat treatment the influence of hydrochloric acid standard taking place the corrosion amount of Al6061/Al₂O₃ alloy was deliberate by technique of tafel polarization. Potentiodynamic division curvatures of Al6061/Al₂O₃ aluminium alloy now dissimilar deliberation of HCl standard at laboratory temperature. Corrosion constraints such by way of corrosion potential ($E_{corr}$), density of corrosion current ($i_{corr}$), slope of anodic and cathodic are gained since curves of tafel polarization technique Figure 8, 9 and 10. Outcomes are listed in table 2. The corrosion amount sprightly attained since CH software. The outcome shows the diminution in the corrosion amount with a cut in the concentration of HCl standard. The Figure 6 and 7 displays the disparity of corrosion current and corrosion rate. By way of a percentage of reinforcement increases the corrosion current also increases, as the size of the reinforcement increases the corrosion current decreases. Then, as a percentage of reinforcement growths the corrosion amount decreases as the size of the particulate increases the corrosion rate increases, this is happened due to creation of oxide film going on the apparent of the components.
Oxide layer Formula,

\[ \text{Al}^+ (\text{OH})_2 = \text{Al} (\text{OH})_2 \]

Where,

\[ \text{Al} = \text{Aluminum} \]
\[ (\text{OH})_2 = \text{Hydracids ions} \]
\[ \text{Al} (\text{OH})_2 = \text{Aluminum Hydracids} \]

In above graph says reinforcement increases corrosion current is increases and corrosion rate decreases. From result we can conclude 8% of 40 microns particle has a good wear properties compare to other two particles such as 60 and 100. Here we can select 8% of 40 microns particles aircraft and automobile application.

### 3.3 SEM Analysis

Scanning electron microscopy (SEM) pictures of the Al6061 alloy previously corrosion trial and reinforcement Al\(_2\)O\(_3\) elements are exposed in picture respectively. The Corrosive performance of Al6061 composites SEM pictures of Al6061 matrix alloy with Al\(_2\)O\(_3\) (0, 4 and 8wt %) composites occupied later polarization trainings in decinormal chloride standard, later common pre-treatment, are existing in pictures. A relationship of the SEM pictures of the models formerly and later the polarization trainings obviously shows simple exterior worsening because of pitting corrosion in all the models. Pitting predisposition intended for aluminum alloys is predominantly affected through the micro structural heterogeneity of these alloys. The reduction in corrosion worsening of composites can be accredited to matrix-reinforcement boundary grit development of micro or sub-micron local cubicles on the metal surface.

![SEM Picture](image_url)

a) Without Heat Treatment (8wt %)
b) With Heat Treatment (8wt %)

**Figure 11.** SEM Photographs of Al6061 -Al2O3 Matrix

4. Conclusion
The corrosion performance of Al6061/Al2O3 alloy in dissimilar concentrations of HCl solutions was researched by potentiodynamic technique. Al6061/ Al2O3 alloy undergoes corrosion in HCl medium. The corrosion rate reduces with reduces in the concentration of HCl solution. Corrosion current enhances with enhance in concentration of hydrochloric acid. SEM images shows that as the concentration of HCl solution enhances, formation of pits on the Al6061/ Al2O3 sample also enhances. A reduction in the corrosion rate by reducing the formation of pits on the surface was noticed upon heat treatment. Interaction between both the phases increases the corrosion resistance of the composite material. The material developed in the present investigation exhibits better corrosion resistance compared to other composites reported in literature.

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