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Study Corrosion Behavior of Alumina Particulate / (AA6061) Aluminum Metal Matrix Composite In Marine Environment

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Abstract

In the present investigation, the static electrochemical corrosion behaviour of (AA6061) Al/Al_2O_3 composites in Marine (3.5% NaCl) Environment solution was evaluated. The composites were fabricated using liquid metallurgy. The effect of weight percentage (3%, 6%, 9% & 12%) on the corrosion behaviour of composites was investigated. The corrosion rates of composites were calculated using electrochemical method. The results showed that Al/Al_2O_3 composites have lower corrosion resistance than (AA6061) Aluminium.
The corrosion rate was increased by increasing of weight percentage of the alumina particles. Optical microscope were carried out to identify the corroded surface.
Keywords: (AA6061) Aluminium alloy, alumina (Al_2O_3)particles, potentiostatic measurements, Marine (3.5% NaCl) Environment, liquid metallurgy, Corrosion rate.

1.Introduction

Aluminum-based metal matrix composites (MMCs) become attractive for the automotive and aerospace industries when a lightweight and near-net-shape component is desired. Aluminum-based MMCs are well known for their high wear resistance, improved elevated temperatures tensile and fatigue strengths[1]. The mechanical and tribological characteristics of MMCs have been extensively studied, while corrosion characteristics are increasing importance as MMCs become candidates for use in specific components subjected to corrosive media. Generally, the corrosion resistance of aluminum-based MMCs is less than the monolithic alloys, due to several reasons such as the crevices at the matrix/reinforcement interface, manufacturing defects, internal stress, microstructural differences and galvanic effects due to coupling of the matrix and reinforcement [2-4]. The composites were produced by stir casting are easier to produce and are compatible with further processing such as machining, welding and deformation [5,6]. Aluminium matrix composites, an epitome of metal matrix composites have been given much attention by researchers due to the lightweight, high strenrgth, ductility, low melting point and corrosion resistance offered by aluminium alloys [7,8]. As a result, they have been used extensively in aerospace, automotive, recreational and marine industries. The application of these materials in the marine industries exposes the materials to chloride ions which could attack and deplete the materials [9].

The aim of study

In the present work, (AA6061) Al/Al_2O_3 metal matrix composites containing various weight percentages are used to study the corrosion behavior in Marine (3.5% NaCl) Environment by potentiostat and at scan rate 3 $mV.sec^{-1}$. Optical microscope were carried out to identify the corroded surface.

2. Experimental procedure

2.1 Materials

Metal matrix composites containing various weight percentages (0,3,6,9&12) of α- alumina particles were produced by liquid metallurgy technique. For the production of MMCs, (AA6061) aluminum alloy used as matrix material while

Al_2O_3 particles with an average size of 25 µm used as reinforcement. The chemical composition of aluminium alloy (AA 6061) is shown in table 1[10].

2.2 Composite preparation

A liquid metallurgy technique has been adopted to fabricate the cast composites.
Preheating of Alumina mixture at 750°C was done for one hour to remove moisture and gases from the surface of the particulates [11]. The stirrer speed lowered vertically up to 3 cm from the bottom of the crucible. The speed of the stirrer was gradually raised to 800 rpm the preheated Alumina particle powder was added (3%, 6% , 9% and 12%) with a spoon at the rate of 10- 20g/min into the melt. After the addition of Alumina powder, stirring was continued for 10 min. get better distribution. The melt was kept in the crucible for one minute in static condition, The slag were removed and Aluminium melt poured in the graphite moulds.

2.3 Polarization measurements

All experiments were carried out in 500 ml of test solution by using a three electrode cell with saturated calomel electrode (SCE) as a reference, platinum electrode as counter electrode and the cylindrical specimens of the alloy with active flat disc of 0.78 cm^2 as the working electrode. All the values of potential are therefore referred to the SCE. Finely polished composite and base alloy specimens were exposed to corrosion medium and allowed to establish asteady stat open circuit potentially, Followed by polarization measurements at a scan rate of 3 mV/s for Tafel plots. Fig. (2) Shows the experimental set up for electrochemical measurement.

The values of corrosion current density (i_{corr}) were obtained from the point of intersection of both linear parts of the anodic and cathodic polarization curves with the stationary corrosion potential (E_{corr}).

Corrosion rate can be calculate by using following equation [12]:

$$\text{Corrosion rate (mm/y)} = \frac{3.27 \times 10^{-3} \times i_{corr} \times EW}{\rho} \quad \text{....(1)}$$

Where , i_{corr} (in µA/cm2) is the corrosion current density, EW (in g) is the equivalent weight of the corroding species, and ρ (in g/ cm^3) is the density of the corroding species.

2.3 Optical Microscopic

The specimens were etched by etchant reagent used for aluminum (killers' reagent (composition: 95ml water, 2.5ml HNO_3, 1.5ml HCL, 1.0ml HF)), the regent stay on the specimen surface for 10 second then clean by water and dry.

3. Results And Discussion

3.1 Corrosion Behavior in Marine (3.5% NaCl) Environment

The corrosion parameters of (AA6061) aluminum alloy and its composites in Marine (3.5% NaCl) Environment are given in Table 2 .

It can be observed from the polarization curves in figures (3) to (7) and table (2) that the corrosion current density (i_{corr}) values and the corrosion rate increase with increase in Al_2O content in the composites due to presence of pitting corrosion was observed in the composites. The presence of reinforcement in the matrix increases cathode to anode ration in the composites, resulting in the formation of pits during localized corrosion the pitting effect was more pronounced in solutions containing Cl- ions.

4. Microstructure

The microstructure of as polished (AA6061) aluminum alloy and Al/Al_2O_3 composites with (3,6,9 & 12) weight percentage before and after corrosion are shown in Fig.(8) and Fig. (9) . Etching in Keller's reagent did not reveal additional contrast. Alumina particles appear darker than the aluminum matrix so the alumina particles are homogeneously distributed.

5. Conclusions

According to results obtained from the current investigation, the following conclusions can be pointed out:

5.1 Corrosion current values (i_{corr}) increase with increase in Al_2O_3 content in the composites for Marine (3.5% NaCl) Environment.

5.2 The composites with 3% Al_2O_3 exhibited slightly superior corrosion resistance than the composites in Marine (3.5%NaCl) Environment.

5.3 The microstructure of (AA6061) aluminum alloy reinforced with alumina particles seem to be distributed homogeneously except some clusters, before and after corrosion.

دراسة سلوك التاكل للمواد المتراكبة المعدنية ذات اساس المنيوم (AA6061) المقواة بدقائق الالومينا في الظروف البحرية

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المستخلص :
تم في هذا البحث تقييم سلوك التاكل الكهروكيمياوي الساكن لسبيكة المنيوم (AA 6061المقواة بدقائق من الالومينا في الظروف البحرية (3.5% كلوريد الصوديوم) . حضرت المواد المتراكبة بتقنية ميتالورجيا الحالة السائلة حيث تم دراسة تأثير النسب الوزنية للدقائق (3% و 6% و 9% و 12%) على سلوك التاكل . وقد تم حساب معدلات التاكل بالطريقة الكهروكيميائية. اظهرت النتائج ان المادة المتراكبة المنيوم المقواة بدقائق الالومينا تبدي اقل مقاومة تاكل مقارنة مع سبيكة الالمنيوم الاساس (AA6061)،ووجد ان معدل التاكل يزداد مع زيادة النسب الوزنية لدقائق الالومينا . وقد استخدم المجهر الضوئي لمعرفة السطح المتاكل.

الكلمات المفتاحية : سبيكة الالمنيوم (AA6061) ، دقائق الالومينا ، قياسات المجهاد الساكن ،الظروف البحرية (3.5% كلوريد الصوديوم) ، ميتالورجيا الحالة السائلة ، معدل التاكل.

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Table 1: The composition of aluminium alloy (AA 6061)

Element	Cu%	Si %	Mg%	Cr%	Fe%	Mn%	Al %
Composition (wt.%)	0.25	0.62	0.92	0.22	0.23	0.03	Balance

Table 2 : Corrosion parameters of (AA6061) aluminum alloy and its composites in Marine (3.5% NaCl) Environment

Composite (AA6061)Al/Al_2O_3	Marine (3.5% NaCl) Environment		
	i_{corr} (μA/cm^2	E_{corr} (mV)	Corrosion Rate (mm/y)
0%	2.19	-613.1	0.0219
3%	4.12	-611.3	0.0412
6%	5.23	-627.0	0.0523
9%	5.63	-741.8	0.0563
12%	10.03	-978.1	0.1003

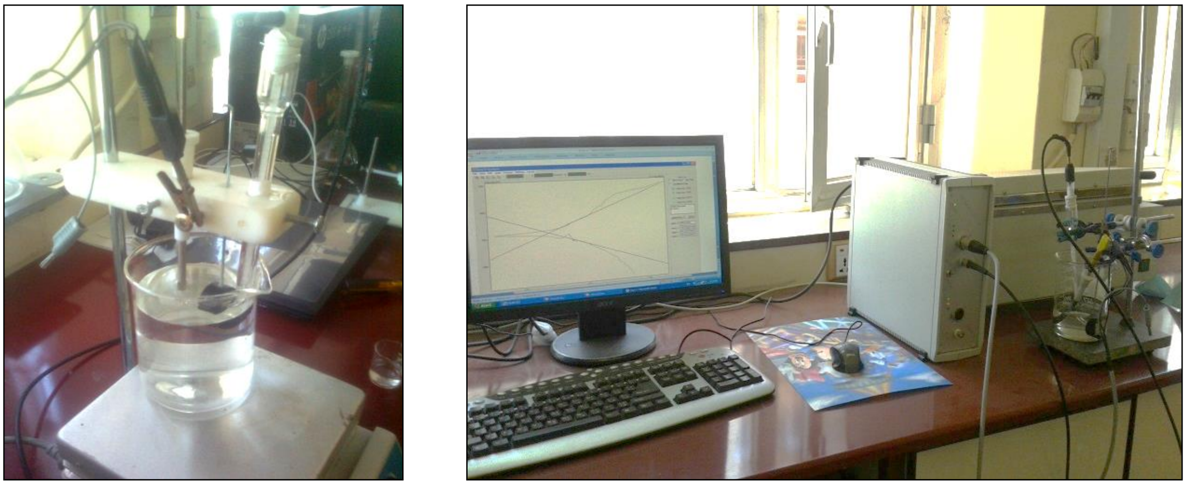


Figure 2 : Experimental set up for electrochemical measurement.

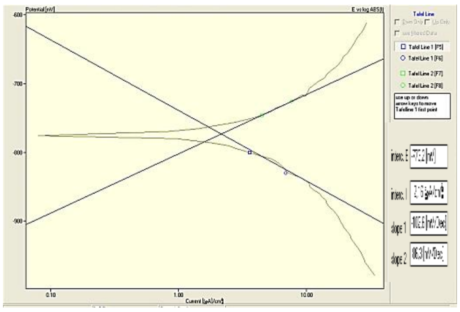


Fig. 3 : Polarization curves for (AA6061) aluminum alloy in Marine (3.5% NaCl) Environment.

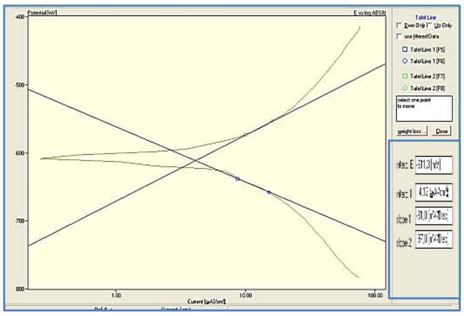


Fig. 4 : Polarization curves for (AA6061) Al /3% Al_2O_3 composite in Marine (3.5% NaCl) Environment.

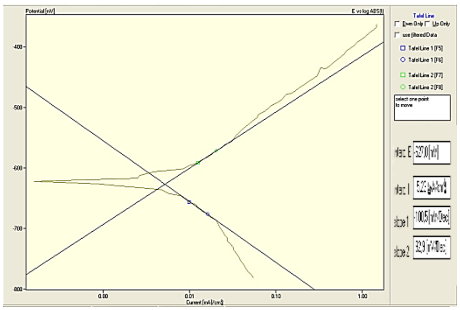


Fig. 5 : Polarization curves for (AA6061) Al /6% Al_2O_3 composite in Marine (3.5% NaCl) Environment.

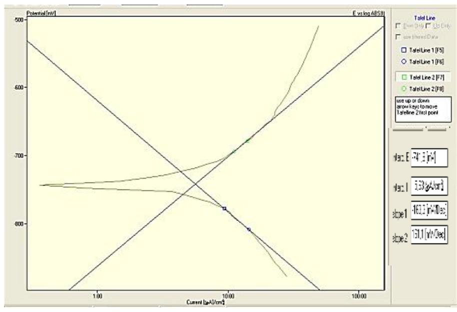


Fig. 6 : Polarization curves for (AA6061) Al /9% Al_2O_3 composite in Marine (3.5% NaCl) Environment.

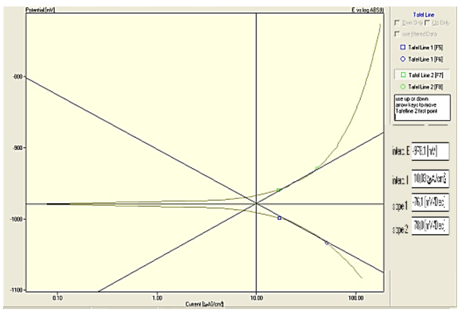
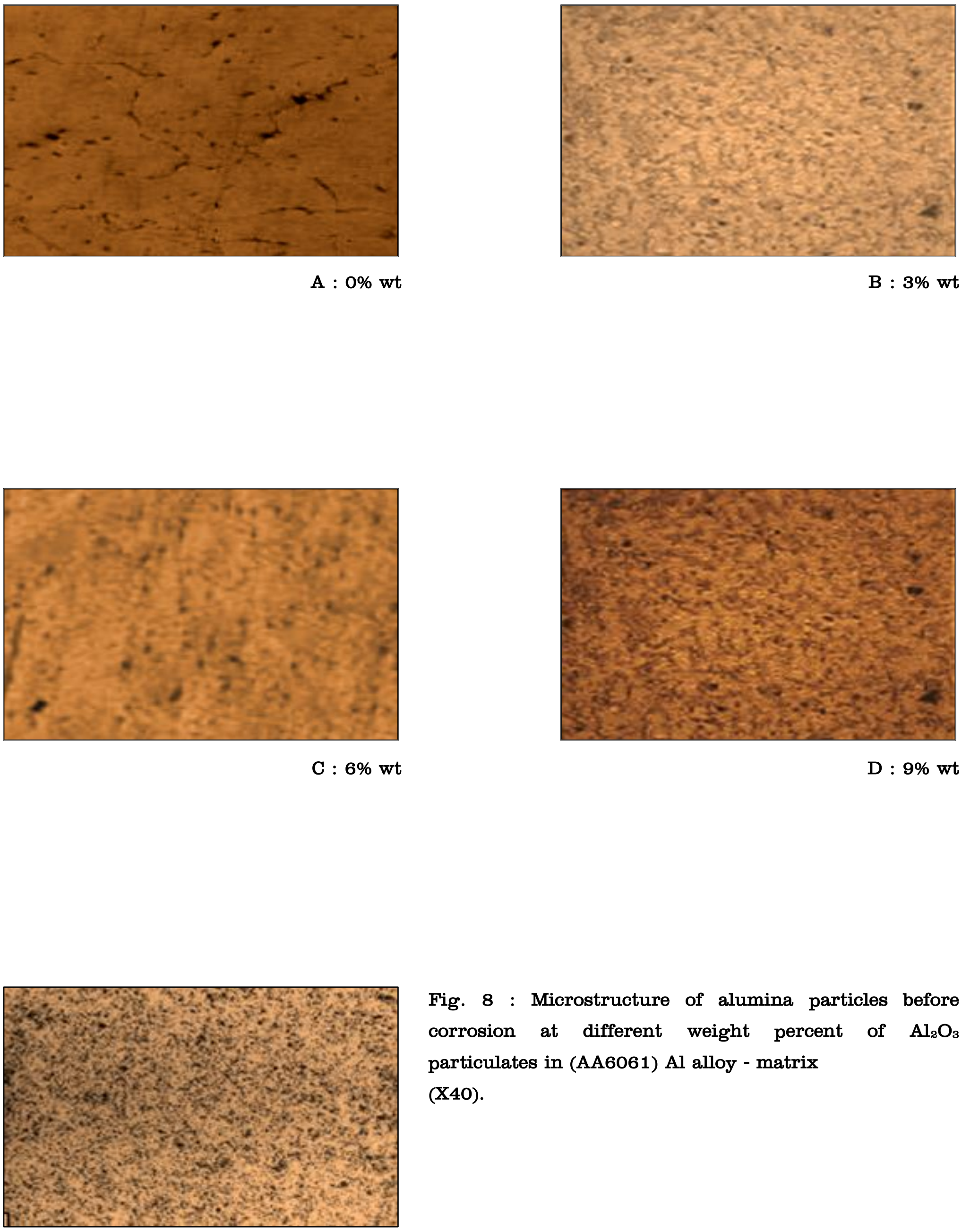


Fig. 7 : Polarization curves for (AA6061) Al /12% Al_2O_3 composite in Marine (3.5% NaCl) Environment.



A : 0% wt

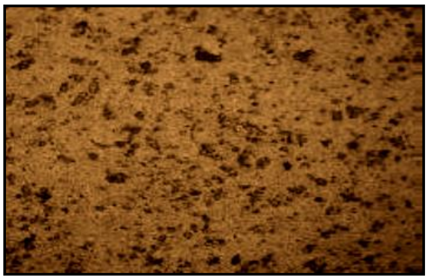
B : 3% wt

C : 6% wt

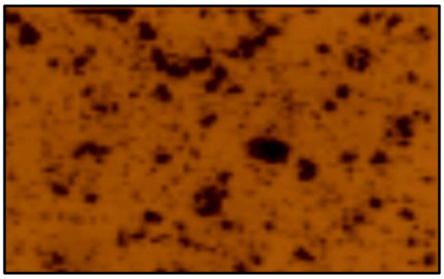
D : 9% wt

E : 12% wt

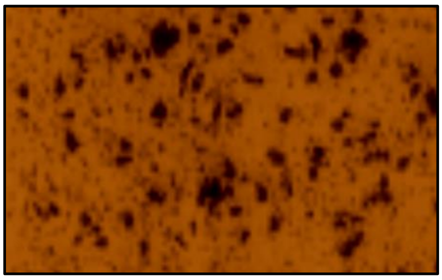
Fig. 8 : Microstructure of alumina particles before corrosion at different weight percent of Al_2O_3 particulates in (AA6061) Al alloy - matrix (X40).



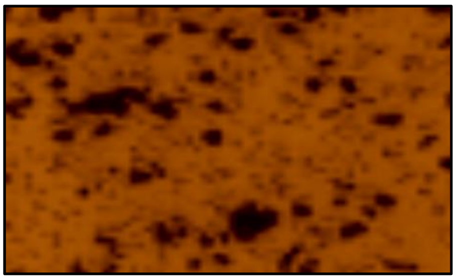
A : 0% wt



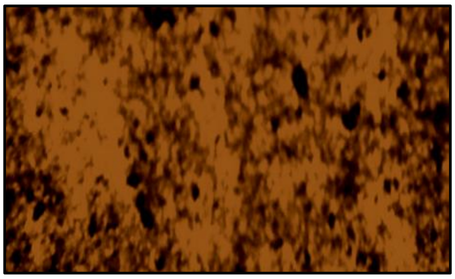
B : 3% wt



C : 6% wt



D : 9% wt



E : 12% wt

Fig.9 : Microstructure of alumina particles after corrosion at different weight percent of Al_2O_3 particulates in (AA6061) Al alloy- matrix (X40),