



CORROSION BEHAVIOR OF ALUMINUM ALLOY MATRIX REINFORCED BY ALUMINA COMPOSITE

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ABSTRACT

The influence of reinforcement (10%Al₂O₃) on the corrosion behaviour of aluminum alloy (Al-3%Mg) was studied in 3.5% NaCl, 1% HCl and 2.5% HCl. The corrosion damage in composite material and aluminum alloy was compared; the composite material had more corrosion rates than aluminum alloy. The corrosion rates increased with the increase in concentration of acid, the corrosion rates were higher in acid medium than salt medium. The behavior of composite material is similar to aluminum alloy with change corrosion solution. Microscopic examination show more pits in composite material where pitting corrosion had great influence on increasing the corrosion rates of composite material especially at the interface between the reinforcement and the matrix alloy.

Keywords: aluminum alloy matrix, composite, corrosion

سلوك التآكل في المتراكبات ذات الأساس من سبيكة الألمنيوم المقواة بالالومينا

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الخلاصة

تأثير التقوية ١٠% الومنيا على سلوك التآكل لسبيكة الألمنيوم (المنيوم - ٣% مغنيسيوم) درست في محاليل ٣.٥% كلوريد الصوديوم، ١% حامض الهيدروكلوريك و ٢.٥% حامض الهيدروكلوريك. وتمت مقارنة ضرر التآكل لكلا المادتين (سبيكة الأساس، المادة المتراكبة) من النتائج أظهرت المادة المتراكبة معدلات تآكل أعلى من سبيكة الألمنيوم وان معدل التآكل يزداد مع ازدياد تركيز الحامض كما بينت النتائج بأن معدلات التآكل في الحامض أعلى من الملح. سلوك المادة المتراكبة يكون مشابه لسلوك سبيكة الأساس مع تغيير محلول التآكل. من فحوصات البنية المجهرية تبين إن المادة المتراكبة أكثر تتقر حيث أن التآكل الأنقري يلعب دور كبير في زيادة معدلات التآكل وخصوصاً عند السطح البيني بين مادة التقوية وسبيكة الأساس.

Introduction

Metal matrix composites are a class of materials that seek to combine the high strength and stiffness of a ceramic with the damage tolerance and toughness provided by a metal matrix. Additional improvement such as enhanced wear resistance and improved high temperature capability may also be obtained. Metal matrix composite was first produced for aerospace applications, where a high cost of manufacture could be justified. However, advances in metal matrix composite manufacturing have led to their being considered for applications in the automotive industry and other industrial applications where high strength and stiffness combined with low density and good wear resistance are required [Tanya M. and *et al.* 2000]. Replacement of such current aluminum, titanium or steel structures by low cost composites offers the potential of significant weight and cost saving ,for these reasons, efforts were initiated to assess the potential of applying low cost aluminum matrix composites to these structure [David L. and *et al.* 1985] .

Casting of metal matrix composites is an attractive processing method since it is relatively inexpensive and offers a wide selection of materials and processing conditions, a method to enhance despire alumina particle in aluminum base alloy casting using magnesium additions to the melt prior to introduction of alumina particles[B.C.PAI and *et al.*1976] .

Corrosion is the deterioration of materials by chemical interaction with their environments. The term corrosion is sometimes also applied to the degradation of plastics , concrete and wood ,but generally refers to metals.[Jamal M. Ali and *et al* 2009] The resistance of particle reinforced MMCs to environmental attack is a critical design criterion. Several studies have indicated that the corrosion resistance of particle-reinforced composites depends on the composition of the base alloy, reinforcing particles, and corrosive environment. Other factors include the fabrication routes for the composites, volume fraction of the reinforcing particles, and the temperature of the corrosive medium..

Feng et al. investigated the pitting corrosion behavior of SiC /Al 2024 composites and attributed the intense corrosion of the composites to pit nucleation and propagation at the SiC/Al interface. Interfacial reactions between liquid aluminum and SiC generated intermetallic particles which formed micro galvanic couples with the matrix [Emenike Raymond Obi 2008].

S. L. Coleman, and et al 1994 Studied the corrosion characteristics, in 3.5 wt% NaCl solution, of aluminum alloy composites containing a range of reinforcements have been investigated using potentiostatic measurements and simple immersion tests. Complementary microstructural studies carried out on corroded surfaces and sections through corroded material have identified a number of

preferential corrosion sites; these include the fiber/matrix interface, especially where it contains chemical reaction products resulting from composite fabrication, as well as second phases and pores in the metal matrix. The effect on corrosion behavior of the different reinforcements, with particular reference to their chemistry and geometry, is discussed, as is the influence of composite manufacturing route.

Corrosion resistance of metal matrix composite is a subject of study to be discussed in order to compare their corrosion resistance towards corrosive environment and some studies have reported based on effect of heat treatment to the corrosion behavior .some work on the mechanical properties and corrosion behavior reported [S .B . Jamaludin and *et al.* 2008]. This search deals with the study of the corrosion behavior of Al-3% Mg -10% Al₂O₃ and Al-3%Mg which prepared by casting process under corrosion environment (3.5% NaCl and 2.5% HCl and 1% HCl) and compare corrosion behavior.

Experimental work

Preparations of matrix alloy

The aluminum alloy (Al-3%Mg) of matrix where produce by using casting process, as following : piece of pure aluminum was melted by using furnace type Mario Di Maio work in range of temperature reach to 1000 °C , magnesium where added to melt after enveloped it by aluminum foils in order to prevent the oxidation of magnesium then stirring melt in order to get homogenous structure, the alloy then poured in mould after heating it to temperature 200 °C in order to reduce effects of shrinkage on casting.

Preparation of composite material

Composite material was prepared by using stir casting, where alloy melt at temperature 750 °C then the temperature lowered to 650 °C and the alumina added in percentage (10%Al₂O₃) to melt and stirring at "650 R.P.M. " for (10)s and then heated the mixture to temperature 700 °C and poured in mold heated to temperature 200 °C

Preparation of test samples

Sample of corrosion test prepared by cutting it from casting by using turning process with dimensions equal to 16 mm for diameter and 4mm height, Test specimens of each material were grounded using several grades of emery paper ranging from 240 to 600 grit, and then polished by

alumina liquid and cloth by using polishing equipment type BUEHLERMETASERV, then rinsed in distilled water and methanol and dried by blower.

Corrosion test

Immersion test

Immersion test technique involves recording the weight loss of a sample immersed in a corrosive medium weight loss (in mg) may be converted to corrosion rates in mm per year using the expression [Emenike Raymond Obi 2008].

$$\text{mm/yr} = 87.6W/DA t$$

Where W is weight loss in mg, D is density in g/cm^3 , A is surface area in cm^2 and t is time in hours.

Immersion corrosion test was used to investigate the weight loss and corrosion rates of each material in the specified electrolytes. They were weighed using an electronic weighing balance 4 decimal type Sartorius. The sample weights were measured in grams to 4 decimal places after weighing the specimens were immersed in 3.5 wt. %, NaCl, 1% vol. HCl and 2.5% vol. HCl

Microscopic examination

This examination done in order to study topographic of sample surface which immerse in used solutions, the microscope used for this purpose from type (Union ME -3154) which supplied with digital camera connected with computer. The picture has been taken with zoom X150.

Results and Discussion:

The variation of normalized weight with time and corrosion rates with time for aluminum alloy (Al-3% Mg) and composite materials (Al-3% Mg -10% Al_2O_3) in 3.5% NaCl are presented in **Figure 1** and **Figure 2** respectively, it observed from **Figure 1** increase weight of samples with increased time while **Figure 2** show decrease in corrosion rates with increased time.

The most important factors that effect on corrosion rates are the passivity of composite material or alloy and the stability of protective oxide film which reduce corrosion activity. The reason for the rise in weight of both composite material and aluminum alloy when immersed in 3.5% NaCl, is the formation of passive layer, since oxide film (MgAl_2O_4) can be easily formed in (Al-Mg) alloy where both component of which are active, formation of film on the surface of (Al-Mg) alloy this film would be more stable to chlorine ions [Takano Michinori and *et al.* 2009]. Also deposit

corrosion product on areas which corroded and in pits which are less cause this rise in weight of sample [باسم محسن واخرون ٢٠٠٩].

The variation of normalized weight with time and corrosion rates with time for aluminum alloy (Al-3% Mg) and composite materials (Al-3% Mg -10% Al₂O₃) in 1%HCl are presented in **Figure 3** and **Figure 4** respectively, it observed from Figure 3 increased of weight loss with increased elapsed time, while **Figure 4** showing corrosion rates decrease with increase the time of immersion.

Corrosion resistance improves with increasing immersion time in 1%HCl which implies the development of a protective layer. The high corrosion rates for both aluminum alloy and composite material occur in first stages of immersion, the second phase in alloy cause intergranular corrosion , so this phase will corrosion ,the corrosion located adjacent Al₂O₃ particle where generation of spinel MgAl₂O₄ which cathodic to the matrix [Grigoris E .and *et al.* 2009] .

The corrosion rates of composite material will decrease gradually with elapsed time for immersed specimens in 3.5% NaCl and 1% HCl , where the passivity of aluminum alloy matrix is responsible for decrease in corrosion rates with increase time of exposure to corrosive medium , it was observed that corrosion of composite material will combined with loss of reinforced particles , the reason of that the most voids found near interface as a result of casting process. The pitting corrosion especially near particle of reinforcement which cause debonding the interface and more attack at these regions. Also the voids which may arise either as a result of poor bonding at the reinforcement/matrix interface or from the presence of cracked reinforcement particles, cause increase of pitting corrosion in composite material and cause for loss the reinforced particles in composite material.

The variation of normalized weight with time and corrosion rates with time for aluminum alloy (Al-3% Mg) and composite materials (Al-3% Mg -10% Al₂O₃) in 2.5%HCl are presented in **Figure 5** and **Figure 6** respectively, it observed from **Figure 5** that as time increase the weight loss increase, where increase the concentration of acid would cause more weight loss, and the composite material exhibit more weight loss than weight loss of aluminum alloy. While **Figure 6** show variation of corrosion rates with time for aluminum alloy and composite material immersed in 2.5%HCl solution it observed that the corrosion rates increase with increased time, and the composite material exhibit more corrosion rates than corrosion rates of aluminum alloy the reason of this behavior is absence of a protective layer in aluminum alloy and composite material make the corrosion rates very high.

However increase in corrosion rates of composite compared to aluminum alloy of matrix is considered to be due to the increased area fraction of intermetallic particles and to differences in the characteristics of the surface film of the aluminum matrix composite and the aluminum alloy, and intermetallic compound in matrix of composite are prefer sits for localized corrosion . The decrease in driving force required for localized corrosion of MMCs is likely attributable to the introduction of the reinforcement/matrix interfaces which have been shown to enhance localized corrosion

Figure 7 and **Figure 8** show microstructure of aluminum alloy and composite material respectively without corrosion, while **Figure 9** and **Figure 10** show both aluminum alloy and composite material after immersed in 3.5% NaCl.

Figure 11 and **Figure 12** show microstructure of both aluminum alloy and composite material respectively after immersed in 1% HCl. **Figure 13** and **Figure 14** show microstructure of both aluminum alloy and composite material respectively after immersed in 2.5% HCl. From the result of microstructure examination it is observed more pits in corroded specimens in acid than corroded specimens in salt, the composite material exhibit more pits than the matrix alloy, especially near the interface between the reinforcement and the matrix alloy. The observation that pitting corrosion increases in the concentration of chloride ions ,while the chloride ions decrease the pitting potential of aluminum by disrupt the formation of the passive film thereby creating initiation sites for pit formation

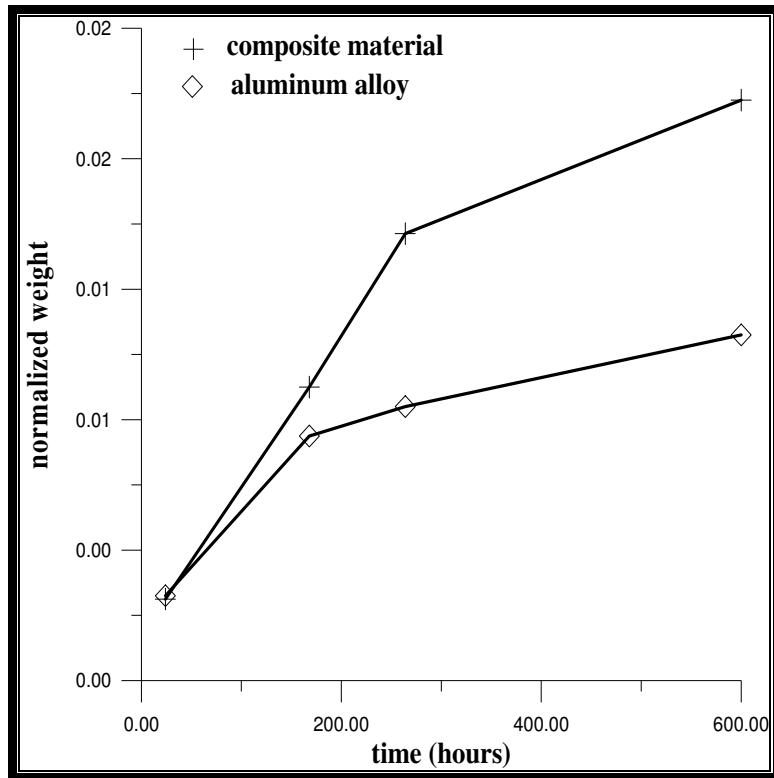


Figure 1 Variation of normalized weight (weight change /initial weight) with time for aluminum alloy and composite material immersed in 3.5%NaCl solution

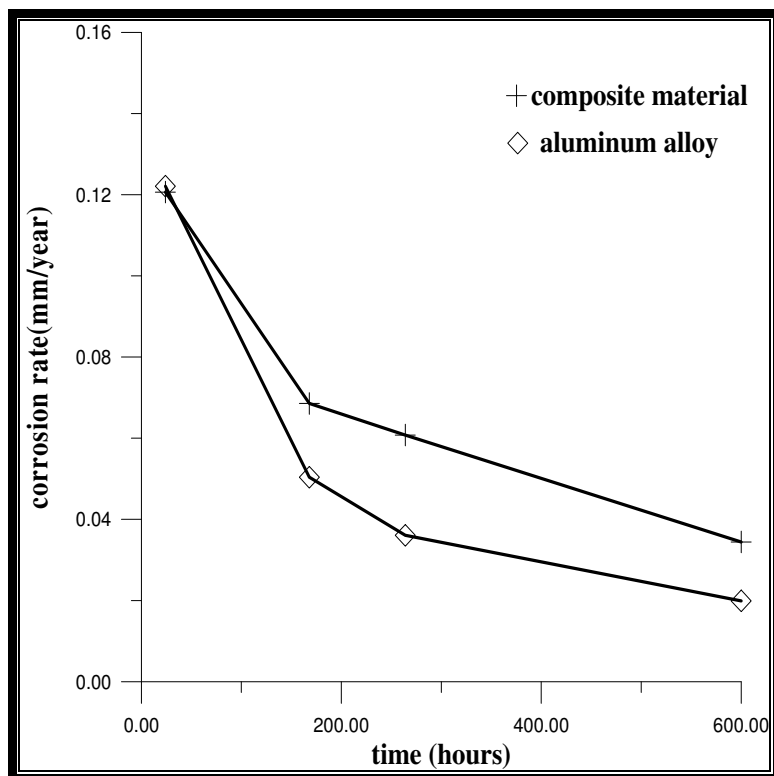


Figure 2 Variation of corrosion rates with time for aluminum alloy and composite material immersed in 3.5%NaCl solution

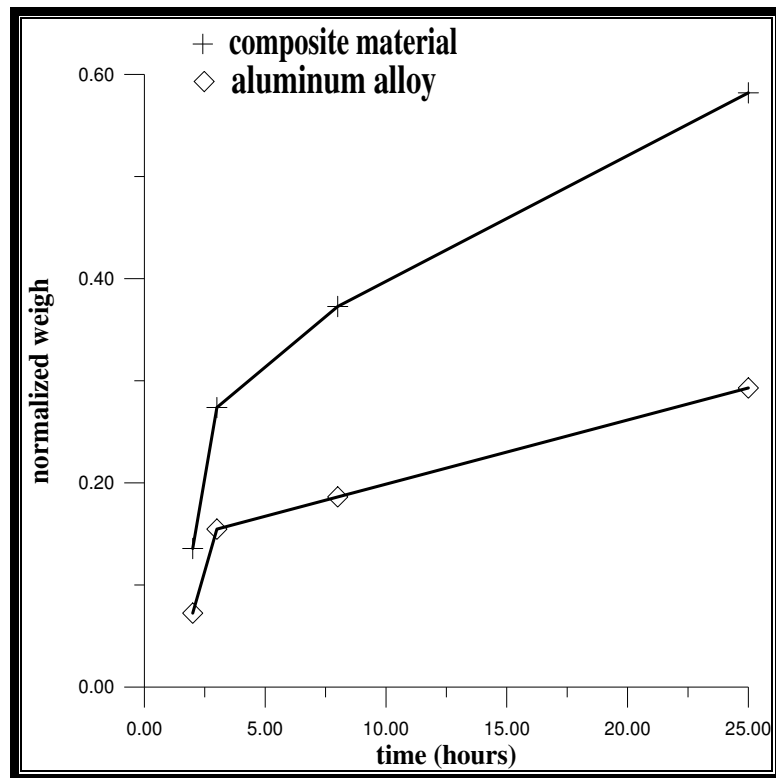


Figure 3 Variation of normalized weight (weight change /initial weight) with time for aluminum alloy and composite material immersed in 1%HCl solution

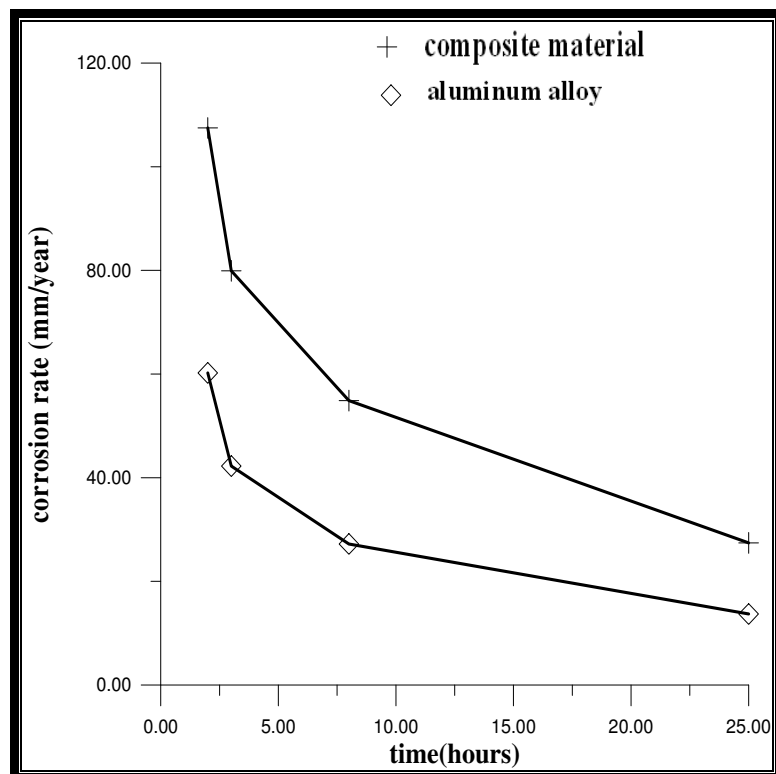


Figure 4 Variation of corrosion rates with time for aluminum alloy and composite material immersed in 1%HCl solution

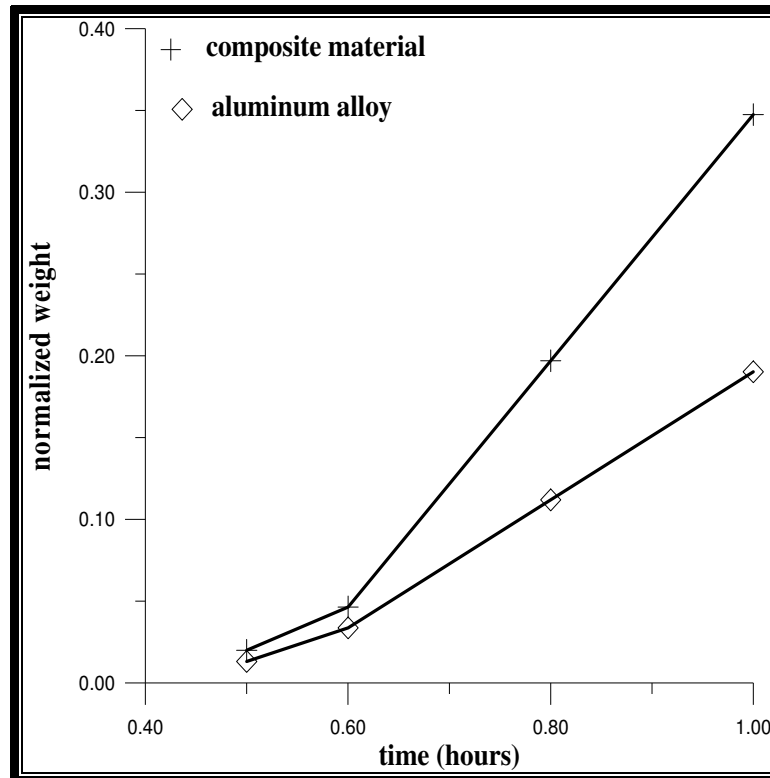


Figure 5 Variation of normalized weight (weight change /initial weight) with time for aluminum alloy and composite material immersed in 2.5% HCl solution

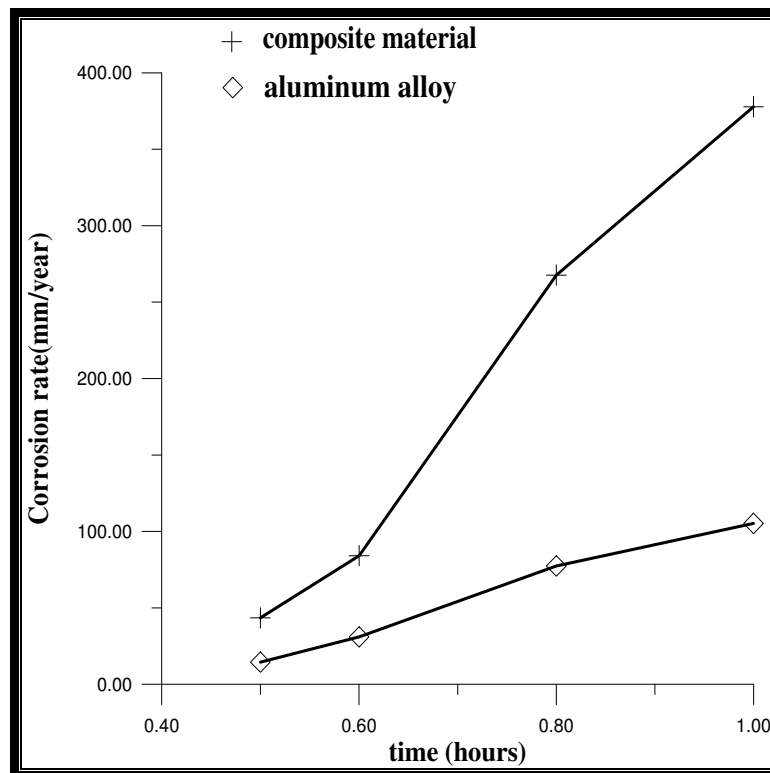


Figure 6 Variation of corrosion rates with time for aluminum alloy and composite material immersed in 2.5% HCl solution

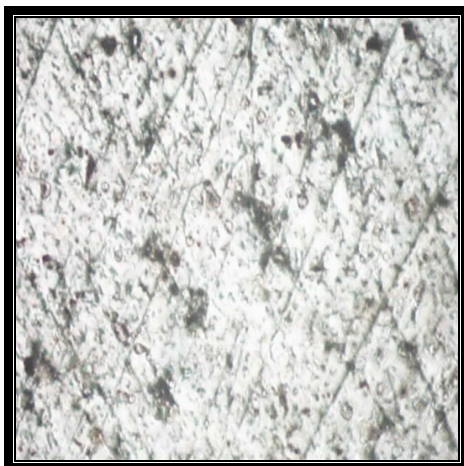


Figure 7 show aluminum alloy without corrosion

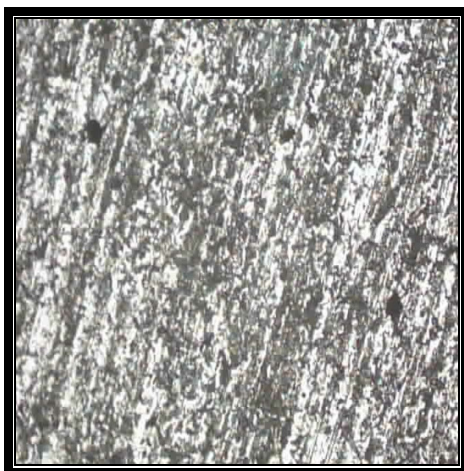


Figure 8 show Composite material without corrosion



Figure 9 Corroded specimen of aluminum alloy exposed in 3.5% NaCl for 600 hours

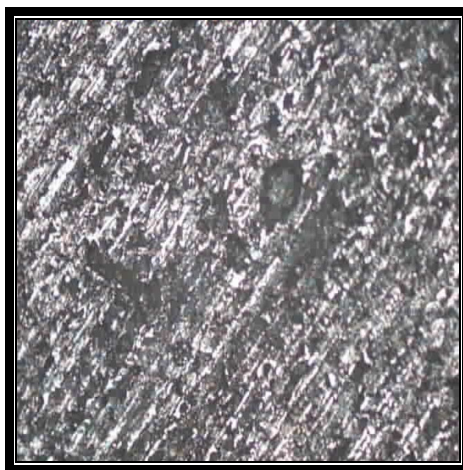


Figure 10 Corroded specimen of Composite material exposed in 3.5% NaCl for 600 hours

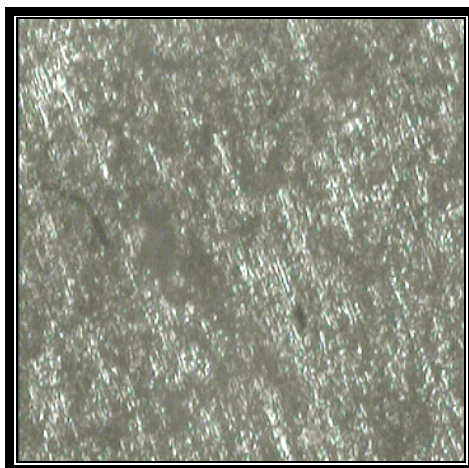


Figure 11 Corroded specimen of aluminum alloy exposed in 1% HCl for 25 hours

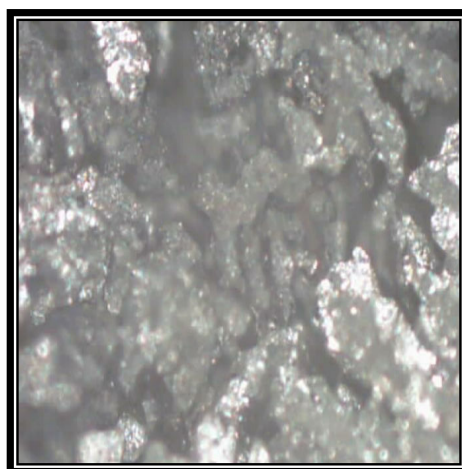


Figure 12 Corroded specimen of Composite material exposed in 1% HCl for 25 hours

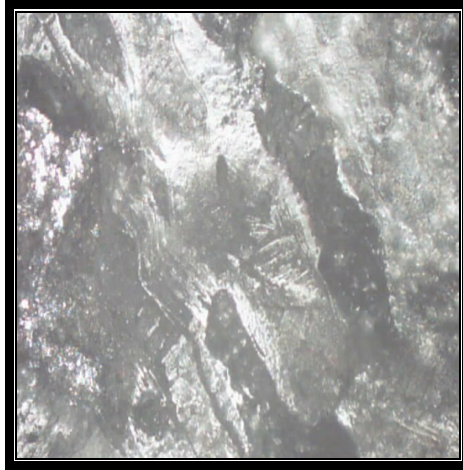


Figure 13 Corroded specimen of aluminum alloy exposed in 2.5% HCl for 1 hours

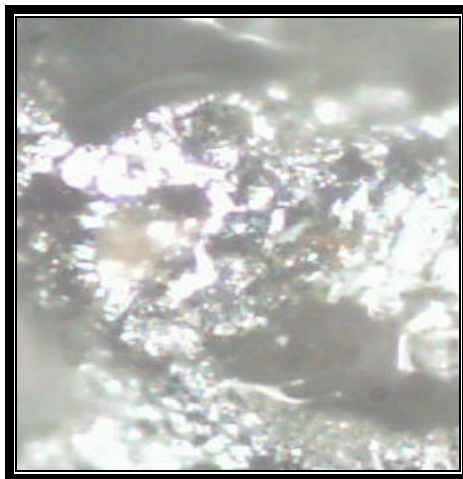


Figure 14 Corroded specimen of Composite material exposed in 2.5% HCl for 1 hour

Conclusions

- 1-Corrosion rates of composite material are higher than aluminum alloy (Al – 3%Mg)
- 2-The pitting corrosion was more intense in composite compare to aluminum matrix because the voids near interface between reinforcement and matrix alloy as a result of processing.
- 3-Corrosion rates increase with increase concentration of solution as a result of degradation of passive layer.
- 4- Increased weight of aluminum alloy and composite material in immersed in 3.5% NaCl as a result of stability of a protective layer that formed on the surface where both aluminum and magnesium are passive in chlorine.

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