IJRAME

INTERNATIONAL JOURNAL OF RESEARCH IN AERONAUTICAL AND MECHANICAL ENGINEERING
WWW.IJRAME.COM
ISSN (ONLINE): 2321-3051

Vol.6 Issue.1, January 2018
Pg: -1-16

Comparisons of Pitting Corrosion characteristics of Al6061matrix alloy and its composite by weight loss and electrochemical method

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Abstract

In the present investigation the pitting susceptibility of Al6061 matrix alloy reinforced with particulate silicon carbide has been studied by conventional weight loss method and by electrochemical technique in acid chloride and neutral chloride medium. Samples were prepared by taking different percentage of SiC and casted by liquid metallurgy and samples were prepared as per ASTM standard. The corrosion studies by conventional weight loss method were carried out in neutral chloride and acid chloride medium at room temperature for 24hrs and weight loss is monitored continuously for a weak. Corrosion test was also carried out in acid chloride medium and neutral chloride medium using Tafel extrapolation technique and electrochemical impedance spectroscopy (EIS). Surface morphology of the sample was examined by scanning electron microscopy. X-ray diffraction technique was used to confirm the inclusion of SiC particulate. The result showed excellent corrosion resistance in neutral chloride media than in acid chloride medium. Further both conventional weight loss and electrochemical technique confirming improved corrosion resistance in Al6061 metal composites as compared to the Al6061 base alloy.

Keywords: Al6061 composite, weight loss, SiC, Tafel, EIS.

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1. Introduction

Aluminium matrix composites are being widely used because of their low density, high strength, good fabric ability, good corrosion resistance and many other beneficial properties if reinforcing material such as graphite, silicon carbide, aluminium oxide, or boron are incorporated in the alloys. The reinforcement may be in the form of particulates, whiskers, short fibre or continuous fibre [1-6].

Studies on corrosion behaviour on aluminium alloys with reinforced with SiC untreated and treated with cerium composite in 3.5% Nacl (W. Neil.C. Grrard1989) reported, cerium pre-treatment decrease the corrosion susceptibility. corrosion behaviour of as cast SiC particulate- Aluminium alloy metal matrix composite(M.M. Buazaiga and S.J.Thorpe 1993) reported the addition of SiC particulate reinforcement produces a change in the pitting corrosion. Al6061matrix composites and its base alloy (Geetha mable pinto et al2009) in 1:1hydrochloric acid and sulphuric acid medium report, corrosion rate for both base alloy and composite increases with increase in the concentration of the acid mixture. Corrosion behavior of alumina reinforced aluminium metal matrix composite (K.K. Alaneme and M.O. Bonurin 2011) report Al6063-Al_2O_3 composites exhibit excellent corrosion resistance in Nacl medium than in the NaOH and H_2SO_4 medium. Weight loss corrosion studies of Al6061/Qurtz metal matrix composites in sea water (Radha H. R et al2014) report corrosion rate decreases with increase in the percentage of reinforcement quartz. Recent studies on the Corrosion resistance of SiC particulate- reinforced Aluminium alloy reinforcement with TiN 2, 4 and 6 Wt % in NaCl media (H C Anandamurthy , V Bheema Raju and C Shivakumara 2012). Corrosion Characterization of Al6061/red mud metal matrix composites (P.V. Krupskaya 2013), SiC Despersoid on the Corrosion behaviour of Squeeze Cast Aluminium alloy – SiC composite (O.P. Modi, M. Sexena , B.K. Praad and A.H . Yegnewaran 1991) Show a marked decrease in the Corrosion rates of the matrix alloy and Composites with increase in the Content of TiN and SiC reinforcement. The reinforcement of SiC alloy increase the susceptibility to pitting Corrosion.

In the present investigation an attempt is made to Compare the Pitting Corrosion characteristics of Al6061matrix alloy and its composite by weight loss and electrochemical method in acid chloride and neutral chloride medium.[7-9]

2. Experimental procedure

2.1. Material selection

Material utilized for present study is Aluminium alloy 6061. Al6061 which exhibit excellent Casting properties and reasonable strength used as the base alloy with good strength, being suitable for mass production of light metal casting and its composition is given in the table 1.

Table1: Percentage Composition of Al6061base alloy

Element	Mg	Si	Fe	Cu	Ti	Cr	Zn	Mn	other	Al
Percentage	0.8-1.2	0.4 – 0.8	Max. 0.7	0.15 – 0.40	Max. 0.15	0.04-0.35	Max. 0.25	Max. 0.15	0.05	95.85

2.2. Reinforcement

SiC of AR Grade used as reinforcement in the form of particulate of mean diameter 25 micron of 99.8 percent of purity.

2.3. Composite preparation

Liquid metallurgy route using vertex technique was employed to prepare the composite. The Al 6061 alloy ingots were charged into a gas –fired crucible furnace and heated to a temperature of 750^{0}C above the liquid temperature of the alloy and the liquid alloy was then allowed to cool in the furnace to a semi solid state at a temperature of 600^{0}C. The preheated Silicon carbide reinforcement of 2%, and 4% Composite was added. The composite slurry was then stirred using a mechanical stirrer at a speed of 300 rpm with graphite coated helical shaped arranged blades using hexachloro ethane or hexafluro ethane as a degassing tablet to improve the distribution of SiC particles in the molten Al6061 alloy. After degassing Scum and other impurities were removed. The molten composite was then cast in the steel moulds. [10-12]

2.4 Specimen Preparation

Cast material was cut into 15X15mm cylindrical pieces using an abrasive cutting wheel for the test coupons samples. The matrix was also cast under identical condition as composites for comparison. The exposed flat surface of the mounted part was polished with 240, 320, 400, 600,800and1000 grade emery papers and polished according to standard metallographic techniques and degreased in acetone and dried. The sample were weighed upto fourth decimal place using electronic balance and the exact specimen dimensions were noted down. For polarization studies, composites and pure alloy matrix were cut into rectangular specimens of 83 length, 21mm length width and 4mm thickness and prepared as described above.[13-16]

3. Experimental procedure

3.1. Experimental procedure for conventional weight loss method

The Corrosion test were carried out in 0.1M acid chloride and 3.5 wt. % of neutral chloride Solutions at room temperature. The prepared Cylindrical sample were weighed initially upto fourth decimal place using electronic balance and the exact specimen dimensions were noted down. Then the samples were immersed in different Corrodent at 24 hours for about 7 days. The specimens after stipulated hours of exposure to corrosion medium are taken out, washed with distilled water and then dried using acetone and finally air dried. Weight of the corroded specimens was determined, weight loss is Calculated using the Conventional weight loss method and corrosion rate is Calculated using the following formula and expressed in mpy [15-18]

Corrosion rate in mpy = 534 W / DAT

Where W is the weight loss in grams, D is the density of the specimen in gm. /cc, calculated using rule of mixture. A is the area of the specimen in cm^2 and T is the exposure time in hours.

3.2. Experimental procedure for Potentiodynamic polarization studies

Potentiodynamic polarization studies of an Al6061 base alloy and its composite have been carried out. A solution of 3.5 wt % of sodium chloride and 0.1M acid chloride solution were prepared. An electrochemical cell with a three-electrode Pyrex glass configuration was used for electrochemical measurements. Al6061 matrix alloy and its SiC composites (2 % SiC and 4 % SiC) were used as a working electrode. A platinum electrode and an Ag/Agcl electrode used as counter and reference electrode respectively. Polarization scan was performed in the electropositive direction at a rate of 0.01V / sec. The open circuit potentials were recorded for Al6061 matrix alloy and its SiC composites (2 % SiC and 4 % SiC) in two different concentrations such as 3.5 % of neutral chloride media and0.1M acid chloride media .

4. Result and Discussion

4.1: Result and Discussion on corrosion evaluation by conventional weight loss method

The results of corrosion evaluation by conventional weight loss method of as casted Al6061 / SiC Composites and Al6061 base alloy in different medium such as 0.1M acid chloride, and 3.5% neutral chloride medium are shown in the figure 1-5 and **C**orrosion rate calculated in mpy are given in the table 2-3.

From Graph 1 & 2 it may be observed that as casted Al-6061 alloy and its composites shows less corrosion in all the mediums for first three days. Further it is noticed that from fourth day there is marginal increase in weight loss up to seventh day in acid chloride medium but in 3.5% neutral chloride medium, corrosion is almost negligible and much weight loss was not observed from the first day. It is also observed that sample in presence of neutral chloride medium exhibits high corrosion resistance in all seven days of exposure, where as in case of acid chloride medium corrosion rate is less for the first three days of immersion due to the formation of stable oxide layer and then marginal increase in corrosion due to rupture in oxide layer by chloride ions. From graph 3 to 5 shows a plot of weight loss of the specimen versus number of day immersed

INTERNATIONAL JOURNAL OF RESEARCH IN AERONAUTICAL AND MECHANICAL ENGINEERING
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ISSN (ONLINE): 2321-3051

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for different composition in the medium and corrosion rate. It may be observed that as the percentage of SiC increases, Corrosion resistance also increases.

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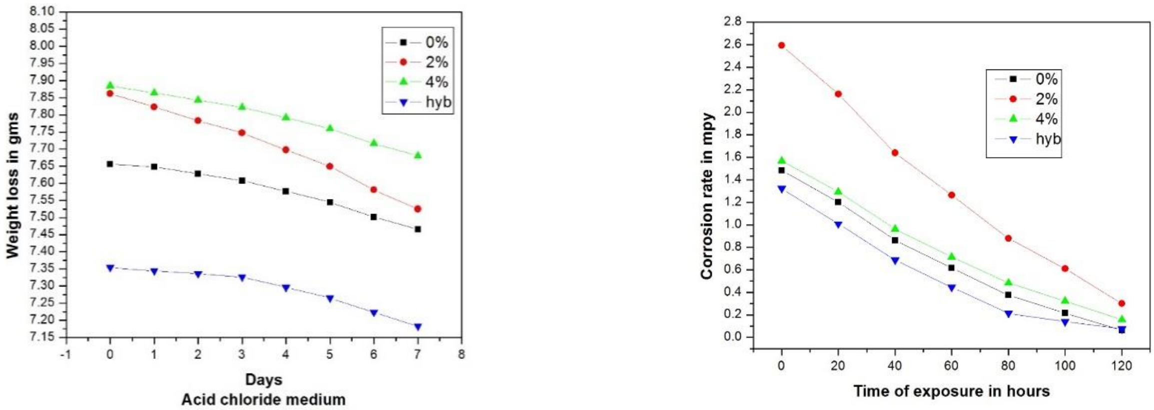

Figure. 1. (a) Weight loss and (b) Corrosion rate of as casted Al6061alloy in acid chloride medium

a b

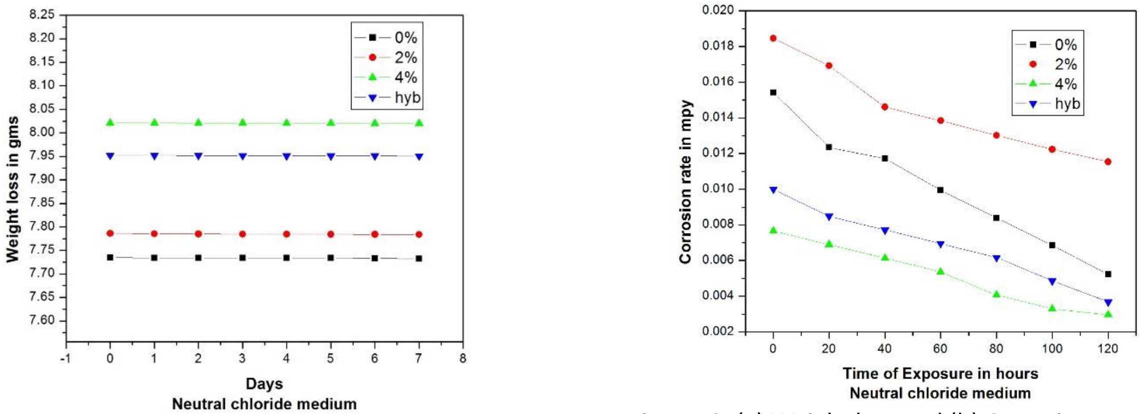

Figure. 2. (a) Weight loss and (b) Corrosion rate of as casted Al6061alloy in neutral chloride medium

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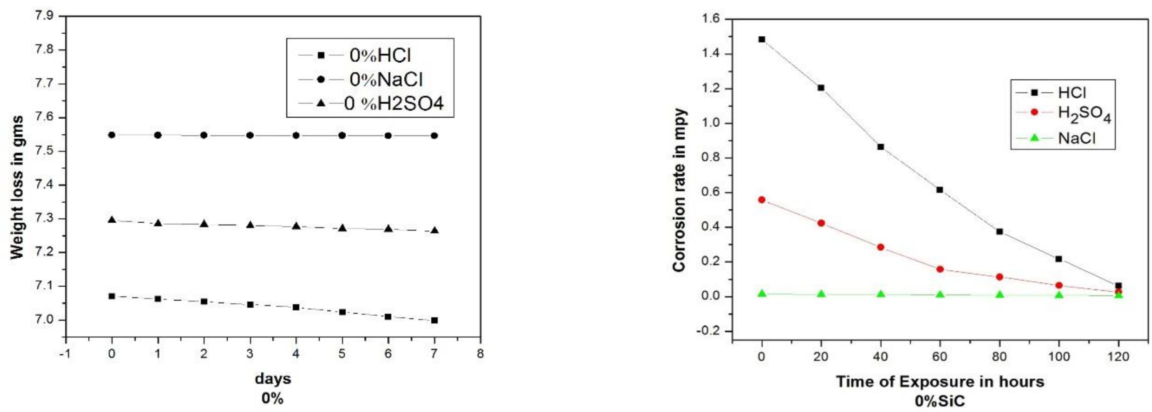

Figure.3. (a) Weight loss and (b) Corrosion rate of as casted Al6061 matrix alloy.

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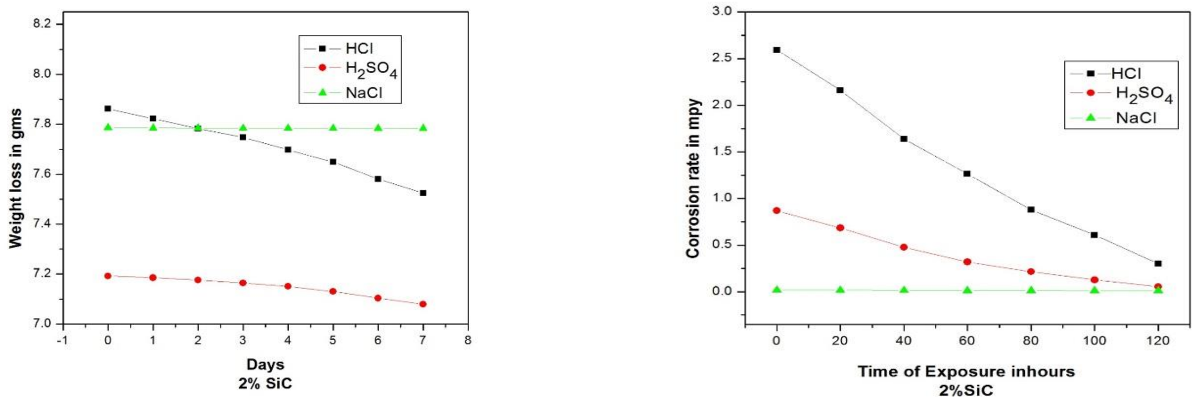

Figure.4. (a) Weight loss and (b) Corrosion rate of as casted Al6061alloy with 2 % SiC reinforcement

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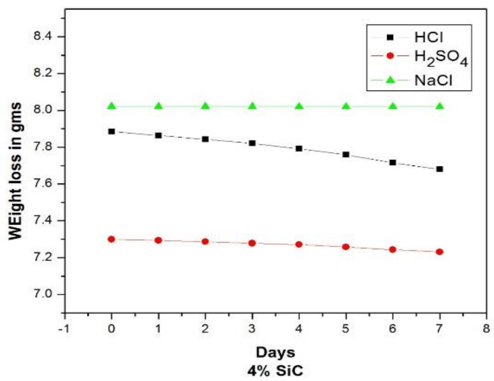

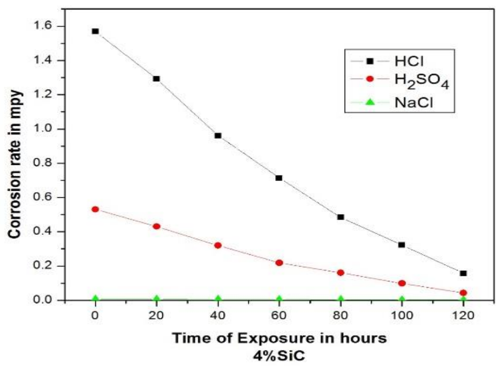

Figure. 5. (a) Weight loss and (b) Corrosion rate of as casted Al6061alloy with 4 % SiC reinforcement

Table 2: Corrosion rate in mpy for Al6061 matrix alloy and its composites in acid chloride medium by conventional weight loss method

Time of exposure (hrs)	0 % SiC	2 % SiC	4 % SiC
0	1.4836	2.5944	1.5684
20	1.2029	2.1613	1.2924
40	0.8631	1.6398	0.9620
60	0.6158	1.2637	0.7144
80	0.3740	0.8791	0.4837
100	0.2171	0.60995	0.32197
120	0.0614	0.30074	0.15791

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Table 3: Corrosion rate in mpy for Al6061 matrix alloy and its composites in neutral chloride medium by conventional weight loss method

Time of exposure (hrs)	0 % SiC	2 % SiC	4 % SiC
0	0.015437	0.018460	0.007665
20	0.012350	0.016921	0.006899
40	0.007718	0.014614	0.006132
60	0.006947	0.013845	0.005366
80	0.005403	0.013016	0.003066
100	0.003859	0.009230	0.002299
120	0.002315	0.005384	0.000766

4.2: Result and Discussion on Polarization measurement:

The Open circuit potential plots for the matrix alloy and the composites in 3.5wt 5 of NaCl, and 0.1M HCl and are shown in the figure 6-7. The evaluated OCP are given in the table 4. It is observed that the OCP values increases in positive direction with increase in SiC content, from -0.7440 V for Al6061 matrix to -0.7170 V for reinforced 4% SiC composites in Neutral chloride medium. Similar increase in OCP values in positive direction with increase in SiC content, from -0.7030 V for Al6061 matrix to -0.6610 V for reinforced 4% composites in acid chloride medium.

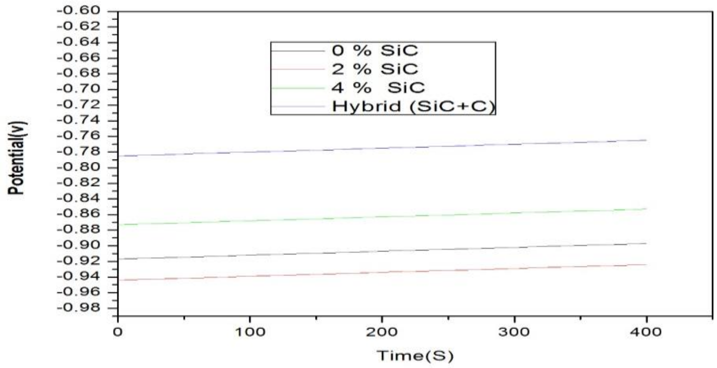

Figure 6: Open circuit potential for Al6061 matrix alloy and its SiC composite in neutral chloride medium

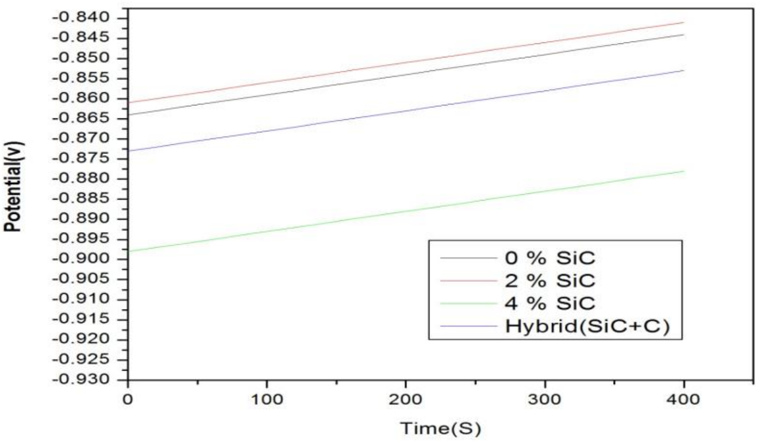

Figure 7: Open circuit potential for Al6061 matrix alloy and its SiC composite in acid chloride medium

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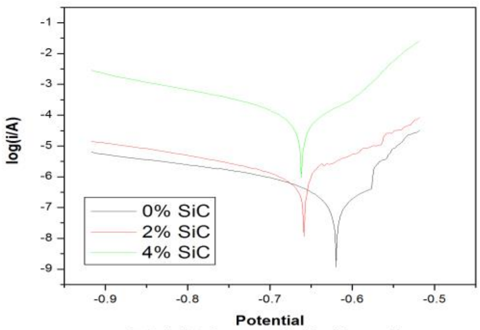
Table 4. Open circuit potentials of Al 6061 matrix alloys and Sic composites in different medium

Percentage of SiC in Al6061 matrix alloy	Open circuit potentials (E_{corr}) values in volts in different medium	
	0.1 M HCl	3.5 % Nacl
0 %	-0.7030	-0.7440
2 %	-0.6810	-0.7030
4 %	-0.6610	-0.7170

Analysis of Tafel extrapolation and A.C. Impedance spectroscopy (EIS) studies were carried out using electrochemical workstation Instrument (Model: CHI608E). Typical polarization curves for Al6061 matrix alloy and its composites containing 2% and 4 % by weight of SiC particulates in different medium such as neutral chloride medium and acid chloride are shown in figure 8-9. The evaluated electrochemical parameters (i_{corr}) , linear polarization resistance (R_p) and Corrosion rate in miles per year that is associated with the polarization measurement for the matrix alloy and the composites are given in the table 5. The corrosion parameters, corrosion current density (I_{corr}) and corrosion rate were obtained from the Tafel polarization measurements. The values of the corrosion potential and corrosion current were obtained from the extrapolation of anodic and cathodic tafel lines located next to the linearized current regions. The pitting potential was determined from the forward anodic polarization curves where a stable increase in the current density occur. it can be observed from the Tafel plot that corrosion current values and corrosion rate decreases with increase in SiC content in the composites. The conducting SiC particulate possibly forms microgalvanic couple with Al6061 matrix alloy and causes pitting corrosion. The decrease in corrosion rate observed in case of composites is due to decoupling between SiC particles and Al6061 due to decoupling of conducting SiC particles after the interfacial corrosion product, thus eliminating the galvanic effect between them. [16-20]



Tafel plot for neutral chloride media

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Figure 8: Tafel polarization plots for Al6061 matrix alloy and its composite SiC (2 % SiC and 4 % SiC) in neutral chloride medium.

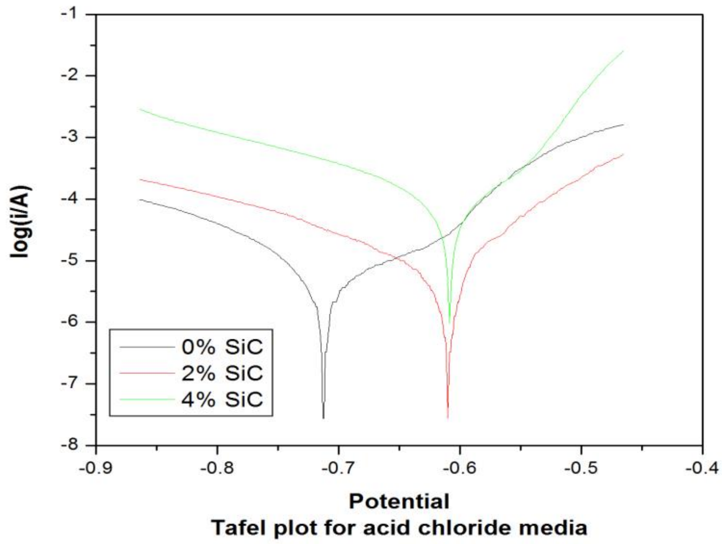

Figure 9: Tafel polarization plots for Al6061 matrix alloy and its SiC (2 % SiC and 4 % SiC) composite in acid chloride medium.

Table 5. Results of Tafel polarization studies, for the Al6061 base alloy and its composite in different media

Medium	Percentage of Composites	R_P (ohm)	I_{Corr} (A)	Corrosion Rate (mpy)
0.1M acid chloride medium	0 %	3910	5.923	2.210 X 10^{-6}
	2 %	4241	5.195	2.539 X 10^{-6}
	4 %	211	1.995	8.431 X 10^{-6}
3.5 wt% of neutral	0 %	99748	1.567	6.716 X 10^{-6}

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chloride medium	2 %	12566	1.659	7.036×10^{-6}
	4 %	211	1.995	8.431×10^{-6}

5. EIS studies

EIS study of the matrix alloy and its composite is carried out at OCP in order to assess the contribution of the composites. Nyquist plots and its equivalent circuit used to fit the experimental data of Al6061 matrix alloy and its composites are shown in the figure.10.It can be observed from the Nyquist plots that radius of the capacitive loops above the real axis increased with increase in SiC content for the composites.

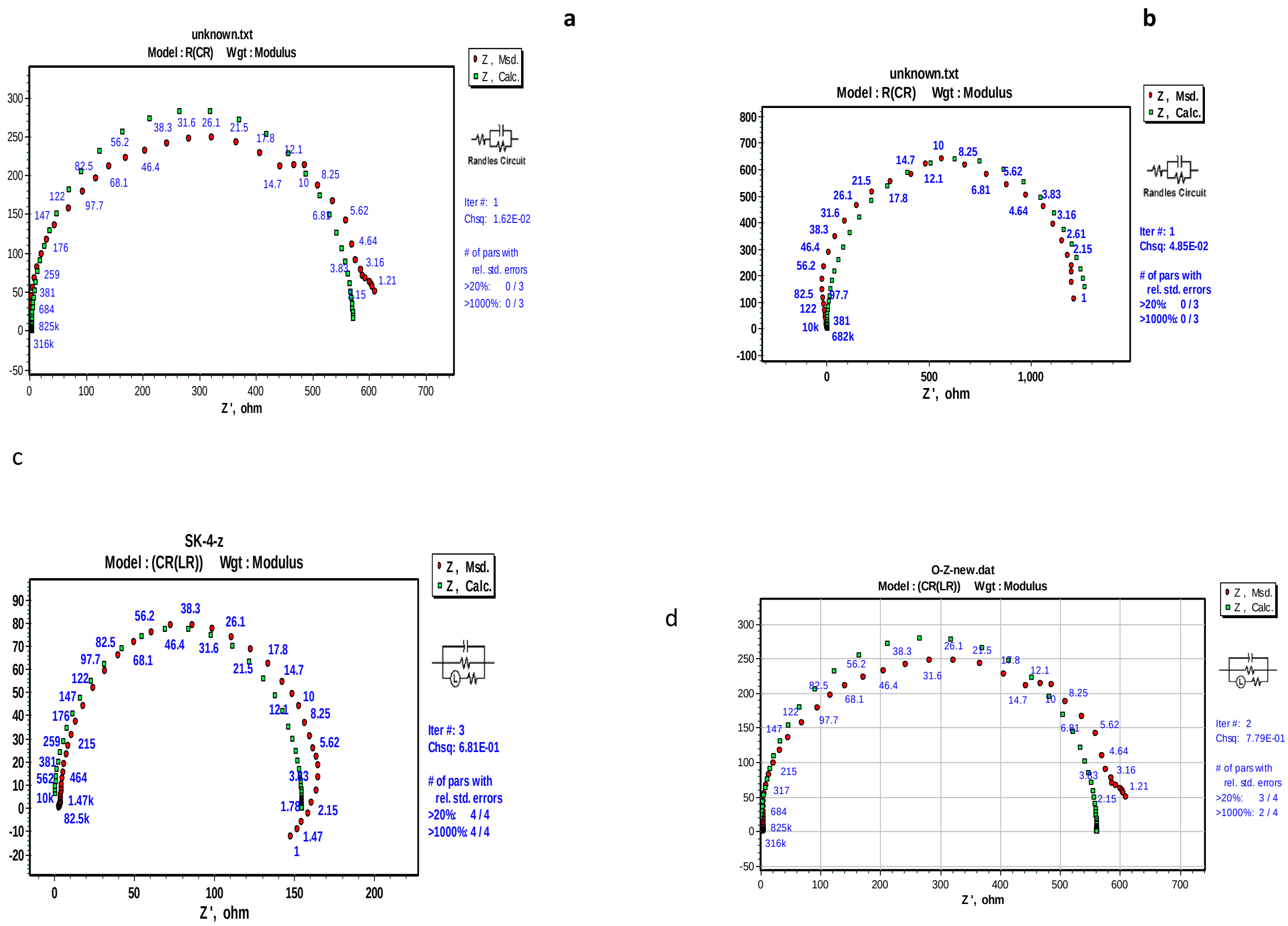

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Figure 10. a, b, c & d: Nyquist plot with Equivalent circuit model used to fit experimental data of Al6061 matrix alloy and its composite (2 % SiC and 4 % SiC)

6. Scanning electron microscopy

Scanning electron microscopy (SEM) images of the Al6061 matrix alloy and its composites (2 % SiC and 4 % SiC) was carried out using Scanning electron microscope (model:Is:1501-2002,RA2007,IISc.) .The SEM images of Al6061 matrix alloy and its composites (2 % SiC and 4% SiC) before corrosion are shown in the figure 8. The particle size of reinforcement SiC particulate is about 20 µm as observed in the SEM images. . The SEM images of Al6061 matrix alloy and its composites (2 % SiC and 4% SiC) in 0.1M acid chloride medium and neutral chloride media are show in the figure 11-13. The corrosion of Al601 alloy and its composites is presumably due to the anodic dissolution either at the grain boundaries or at the metal-media interface. A comparison of the SEM images of the samples before and after the polarization studies clearly indicates severe surface deterioration in acid chloride media than neutral chloride medium due to pitting corrosion in all the samples. Pitting susceptibility for aluminium alloy is mainly affected by the microstructural heterogeneity of these commercial alloys. The decrease in corrosion deterioration of composites can be attributed to matrix – reinforcement interface and formation of micro and sub micro load cells at the metal surface.

(a) (b) (c)

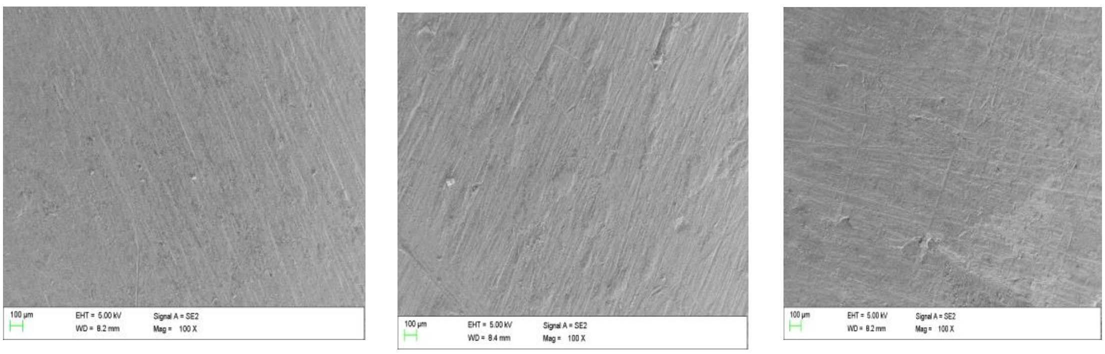

Figure.11: SEM micrograph of Al6061 matrix alloy and its composites (2% SiC and 4% SiC) before corrosion

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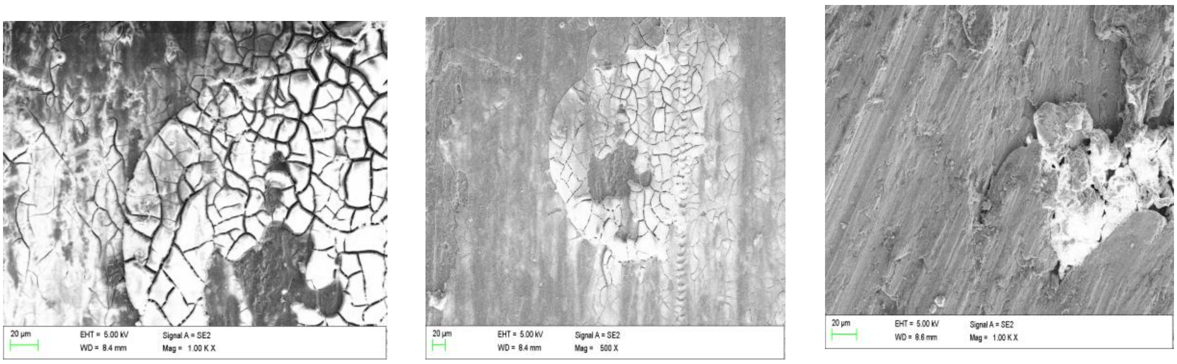

Figure .12: SEM micrograph of corrode Al6061 matrix alloy and its composites (2% SiC and 4% SiC) acid chloride medium

a b c

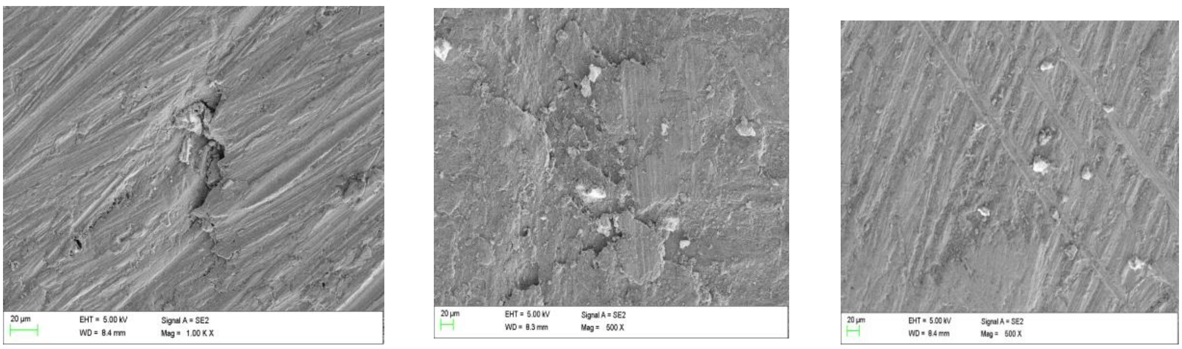

Figure.13: SEM micrograph of corrode Al6061 matrix alloy and its composites (2% SiC and 4% SiC) in neutral chloride medium

7. Conclusion:

In this paper the corrosion characteristics of unreinforced Al6061 matrix alloy and its composite reinforced with SiC (2% and 4%) were experimentally assessed in 0.1M HCl and in 3.5% NaCl using Tafel extrapolation technique and conventional weiht loss method . The study was also complimented by scanning electron microscopy (SEM).

From the result it is observed that Al6061 composite exhibited excellent Corrosion resistance in neutral chloride medium than in acid chloride medium. The Corrosion rate of the composites was lower than that of the corresponding matrix alloy in both Tafel extrapolation technique and conventional weight loss method.

The Corrosion rate of composites decreases with increase in percentage of reinforcement which may be due to increase in bonding strength. Increased corrosion resistance in composites is believed to be due to reinforcement particulate modifying the microstructure of matrix and also acting as physical barrier to the initiation and development of pitting corrosion.

Accuracy of the Tafel extrapolation method is greater than the conventional weight loss methods. By this technique it is possible to measure extremely low corrosion rate and it can be used for monitoring the corrosion rate of a system and polarization curve can be measured in less than 10 minutes.

8. Acknowledgement:

I sincerely thanks Vision Group on Science and Technology (VGST), Government of Karnataka for funding this research work and also R& D Centre, Department of Chemistry, Ghousia college of Engineering, Ramanagaram.

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A Brief Author Biography

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