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EFFECTS OF VARIOUS PARTICULATES REINFORCEMENTS ON THE CORROSION RESISTANCE OF ALUMINUM ALLOY (AA2618) MATRIX COMPOSITE

S. E. Ede, A. O. Agbo, and C. C. Nwogbu
Department of Metallurgical and Materials Engineering, Faculty of Engineering, Enugu State University of Science and Technology, Enugu, Nigeria

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Abstract: Study on the effects of various particulate reinforcements on the corrosion resistance of aluminum alloy (AA2618) matrix composites in different environments has been carried out. Metallic permanent molds were used to cast specimens in which 0vol%, 5vol%, 10vol%, 15vol%, 20vol%, 25vol% and 30vol% each of AA2618/SiC, AA2618/TiC and AA2618/fly ash composites were made. The cast specimens were machined to different dimensions for gravimetric and potentiostatic corrosion rate tests in one mole hydrochloric (1MHCl), sodium hydroxide (1MNaOH) and sea water environments where these composite specimens are normally exposed while in service. The results of the tests show that corrosion penetration rates of both gravimetric and potentiostatic of the composite samples increased along with increase in the vol% addition of these particles in the matrix of the alloy in these environments. The reason for this is that these particles promote localized corrosion within the matrix of the alloy by acting as anodic sites. The presence of these particles in the matrix of the alloy also helped in the infringements of dislocation movements in the matrices of the composites which are associated with particle clusters that generate high stress triaxiality in such regions. The increase in dislocation density resulted in high stress levels within the composites and this phenomenon caused high corrosion susceptibility as the percentages of these particles increased in the matrix of the alloy. AA2618/SiC immersed in NaOH environment recorded severe corrosion attack while least corrosion attack was recorded on composites immersed in sea water environment.

Keywords: Corrosion Composite, Reinforcement, Particles, Environment, Specimen, Aluminum.

INTRODUCTION

Corrosion is the degradation of a material by electrochemical or chemical reaction with its environment. It is also the natural tendency of materials to return to their most thermodynamically stable state [1]. Corrosion causes many problems to humankind. It damages equipment, structures, and the environment in the vicinity of corroded structures. Corrosion can be classified as dry and wet corrosion. Dry corrosion occurs with gases as the corrosive agent and in the absence of aqueous phases on the metal surface. Wet corrosion occurs when aqueous phases are present on the surface of the metal [1]. Aluminum resists corrosion attack in neutral, mildly acidic, and alkaline solutions by forming a thin, tenacious, protective oxide film. Electrochemical, chemical, and environmental changes such as polarization, changes in pH, and the solubility of corrosion products affect the stability of this oxide film. As aluminum is a very active metal, it oxidizes to Al^{3+} in acid solutions with pH below 3.

In alkaline solutions with pH above 9, it is reduced to aluminate ions (AlO). In solutions with pH between 4 and 9, aluminum instantaneously covers its surface with an oxide film and resists corrosion attack, that is, aluminum passivates [2]. *Pourbaix* [3] stated that "in practice, the corrosion behaviour of aluminum is determined essentially by the behaviour of the oxide film with which it is almost always covered in the corroding media. Cases of bad resistance to corrosion are often connected with a change in this oxide film, notably in its degree of hydration and porosity". Aluminum oxide (Al_2O_3) exists in various forms such as α-alumina or corundum (in the rhombohedral system), β-alumina (with hexagonal crystals), γ-alumina (with cubic crystals), and δ-alumina (with rhombohedral crystals) [3]. On the other hand, aluminum hydroxide, $Al(OH)_3$, exists as a gel which is amphoteric in nature. That is, it can react as an acid or a base. Aluminum hydroxide gel is not stable but crystallizes progressively to form different hydrated products as follows [3]: firstly, to monohydrate γ-$Al_2O_3.H_2O$ or bohmite (with rhombohedral crystals); secondly, to trihydrate Al_2O_3. $3H_2O$ or bayerite (in the monoclinic system); and then, to a trihydrate hydroxide called hydrargillite (in the monoclinic system). Furthermore, *Pourbaix* [3] stated that "the various hydrates formed during the ageing are characterized by an increasing stability and an accompanying variation in all their properties, in particular their solubility in acids, bases, and pure water". Corrosion behaviours of aluminium alloys in different environments are complex processes. Scholars have studied these phenomena via the formation of their protective oxides films in different environments and reported thus: *Wood* [4] reported that the barrier film formed on anodic surfaces is not a layer of pure oxide. It contains imperfections including impurities such as water and solution anions, pores, flaws, and cracks. He defined "pores" as capillaries and cavities visible under high resolution microscopes. Flaws may be defined as thin regions or holes present in the protective film at sites containing second phase particles and gas bubbles. The stability of the oxide film depends on the presence, configuration, density, and distribution of micro and macro defects such as vacancies and voids, inclusions, second phase particles, crystal structure of the oxide film, and composition, potential, and temperature of the electrolyte [4].

Szklarska-Smialowska [5] reported that localized corrosion of aluminum in halogen-containing electrolyte can occur in the absence of pores, flaws and cracks in the barrier protective film. She reported that Al_2O_3 had a grain boundary thickness of 8.5 nm while the diameters of chloride ion and water molecule were 0.36 and 0.31 nm, respectively [5]. Therefore, it is conceivable that the chloride ions can instantaneously arrive at the metal-passive film interface in a chloride-containing electrolyte. The presence, magnitude, and distribution of defects in the oxide film provide access for the chloride ions to reach the aluminum metal. The transportation of the chloride ions to the metal-passive film interface also depends on chloride ion concentration, temperature, potential, and defect size in the oxide film [6]. *Szklarska-Smialowska* reported that the penetration of the barrier film by chloride ions and their arrival at the metal-passive film interface are not the rate-determining step in pitting corrosion of aluminium alloys. She stated that the rate-determining step is the formation and maintenance of appropriate solution acidity in the pre-existing defects at the metal-passive film interface. The acidity of the solution within the pits permits the dissolution of aluminium and, consequently, the propagation of pits. *Szklarska-Smialowska* [6] reported that repassivation of metastable pits occurs when metal dissolution and hydrolysis do not furnish the critical quantity of hydrogen ions to sustain low pH for pit propagation. Furthermore, repassivation also occurs when the oxide films formed by aluminium and other alloying elements within the pits are insoluble or partially soluble in the acidic pit environment. Insoluble or partially soluble oxides increase the pitting potential of the aluminium alloy or cause metastable pits to passivate. Passivation of metastable pits drives the repassivation potential of the alloy to more noble potentials. Other scholars that investigated the corrosion behaviours of aluminium alloys and their composites in different environments include thus: *Hosni Ezuber et al* [7] reported that weight loss tests revealed low corrosion rate values for aluminium alloys in marine environment indicating a beneficial use of the alloys in the environment. They further stated that polarization plots showed that the alloys suffered from pitting attack after a prolonged exposure in the environment. *Jun Cheng et al* [8] reported excellent corrosion resistance of the alloy in marine environment and that the tribological behaviour of the alloy in sea water depends on the properties of the tribo-pairs. *Garrigue L. et al* [9] reported predominant crevice and pitting corrosion attack of the alloy in chloride environments due to the formation of Cl^-ions in the solution. Manish Gupta et al [10] observed that amongst several corrosive media, alkaline medium is the most dangerous for the corrosion of aluminum especially sodium hydroxide NaOH environment. *Sarawathi Y. L. et al* [11] also reported that a comparative study of corrosion behaviour of Al/SiCp composite with cast iron in sodium hydroxide environment showed that the former suffered severe corrosion attack in 3.5w% NaOH solution. *Ede S.E et al* [12] confirmed this development in their work on characterization of corrosion susceptibility of aluminum 0.8% binary alloy in some selected acidic and alkaline environments. They further stated that aluminum alloy reacts slowly with dilute hydrochloric acid but more rapidly with concentrated acid to displace hydrogen in the solutions. This implies that hydrochloric acid acts as a reducing agent that facilitates the formation of $AlCl_3$ in the solution. The rate of formation of this amorphoteric salt is dependent on the molar concentration of the acid. *T. W Clyne and P.J Whithers* [13] reported that high corrosion susceptibility in aluminum alloy composite specimens with large weight percentage of ceramic particles was as a result of segregation of ceramic particles in the matrix which is very common in as-cast composites. This segregation promotes nucleation of pits which facilitates corrosion. From the scholarly data above, scanty information is available on the effects of particulate reinforcement on the corrosion resistance of AA2618. Consequent upon these, the aim of this work is to investigate the effects of titanium carbide, silicon carbide and fly ash particles addition in the matrix of aluminium alloy (AA2618) on its corrosion resistance in simulated environments of hydrochloric acid, sodium hydroxide and sea water environments where this composite material is normally exposed during service.

EXPERIMENTAL METHODS

In this experimental work, gravimetric weight loss analysis was used. The corrosion rate or the rate of material removal as a consequence of the chemical action is an important corrosion parameter. This may be expressed as the corrosion penetration rate (CPR) or the thickness loss of material per unit of time. The formular for this calculation is

$$CPR = \frac{KW}{\rho At}$$

Where W is the weight loss after exposure time t, ρ and A represent the time, density and exposed specimen area respectively, and K is a constant. The magnitude of K depends on the system of unit used. The CPR is conveniently expressed in terms of either mil per year (mpy) or millimeter per year (mm/yr). In the first case K =534 to give the CPR in mpy (where 1mil = 0.001 inch) and W, ρ, A and t are specified in units of milligrams, grams per cubic centimeter, square inches and hours respectively [1]. A total of 57 specimens and three environments were used in this experiment. The environments were one mole hydrochloric acid solution (1MHCl), one mole sodium hydroxide (1MNaOH) solution and sea water. These environments were selected to represent common environments most aluminum alloys and their composites are normally exposed to while in service. In each environment, 19 specimens were immersed and one specimen withdrawn from the environment on seven days interval (i.e. 168 hours). The removed specimens were washed with detergent to remove greasy stains and corroded particles, rinsed in distilled water, cleaned, dried with acetone and in an open air. The final weight of each of the test specimens was determined using an electronic digital analytic weighing balance to enable calculation of corrosion penetration rate from weight loss data. The duration of the entire experiment was 42 days i.e. 1008 hours. Potentiostatic corrosion rate tests on the samples were done using model CH660E electrochemical analyzer. The equipment is a potentiostatic setup which records the corrosion rates of samples using open circuit potential against time (OCPT) and Tafel extrapolation plots to determine some corrosion parameters. In this experiment, cathodic slope, anodic slope, cathodic intercept, anodic intercept, limiting polarization, corrosion current, corrosion rate in mil per year, corrosion rate in Angstrom per minute and corrosion rate in gram per hour of samples immersed in one mole sodium hydroxide, one mole hydrochloric acid and sea water environments were calculated by the electrochemical analyzer. The potentiostat used in this work kept a set electrode potential (ie the material we are investigating constant) and it delivered the current which is instantaneously needed to hold the potential constant. The potentiostatic set-up shown below in figure 1 has three electrodes: 1. The working electrode, W ie the specimen to be investigated, 2.The counter electrode C, and 3. The reference electrode R. The reference electrode usually has an electrolytic connection to the working electrode through a salt bridge with a narrow tube near the working electrode.

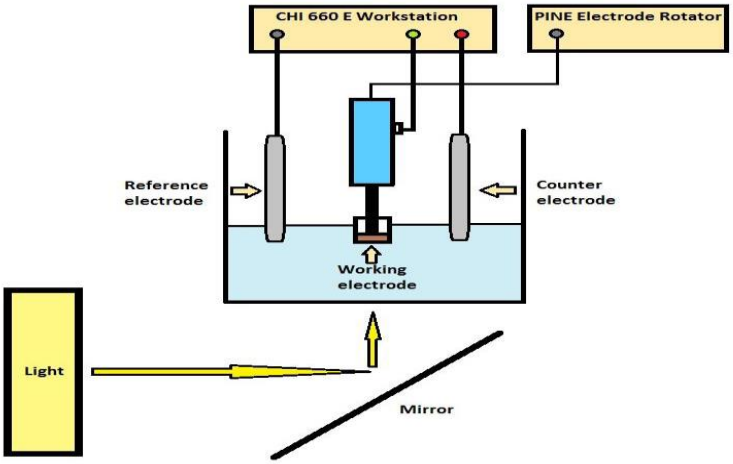

Fig 1: Potentiostat setup [1]

RESULTS AND DISCUSSIONS

The results of corrosion penetration rates of the composites and control sample evaluated in three different environments of one mole concentration each of hydrochloric acid solution (1MHCl), sodium hydroxide solution (1MNaOH) and sea water using gravimetric analysis method are presented in the figures below. Figure 1 is the corrosion rates (mpy) against the exposure time (hrs) of AA2618/SiC composites immersed in one mole concentration of hydrochloric acid solution (1MHCl) for 1008 hours. The result displayed active – passive trend throughout the experiment (i.e. high corrosion rate at the initial stage of the experiment and subsequently reduction in corrosion rate at the final stage of the experiment). This behavior is a common characteristic feature of a passivating metal. It also recorded the highest corrosion rate on the first point of exposure in the environment and subsequently the corrosion rates decreased gradually for the rest of the experiment. However, the rates of corrosion attack on the specimens showed that increase in the volume percent of silicon carbide (SiC) particles had deleterious effects on the corrosion resistance of these composites as the specimens with 30vol%, 25vol% were seen to exhibit high corrosion susceptibility while those of the control, 5vol% and 10vol% specimens showed low susceptibility to corrosion attack. The reason(s) for this behaviour can be attributed to the formation of anodic points at the interfaces between the matrix and silicon carbide (SiC) particles. This phenomenon promotes localized forms of corrosion like stress corrosion cracking SCC, pitting corrosion, galvanic corrosion, etc within the internal structures of the specimen. The more the percentages of these reinforcement particles increased within the matrix, the more the tendency for increase in localized forms of corrosion. Furthermore, the presence of these particles increased the dislocation density within the matrix of the composites by acting as points of infringements to dislocation movements in the matrices of the composites which are associated with particle clusters that generate high stress triaxiality in such regions [15]. The increase in dislocation density results in high stress levels within the composites. Consequent upon this, pits, voids, and flaws were seen on the morphology of these samples at the end of the experiment indicating that the samples suffered both uniform corrosion and other forms of localized corrosion. T. W Clyne and P.J Whithers reported that high corrosion susceptibility in the specimens with large weight percentage of ceramic particles was as a result of segregation of ceramic particles in the matrix which is very common in as-cast composites. This segregation promotes nucleation of pits by acting as anodic points which facilitated corrosion. However, surface variations due to the presence of these ceramic reinforcements in the matrix can also promote film flaws and hence increase pitting corrosion. Figures 2 and 3 are corrosion rates in mpy against exposure time (hours) for AA2618/fly ash and AA2618/TiC composites immersed in 1MHCl solution for 1008 hours respectively. The trend of the graphs also show active passive behaviour as displayed by figure 1, but the presence of these various volume percentage particles of fly ash and titanium carbide did not have effects on corrosion susceptibility of the composites. Surface morphology of the composites after the experiment did not show pit formation on the composites. Corrosion trend of AA2618/fly ash composites showed less corrosion susceptibility than the other composites. This implies that fly ash particles promote cathodic polarization as against titanium carbide (TiC) and silicon carbide (SiC) within the matrix when the composite is immersed in hydrochloric acid environment.

The active passive trend behaviour exhibited by these composites in dilute hydrochloric acid environment was reported by S.E. Ede et al. The report states that aluminum alloy reacts slowly with dilute hydrochloric acid but more rapidly with concentrated acid to displace hydrogen in the solutions. This implies that hydrochloric acid acts as a reducing agent that facilitates the formation of $AlCl_3$ in the solution. The rate of formation of this amphoteric salt is dependent on the molar concentration of the acid. Finally, the trend of corrosion behaviour of these composites and their alloys is in agreement with that of passivating metals in simulated environments. It shows initial high corrosion rate (active region) and then a gradual decrease in corrosion rate as the exposure time increases until a limit is attained when the corrosion rate is observed to be quite negligible i.e. until the onset of cathodic polarization of the alloy (passive regions). Figures 4, 5 and 6 show the corrosion behaviour of the composites and the alloy immersed in one mole sodium hydroxide solution (1MNaOH) for 1008 hours. The trends of corrosion rates of the composites were common. Highest corrosion attack was seen in figure 4 representing the corrosion behaviour of AA218/SiC composites. Though severe corrosion rates were observed in figures 5 and 6, the fly ash and titanium carbide addition did not promote corrosion attack on these composites. This behaviour is in line with that shown in figures 2 and 3 as earlier discussed. Figure 4 shows severe corrosion attack on the specimens. It is as a result of the reasons given in Figure 1. More reasons for this could also be the highly brittle, coarse and hard nature of SiC. When this refractory material is dispersed in the matrix of AA2618, it strains the matrix and promotes the formation of anodic points. This will therefore increase corrosion attack on the composites. Fly ash and titanium carbide particles are pliable, finer, slippery and less brittle. When used as reinforcement material, they tend to settle readily in the matrix of AA2618 without unduly straining the matrix. Moreover, their densities are lower than that of silicon carbide (SiC). These properties give them an edge over SiC which is denser, coarse and very brittle. Another reason that has contributed to severe corrosion attack of these composites in sodium hydroxide (NaOH) environments is that this environment is a strong electrolyte which ionizes completely in its solution. When it reacts with aluminum alloys/composites, it will readily dissolve to form sodium aluminates (III) with the evolution of hydrogen gas. The resultant hydroxides are amorphoteric and will re-dissolve in an excess of NaOH solution to form complex salt. This process keeps these composites in active state. This is the reason highest corrosion rate was recorded on the composites immersed in this environment

Figures 7, 8 and 9 represent corrosion rates (mpy) against time in hours for the composites immersed in sea water environment. In engineering applications of these composites, sea water environment plays vital roles. It is a common environment where ships, yachts, submarines, flying boats which most of their body components like hull is made of this composite etc are normally exposed to while in service. A close look at the graphs shows that they exhibit different trends compared to the previous graphs earlier discussed in other environments. Here corrosion rates were very small, less than one mpy. Corrosion rate is usually not particularly large in this environment because sea water contains a lot of non-aggressive salts like NaCl $MgCl_2.6H_2O$, $Na_2SO_4CaCl_2$, KCl, $NaHCO_3$ etc at different proportions. This implies that sea water is not an aggressive environment on these materials. Variation in volume percentages of these reinforcement particles has no effect on the corrosion susceptibility of the composites. Moreso, the strange increase in the corrosion rates towards the end of the experiment in sea water environment was as a result of the formation of weak oxide films called fouling or marine growth. These films are weak and porous, when the thickness of the deposited films became large on the surface of the specimens; they readily flaked off and exposed the specimens to active state. This phenomenon facilitated oxygen diffusion on specimen which was accompanied by increase in corrosion rates of the specimen. The development of this porous layer (fouling) or marine growth depends on the composition of the solution and the length of exposure. It can be seen from the graph that this development started after a prolonged exposure of the specimens in the environments i.e. towards the end of the experiment. Morphological appearance of the specimens after the experiment showed black coloured porous fouls that stuck on the specimens.

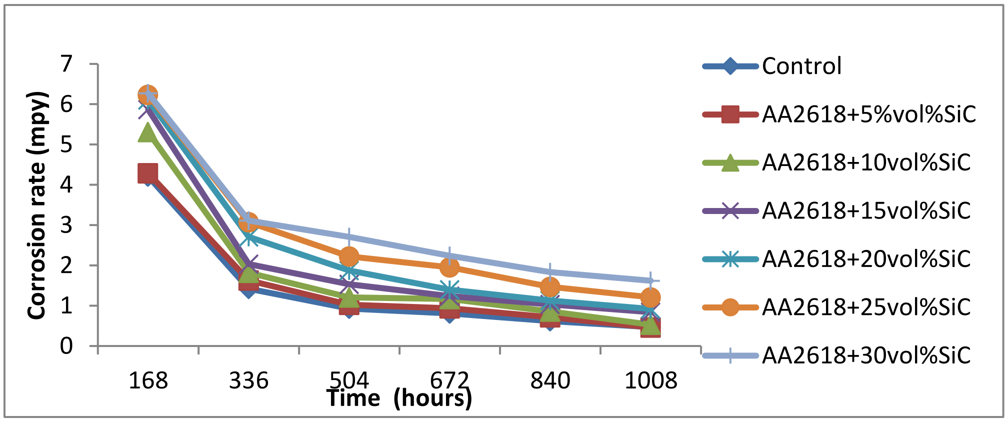

Figure 1: *Corrosion rate (mpy) vs exposure time (hrs) of AA2618/SiC immerse In 1MHCl solution using gravimetric analysis method*

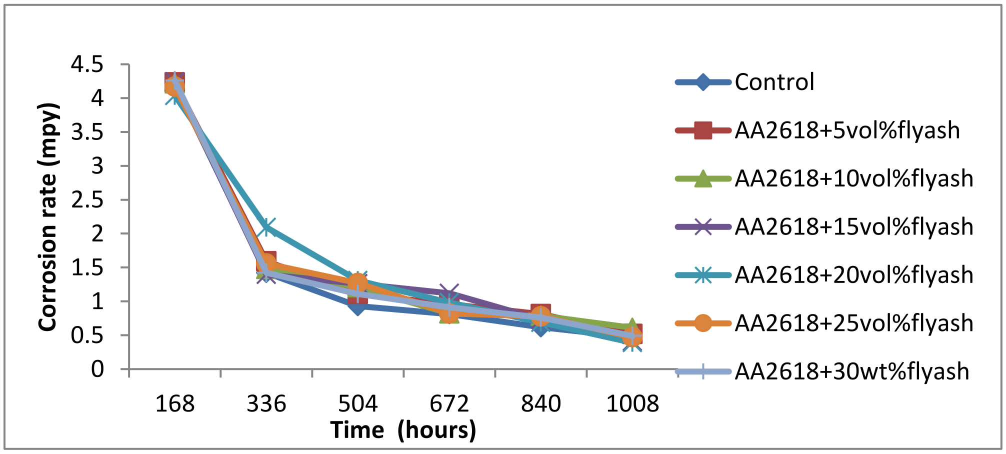

Figure 2: *Corrosion rate (mpy) vs exposure time (hrs) of AA2618/fly ash immersed*

in 1MHCl solution using gravimetric analysis metho

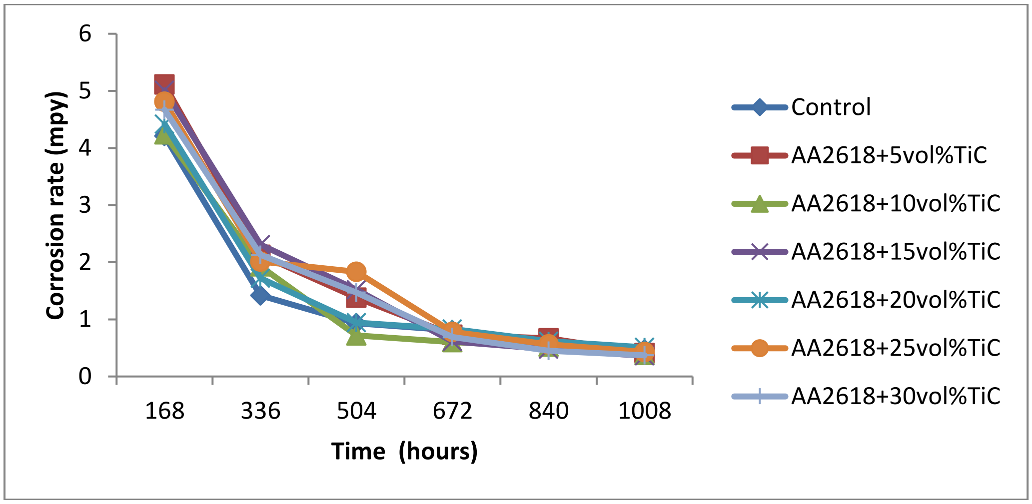

Figure 3: *Corrosion rate (mpy) vs exposure time (hrs) of AA2618/TiC immersed in 1MHCl solution using gravimetric analysis method*

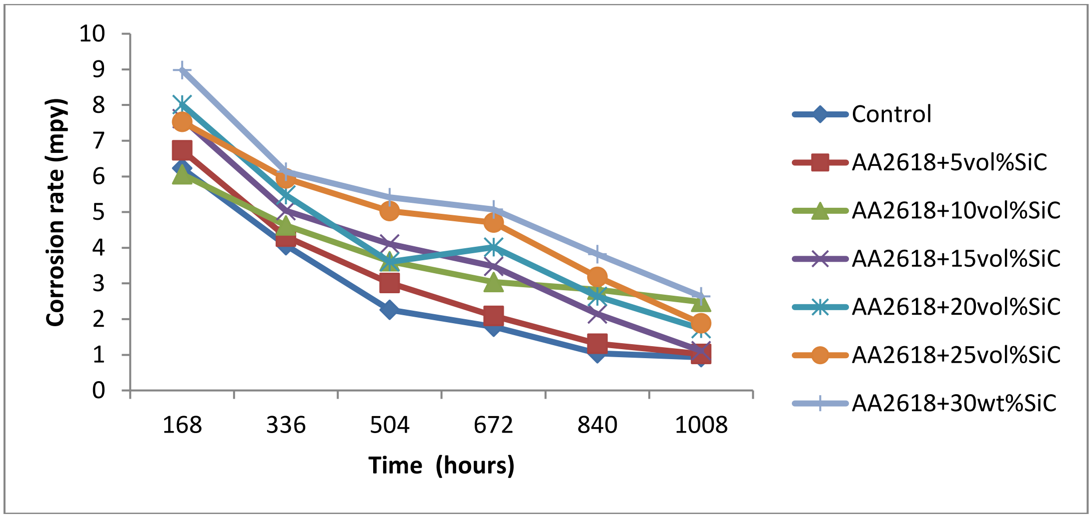

Figure 4: *Corrosion rate (mpy) vs exposure time (hrs) of AA2618/SiC immersed in 1MNaOH solution using gravimetric analysis method*

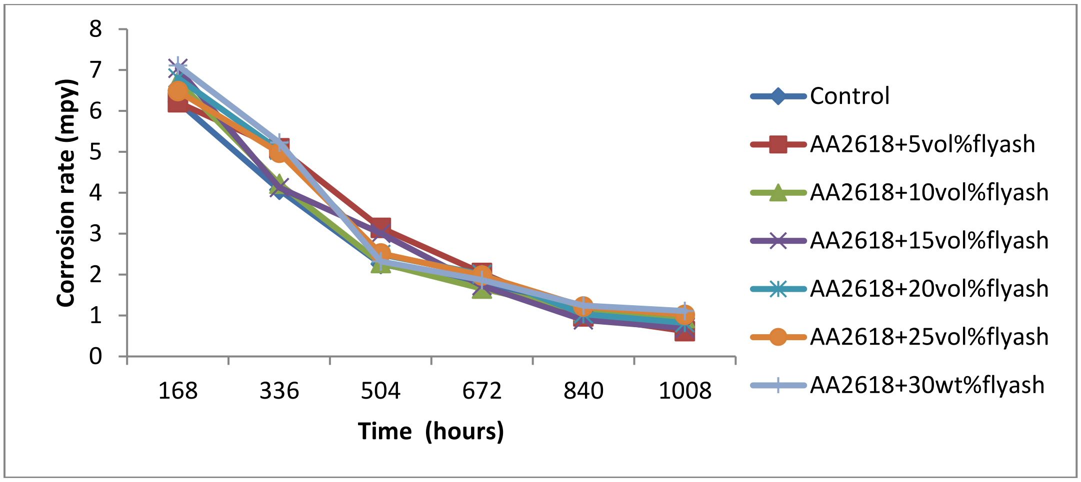

***Figure** 5: Corrosion rate (mpy) vs exposure time (hrs) of AA2618/fly ash immersed in 1MNaOH solution using gravimetric analysis method*

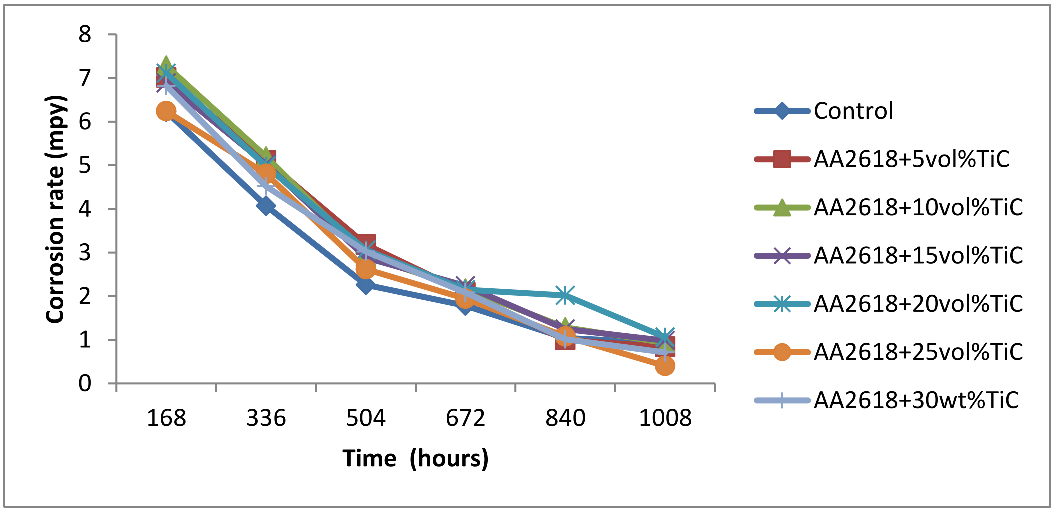

***Figure 6:** Corrosion rate (mpy) vs exposure time (hrs) of AA2618/TiC immersed in 1MNaOH solution using gravimetric analysis method*

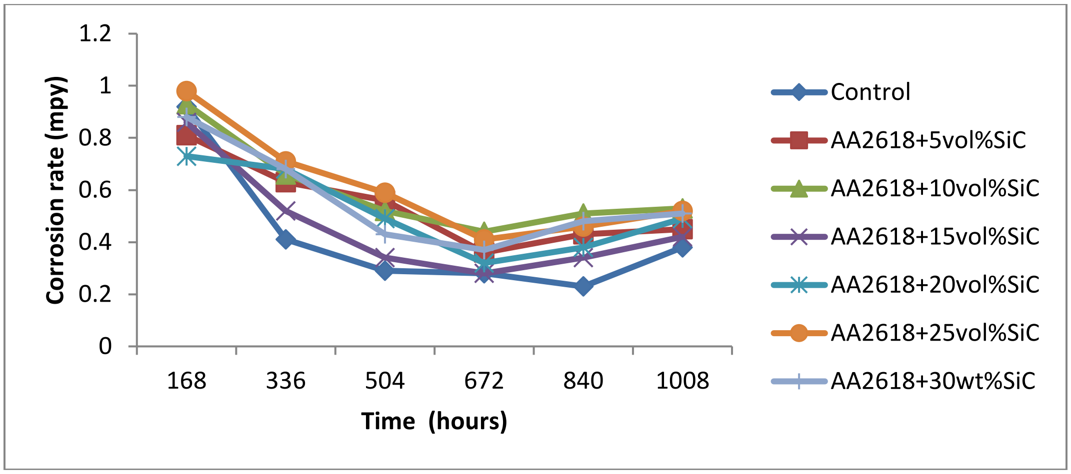

Figure 7: *Corrosion rate (mpy) vs exposure time (hrs) of AA2618/SiC immersed in sea water using gravimetric analysis method.*

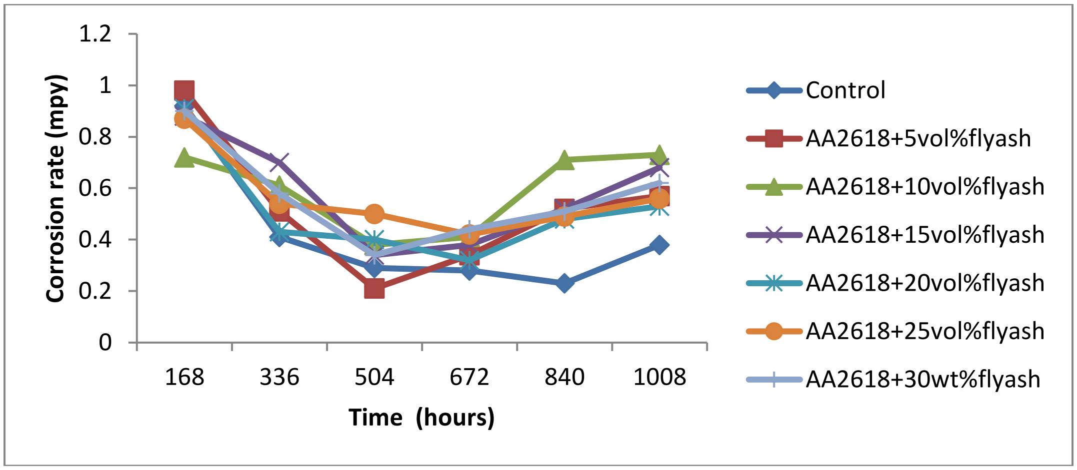

Figure 8: *Corrosion rate (mpy) vs exposure time (hrs) of AA2618/fly ash immersed in sea water using gravimetric analysis method*

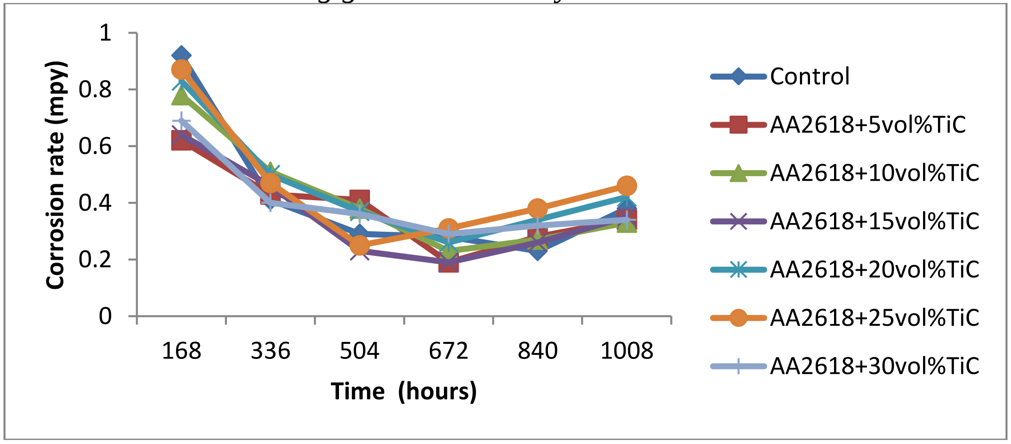

Figure 9*: Corrosion rate (mpy) vs exposure time (hrs) of AA2618/TiC immersed in sea water using gravimetric analysis method*

The results of corrosion data of the composite samples using potentiostat method are presented in table 1 below and they include cathodic slope, anodic slope, cathodic intercept, anodic intercept, limiting polarization, corrosion current, corrosion rates (mil/year), corrosion rate (Angs/min) and corrosion rate (gram/hour). Plots of corrosion rates of samples in mill per year are presented in figures 10, 11 and 12. The results are in conformity with the results of gravimetric analysis earlier discussed in this work. This indicates active passive trend behavior of the samples in the environments studied. Corrosion rate was highest in the sodium hydroxide environment followed by the hydrochloric acid environment while the least was sea water environment. The particulate addition in the sample had deleterious effects in sodium hydroxide environment while other environments did not show appreciable effects of this particulate addition on corrosion susceptibility of the samples. When a metal (except gold) is immersed in an aqueous solution, the oxide film tends to dissolve. If the solution is acidic or aggressive, the oxide film will dissolve completely leaving a bare metal surface which is said to be in active state (metal dissolution or more positive electrode potential). As the oxide free surface of the metals become exposed to the solution, positively charged metals ions tend to pass from the metals into the solution, leaving electrons behind on the metal. The accumulation of negative charge on the metal due to the residual electron leads to an increase in the potential difference between the metal and the solution. This potential difference of the metal becomes more negative and thus more metal deposition is encouraged than dissolution. In this case, passivation is said to set in (metal deposition). The entire process is called active passive behavior which had earlier been explained in this work. Therefore, the potentiostatic electrochemical corrosion rates trend of the composites samples are in conformity with the gravimetric corrosion rates process earlier discussed.

Table 1: Potentiostat Corrosion Rates Data

SN	Specimen samples	Cathodic Slope (1/V)	Anodic slope (1/V)	Cathodic. Intercept (log i)	Anodic Intercept (log i)	Limiting Polarization R (ohm)	Corrosion current (Amp)	Corrosion Rate (mill/yr)	Corrosion Rate (Angs/mi)	Corrosion Rate (gram/hr)
1.	Control (sea water)	5.482	5.545	-5.925	-5.924	24422	$1.614e^{-006}$	$3.833e^{-001}$	$1.852e^{-001}$	$1.807e^{-007}$
2.	Control (1 MNaOH)	6.567	5.593	-5.725	-5.596	13915	$2.570e^{-006}$	$6.101e^{-001}$	$2.948e^{-001}$	$2.876e^{-007}$
3.	Control (1M HCl)	5.189	5.455	-5.967	-5.992	30778	$1.3287e^{-006}$	$3.151e^{-001}$	$1.523e^{-001}$	$1.486e^{-007}$
4.	5vol% FA (sea water)	8.465	8.359	-5.999	-5.983	14498	$1.783e^{-006}$	$4.233e^{-001}$	$2.045e^{-001}$	$1.996e^{-007}$
5.	5% vol FA (1MNaOH)	6.188	7.064	-5.803	-5.814	14496	$1.882e^{-006}$	$4.468e^{-001}$	$2.159e^{-001}$	$2.107e^{-007}$
6.	5% vol FA (1M HCl)	6.049	6.647	-5.871	-5.894	17432	$1.618e^{-006}$	$3.842e^{-001}$	$1.857e^{-001}$	$1.811e^{-007}$
7.	25% vol FA (sea water)	5.140	5.281	-6.103	-6.107	40623	$1.027e^{-006}$	$2.438e^{-001}$	$1.178e^{-001}$	$1.150e^{-007}$
8.	25% vol FA (1MNaOH)	6.323	4.450	-5.685	-5.451	13389	$3.043e^{-006}$	$7.224e^{-001}$	$3.491e^{-001}$	$3.406e^{-007}$
9.	25% vol FA (1M HCl)	5.598	6.226	-5.863	-5.902	20493	$1.794e^{-006}$	$4.260e^{-001}$	$2.059e^{-001}$	$2.008e^{-007}$
10.	25% vol TiC (1MNaOH)	5.239	5.641	-5.906	-5.924	22955	$1.741e^{-006}$	$4.133e^{-001}$	$1.949e^{-001}$	$1.949e^{-007}$
11.	25% vol TiC (sea water)	5.868	6.362	-5.877	-5.884	22191	$1.602e^{-006}$	$3.803e^{-001}$	$3.838e^{-001}$	$1.793e^{-007}$
12.	25% vol TiC	5.553	6.169	-5.858	-5.898	21864	$1.696e^{-006}$	$4.028e^{-001}$	$1.946e^{-001}$	$1.899e^{-007}$

	(1M HCl)									
13.	25% vol SiC (sea water)	6.659	6.551	-5.943	-5.914	20215	$1.628e^{-006}$	$3.866e^{-001}$	$1.868e^{-001}$	$1.823e^{-007}$
14.	25% vol SiC (1MNaOH)	5.343	3.107	-5.566	-5..316	12707	$4.049e^{-006}$	$9.614e^{-001}$	$4.646e^{-001}$	$4.533e^{-007}$
15.	25% vol SiC (1M HCl)	2.801	6.346	-5.854	-5.854	18914	$1.893e^{-006}$	$4.493e^{-001}$	$2.171e^{-001}$	$2.118e^{-007}$
16.	15% vol TiC (1M HCl)	5.011	5.134	-6.098	-6.095	43527	$9.846e^{-007}$	$2.388e^{-001}$	$1.130e^{-001}$	$1.102e^{-007}$
17.	15% vol SiC (sea water)	5.637	5.841	-5.925	-5.925	23908	$1.584e^{-006}$	$3.762e^{-001}$	$1.828e^{-001}$	$1.776e^{-007}$
18.	15% vol SiC (1MNaOH)	6.037	6.853	-5.832	-5.831	18463	$1.827e^{-006}$	$4.338e^{-001}$	$2.096e^{-001}$	$2.045e^{-007}$
19.	15% vol SiC (1M HCl)	5.096	5.436	-5.436	-5.986	30921	$1.335e^{-006}$	$3.170e^{-001}$	$1.532e^{-001}$	$1.494e^{-007}$
20.	15% vol FA (sea water)	5.272	6.186	-5.980	-6.008	32215	$1.178e^{-006}$	$2.797e^{-001}$	$1.352e^{-001}$	$1.319e^{-007}$
21.	15% vol FA (1MNaOH)	5.712	8.176	-5.860	-6.010	20010	$1.565e^{-006}$	$3.715e^{-001}$	$1.795e^{-001}$	$1.751e^{-007}$
22.	15% vol FA (1M HCl)	5.443	5.227	-6.070	-6.002	34490	$1.182e^{-006}$	$2.805e^{-001}$	$1.356e^{-001}$	$1.323e^{-007}$
23.	10% vol TiC (sea water)	5.315	5.751	-5.929	-5.902	36075	$1.507e^{-006}$	$3.577e^{-001}$	$1.720e^{-001}$	$1.687e^{-007}$
24.	10% vol TiC (1MNaOH)	5.185	4.284	-5.623	-5.44	12603	$8.111e^{-006}$	$8.111e^{-001}$	$3.920e^{-001}$	$3.824xe^{-007}$
25.	5% vol TiC (1MNaOH)	3.658	1.500	-5.378	-5.149	10799	$7.809e^{-006}$	$1.854e^{-006}$	$8.960e^{-001}$	$8.741e^{-007}$
26.	5% vol TiC (1M HCl)	5.620	6.023	-5.915	-5.933	23580	$1.584e^{-006}$	$3.760e^{-001}$	$1.817e^{-001}$	$1.773e^{-007}$
27.	5% vol SiC (sea water)	5.584	5.769	-6.019	-6.029	31793	$1.205e^{-006}$	$2.860e^{-001}$	$1.382e^{-001}$	$1.348e^{-007}$
28.	5% vol SiC (1MNaOH)	7.146	6.648	-5.618	-5.587	3248	$2.82\ e^{-006}$	$5.338e^{-001}$	$2.680e^{-001}$	$2.617xe^{-007}$
29.	5% vol SiC (1M HCl)	5.130	5.450	-6.013	-6.045	34023	$1.208e^{-006}$	$2.868e^{-001}$	$1.386e^{-001}$	$1.352e^{-007}$
30.	5% vol TiC (sea water)	5.571	5.107	-6.050	-6.033	32611	$1.249e^{-006}$	$2.964e^{-001}$	$1.433e^{-001}$	$1.398e^{-007}$

NB: *FA=Fly Ash, TiC =Titanium Carbide, SiC= Silicon Carbide*

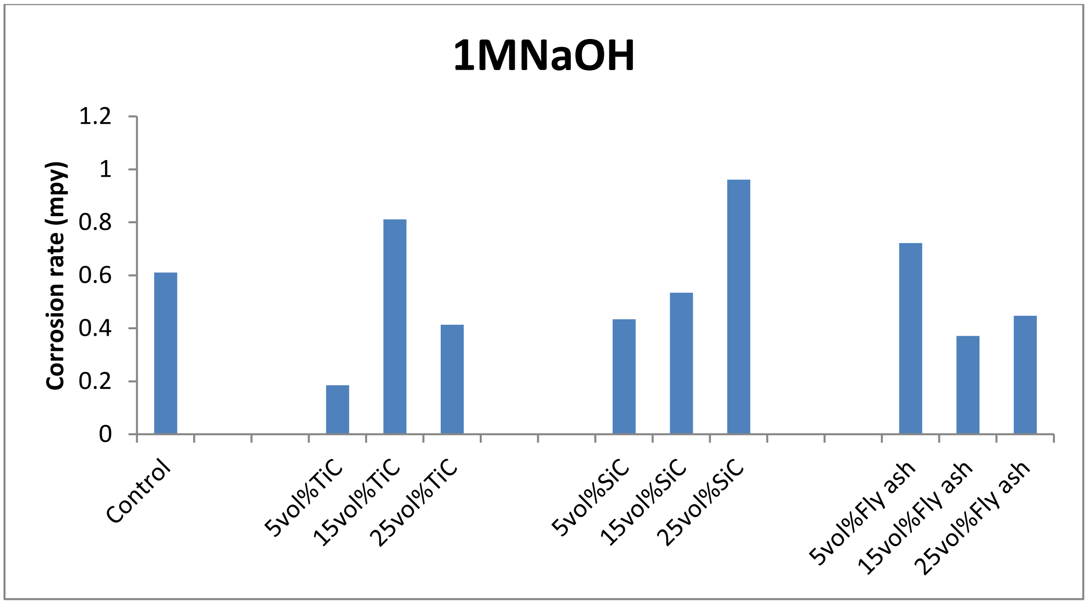

Figure 10: *Corrosion rate in (mil/year) of composite samples immersed in1MNaOH environment for one hour using potentiostat analysis method.*

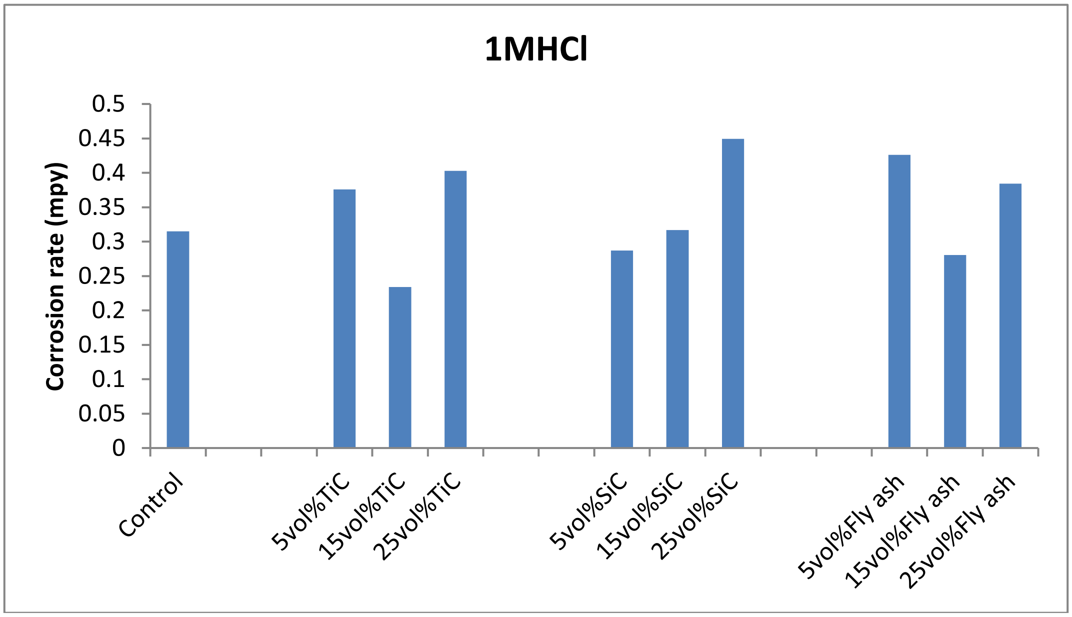

Figure 11*: Corrosion rate in (mil/year) of composite samples immersed in 1MHCl environment for one hour using potentiostat analysis method*

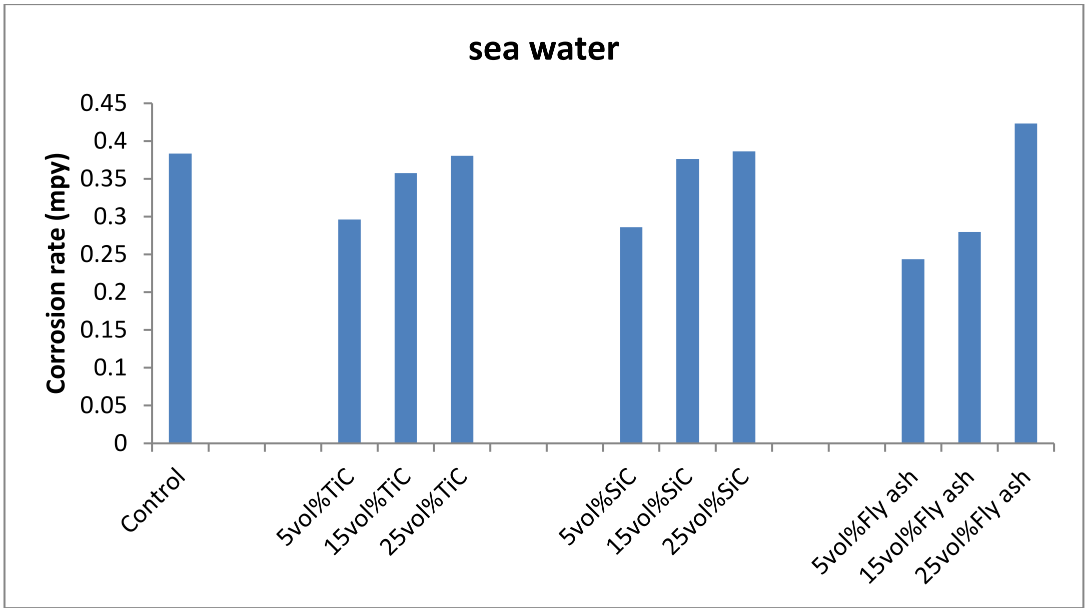

Figure 12: *Corrosion rate in (mil/year) of composite samples immersed in sea water environment for one hour using potentiostat analysis method.*

CONCLUSION

The effects of various reinforcements on the corrosion resistance of AA2618 matrix composites show that corrosion penetration rate tests of the composites and control sample indicated that SiC particulate reinforcement has deleterious effects on the corrosion resistance of the composites as the volume percent addition of these particles increased. The reason(s) for this behaviour can be attributed to the formation of anodic points at the interfaces between the matrix and silicon carbide (SiC) particles. This phenomenon promotes localized forms of corrosion like stress corrosion cracking SCC, pitting corrosion, galvanic corrosion, etc within the internal structures of the specimen. The more the percentages of these reinforcement particles increased within the matrix, the more the tendency for increase in localized forms of corrosion. Furthermore, the presence of these particles increased the dislocation density within the matrix of the composites by acting as points of infringements to dislocation movements in the matrices of the composites which are associated with particle clusters that generate high stress triaxiality in such regions. Addition of fly ash particles did not promote appreciable corrosion susceptibility within the matrix of the alloy in all the environments in which corrosion rate tests were conducted. This is because of the dissolution of fly ash particles in the matrix of the alloy which promotes cathodic polarization as against titanium carbide (TiC) and silicon carbide (SiC) that did not dissolve in AA2618 matrix.

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