



Corrosion Behaviour of Aluminium-Iron (Al-Fe) Metal Matrix Composite (MMC) Reinforced with Silicon Carbide (SiC) Particles in Various Media Concentration of Tetraoxosulphate IV Acid (H₂SO₄)

Anyalebechi, Onyebuchi^{1*}, Ogobiri E. Godwin² and Opuaye, Reginald³

¹*Department of Physics, University of Port Harcourt, Port Harcourt, Rivers State, Nigeria.*

²*Department of Physics, Niger Delta University, Wilberforce Island, Amassoma, Bayelsa State, Nigeria.*

³*Department of Computer Science, University of Calabar, Calabar, Cross River State, Nigeria.*

Authors' contributions

This work was carried out in collaboration between all authors. Author AO designed the study, managed the literature searches, wrote the protocol and wrote the first draft of the manuscript. Author OEG managed the analyses of the study and author OR performed the statistical analysis. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IRJPAC/2017/39461

Editor(s):

(1) Hao-Yang Wang, Department of Analytical, Shanghai Institute of Organic Chemistry, Shanghai Mass Spectrometry Center, China.

Reviewers:

(1) Michael Niame Nwigbo, Ken Saro-Wiwa Polytechnic, Nigeria.

(2) Makanjuola Oki, Landmark University, Nigeria.

Complete Peer review History: <http://www.sciencedomain.org/review-history/23423>

Original Research Article

Received 6th December 2017

Accepted 8th February 2018

Published 5th March 2018

ABSTRACT

The current study focused on the investigation of the corrosion behaviour of aluminium-iron (Al-Fe) Metal matrix Composite (MMC) reinforced with silicon carbide (SiC) particles in various media concentration of tetraoxosulphate iv acid (H₂SO₄). The Al/Fe materials were combined in the various proportion of 10% wt Al/87.5% wt Fe, 15%wt Al/80% wt Fe and 20%wt Al/73% wt Fe respectively. They were fed into an electric furnace and mechanically stirred to form a fine vortex. The respective molten compositions were reinforced with silicon carbide (SiC) particles. The fabricated composite were of the composition; 2.5% SiC/10% wt Al / 87.5% wt Fe, 5%wtSiC/15%wt Al/80% wt Fe and 7%wt SiC/20%wt Al/73% wt Fe. The materials were subjected to weight loss analysis and the results were analyzed using regression analysis. Micro-structural scans showed signs of porosity and the weight loss corrosion test result expressed reduction in corrosion resistance with SiC addition.

*Corresponding author: E-mail: onyebu@yahoo.com;

Keywords: Corrosion; iron; analysis; regression; statistics.

1. INTRODUCTION

1.1 Background of Study

Corrosion is mostly a naturally occurring phenomenon commonly defined as the deterioration of a substance or its properties because of a reaction with contents in its environment. Like other natural hazards such as earthquakes, or severe weather disturbances, corrosion can cause dangerous and expensive damage to everything from automobiles, home appliances drinking water system, pipeline of various categories, bridges, glass waves, metals of different shades and buildings. It has been shown that virtually everything responds to corrosion impact from metallic and nonmetallic materials to living things in one form transformation in either shapes or content [1-2].

Corrosion control and treatment are of vital concern because corrosion of equipment and primary structures has a great effect on the operational and structural integrity of systems including economy. Time proven methods for preventing and controlling corrosion depend on the specific nature of the material, environmental factors such as soil resistivity, humidity, acidity or alkalinity of the conducting medium (PH factor), temperature, active of biological organism (precisely anaerobic bacterial), variation in composition of the corrosive medium and water intrusion [2]. In general, the severity of the corrosion damage cannot be overemphasized. Therefore, it is important to make corrosion prevent and control a priority in Material selection and usage in various fields of science and engineering. Among the methods employed in corrosion control and prevention are; organic and metallic protective coating, corrosion resistant alloys, plastic and polymer, corrosion inhibitors and cathodic protection used in pipeline, underground storage tanks and shore structures that create an electrochemical cell in which the surface to be protected in the cathode and corrosion reactions are mitigated [3].

One of the best procedures for corrosion control is to minimize the potential for corrosive attack while designing the material and equipment through the use of corrosive resistant materials and avoiding dissimilar metal couple. Metal matrix composite is a material design technique aimed at improving material quality and corrosion resistance. A composite is a material having two or more distinct constituents, whose corrosion is affected by; the specificity of a given corrosion toward the individual components and galvanic interactions between them [1,4]. Considering the importance of composite, [5] stressed the need to assess composite in environments in which they may be likely operating. In line with the suggestion, some researchers have studied composite behaviour in a number of environments. [1] studied the reduction of corrosion in various concentrations of hydrochloric acid by compositional design. Their findings showed that 30wt%Al/ 70wt%Fe composition reduced corrosion by 50%. [4] evaluated the corrosion resistance of aluminium alloy matrix 2.5% particulate glass reinforced composite in HCl, NaOH and NaCl solution. They concluded that the composition cannot be used in NaOH and HCl environments but NaCl. [6] studied the corrosion susceptibility of squeeze cast Aluminum based metal composites. The work submitted that the rate of corrosion attack was proportional to the volume fraction of the reinforcement agent alumina. Other relevant works are; [7-11].

1.2 Aim of Study

The aim of this study is to evaluate the corrosion behaviour of Aluminum/iron metal matrix composite, reinforced with Silicon carbide (SiC) particulate in various media concentration of tetraoxosulphate IV acid solution.

2. MATERIALS AND METHODS

2.1 Materials

The materials used are Aluminum alloy with determined chemical composition of;

Al	Cu	Mg	Si	Fe	Mn	Zn	Ti	Cr	Ni	K
92.01	0.06	0.57	6.58	0.16	0.06	0.20	0.14	0.20	0.01	0.01

Iron (Fe) material and silicon carbide (SiC) particles used as reinforcing material other were materials for weight loss analysis, electric furnace and string rod, electronic weighing machine, mould for fabrication.

2.2 Procedure

The Al/Fe material were combined in various proportion by 10%wt Al/ 87.5%wt Fe, 15%wtAl/80%wt Fe and 20%wtAl/ 73%wt Fe respectively by weight in gram. They were separately fed into an electric furnace of 1000°C capacity. The metal composition was stirred with

the help of mechanical stirrer to form a fine vertex. The silicon carbide particles preheated was added to the molten metal composite. The molten mixture is then stirred continuously at 320 censuses. The final molten liquid metal of Al/Fe/SiC is poured into the mould which has preheated at 400°C. The various fabrications composite was at composite 2.5%wtSiC/ 10%wt Al/ 87.5%wtFe, 5%wtSiC/ 15%wtAl/80%wtFe and 7%wtSiC/ 20%wtAl/ 73wtFe respectively. The various fabricated composite was subjected to weight loss corrosion test using various concentration of H₂SO₄ of 0.1m, 0.5m and 1.0m respectively.



Fig. 1.1. Electronic weighing machine



Fig. 1.2. Electric sandpaper machine



Fig. 1.3. Micrograph of 2.5%wt.sic/10%wt.Al/87.5%wt.Fe

3. RESULTS AND DISCUSSION

The results of this work are as presented in the Tables 1-3 and Figs. 2.1-2.6.

Table 1. Specimen (2.5%wt sic/ 10%wt Al/ 87.5%wt Fe) in 0.1m H₂SO₄

Time (hours)	Initial weight (g) wi	Final weight (g) wf	Weight loss Δw=wi-wf	%weight loss $\frac{\Delta w}{w_i} \times 100$	Change in weight wi-Δw	Log (wi-Δw)
24	34.8560	33.9253	0.9307	2.6700	33.9253	1.5305
48	34.8560	33.1515	1.7045	4.8900	33.1515	1.5202
72	34.8560	32.8553	2.0007	5.7400	32.8533	1.5166
96	34.8560	32.6148	2.2412	6.4300	32.6148	1.5134
120	34.8560	32.4160	2.4400	7.0000	32.6160	1.5107
144	34.8560	31.8235	3.0325	8.7000	31.8235	1.5027
168	34.8560	30.4990	4.3570	12.5000	30.4990	1.4883

Regression Analysis: Log versus Time (hrs)

The regression equation is

$$\text{Log} = 1.536 - 0.000249 \text{ Time (hrs)}$$

Model Summary

S	R-sq	R-sq(adj)
0.0040026	92.60%	91.12%

Analysis of Variance (ANOVA)

Source	DF	SS	MS	F	P
Regression	1	0.0010020	0.0010020	62.54	0.001
Error	5	0.0000801	0.0000160		
Total	6	0.0010821			

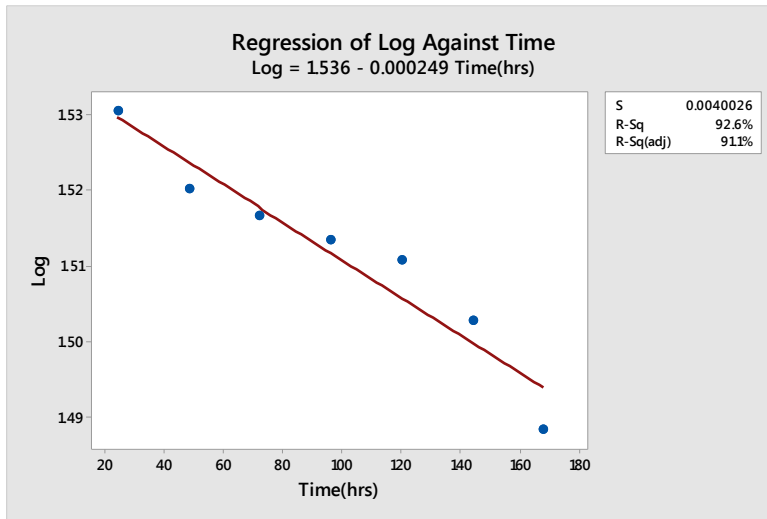


Fig. 2.2. Regression of log versus time (hrs)

Regression Analysis: %Weight Loss versus Time (hrs)
 The regression equation is
 %Weight Loss = 1.366 + 0.05710 Time (hrs)

Model Summary

S	R-sq	R-sq(adj)
1.04970	90.52%	88.62%

Analysis of Variance (ANOVA)

Source	DF	SS	MS	F	P
Regression	1	52.5806	52.5806	47.72	0.001
Error	5	5.5093	1.1019		
Total	6	58.0899			

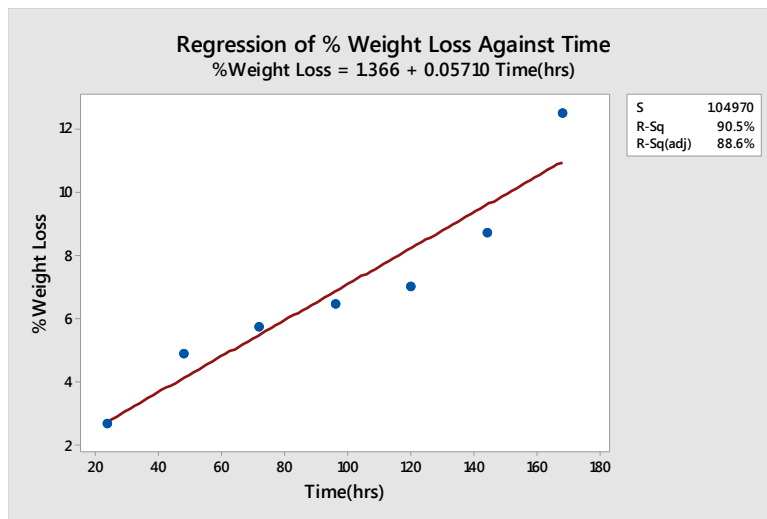


Fig. 3.2. Regression of %weight loss versus time (hrs)

Table 2. Specimen (2.5%wt sic/ 10%wt Al/ 87.5%wt Fe) in 0.5m H₂SO₄

Time (hours)	Initial weight (g) wi	Final weight (g) wf	Weight loss Δw=wi-wf	%weight loss $\frac{\Delta w}{wi} \times 100$	Change in weight wi-Δw	Log (wi-Δw)
24	28.4510	27.5975	0.8535	3.0000	27.5975	1.4409
48	28.4510	27.0284	1.4226	5.0000	27.0184	1.4263
72	28.4510	26.6870	1.7640	6.2000	26.6870	1.4263
96	28.4510	26.2318	2.2192	7.8000	26.2318	1.4188
120	28.4510	26.0371	2.4183	8.5000	26.0327	1.4155
144	28.4510	25.7766	2.6744	9.4000	25.7766	1.4112
168	28.4510	25.3214	3.1296	11.0000	25.3214	1.4035

Regression Analysis: Log versus Time (hrs)

The regression equation is

$$\text{Log} = 1.442 - 0.000228 \text{ Time (hrs)}$$

Model Summary

S	R-sq	R-sq(adj)
0.0031130	94.54%	93.44%

Analysis of Variance (ANOVA)

Source	DF	SS	MS	F	P
Regression	1	0.0008382	0.0008382	86.50	0.000
Error	5	0.0000485	0.0000097		
Total	6	0.0008867			

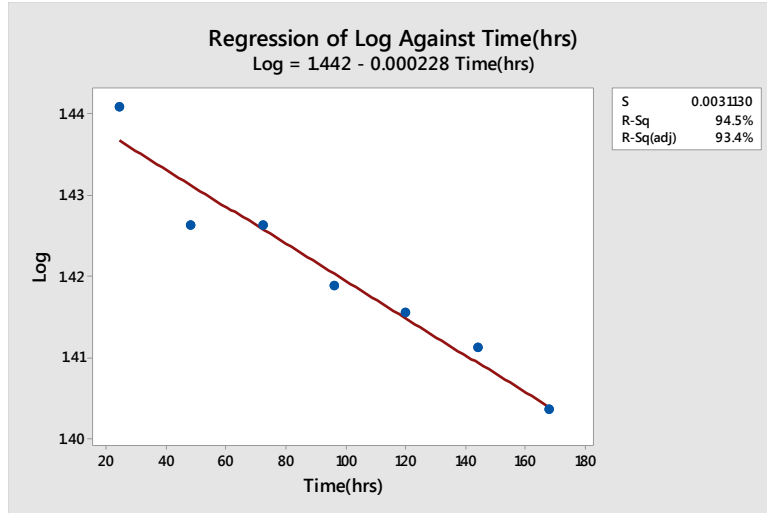


Fig. 2.4. Regression of log versus time (hrs)

Regression Analysis: %Weight Loss versus Time (hrs)

The regression equation is

$$\% \text{Weight Loss} = 2.257 + 0.05223 \text{ Time (hrs)}$$

Model Summary

S	R-sq	R-sq(adj)
0.393428	98.27%	97.93%

Analysis of Variance (ANOVA)

Source	DF	SS	MS	F	P
Regression	1	44.0004	44.0004	284.27	0.000
Error	5	0.7739	0.1548		
Total	6	44.7743			

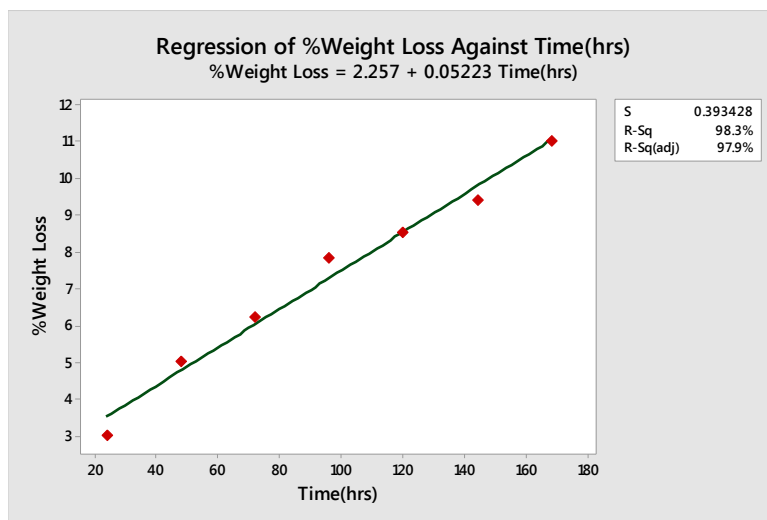


Fig. 2.5. Regression of %weight loss versus time (hrs)

Table 3. Specimen (2.5%wt sic/ 10%wt Al/ 87.5%wt Fe) in 1.0m H₂SO₄

Time (hours)	Initial weight (g) wi	Final weight (g) wf	Weight loss Δw=wi-wf	%weight loss $\frac{\Delta w}{wi} \times 100$	Change in weight wi-Δw	Log (wi-Δw)
24	33.6712	32.2223	1.4479	4.3000	32.2223	1.5082
48	33.6712	31.7519	1.9193	5.7000	31.7519	1.5018
72	33.6712	31.3816	2.2896	6.8000	31.3816	1.4987
96	33.6712	30.9775	2.6937	8.0000	30.7081	1.4872
120	33.6712	30.7081	2.9631	8.8000	30.7081	1.4830
144	33.6712	30.4051	3.2661	9.7000	30.4051	1.4737
168	33.6712	29.7653	3.9059	11.6000	29.7653	1.4702

Regression Analysis: Log versus Time (hrs)

The regression equation is

$$\text{Log} = 1.516 - 0.000277\ \text{Time (hrs)}$$

Model Summary

S	R-sq	R-sq(adj)
0.0019540	98.48%	98.17%

Analysis of Variance (ANOVA)

Source	DF	SS	MS	F	P
Regression	1	0.0012342	0.0012342	323.25	0.000
Error	5	0.0000191	0.0000038		
Total	6	0.0012533			

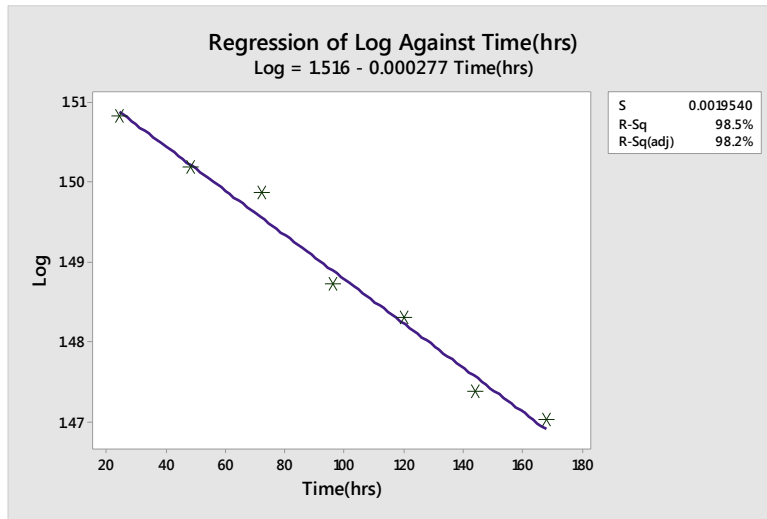


Fig. 2.6. Regression of log versus time (hrs)

Regression Analysis: %Weight Loss versus Time (hrs)

The regression equation is

$$\% \text{Weight Loss} = 3.286 + 0.04747 \text{ Time (hrs)}$$

Model Summary

S	R-sq	R-sq(adj)
0.280688	98.93%	98.71%

Analysis of Variance (ANOVA)

Source	DF	SS	MS	F	P
Regression	1	36.3432	36.3432	461.29	0.000
Error	5	0.3939	0.0788		
Total	6	36.7371			

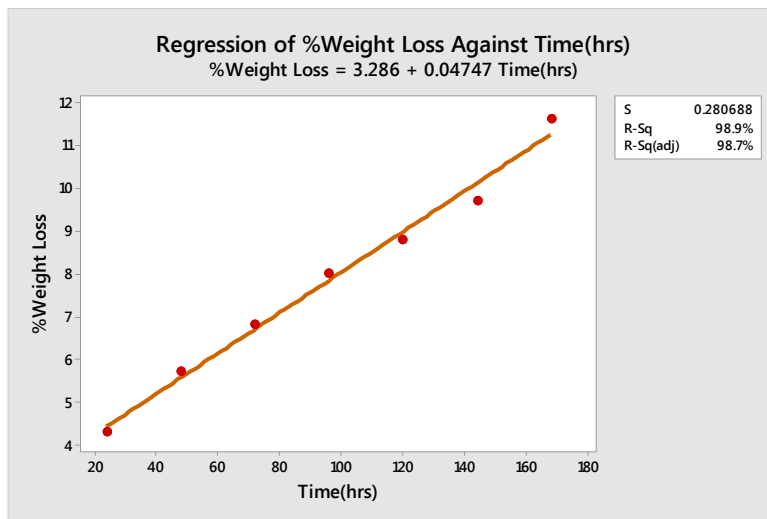


Fig. 2.7. Regression of %weight loss versus time (hrs)

3.1 Discussion

The graphs of $\log(w_1 - \Delta w)$ plotted against time as shown in Figs. 2.1, 2.3 and 2.5 above show a straight line indicating a first-order reaction kind of corrosion mechanism. The rate is found to be faster at the initial time, arising from quick depletion of dissolved oxygen (O_2) and possible temperature variation as the kinetic of the reactions are affected by the ambient environmental conditions. This is supported by the result of the regression analysis for the same $\log(w_1 - \Delta w)$ with time which gave a regression of equation of:

$$y = 1.536 - 0.000249x \quad (\text{eqn. 3.1})$$

Indicating that reactivity was reducing with time. The reaction rate depends on the composition and the temperature of the reacting mixture [8]. This observed trend did not change remarkably throughout the composites. The graph of percentage weight loss i.e. %weight loss $(\frac{\Delta w}{w_i} \times 100)$ against time (see Figs. 2.2, 2.4 and 2.6 above) was linearly increasing with an increase in SiC addition. The tendency for weight loss to increase with concentrate is obvious, initially without the addition of SiC, given that Aluminum (Al) dissolves in diluted mineral acid to liberate Hydrogen, also in Sodium Hydroxide (NaOH) solution. Again Fe/Al are amphoteric slightly, hence, the observed behavior was further enhanced by SiC addition. This is in line with [9], observation on issue of porosity in metal matrix composite (MMCs). [11] noted that in aqueous solution silicon carbide can serve as an inert electrode for proton or oxygen reduction depending on the SiC type, galvanic corrosion with aluminum is possible. The extent of the galvanic corrosion is strongly dependent on the type of SiC reinforcement. The electrical resistivity of SiC depends on its purity. Pitting attack is reported to be the major form of corrosion in SiC/ aluminum MMCs. The resolution here is further buttressed by [12] who noted that porosity in cast metal matrix composite (MMC) has been known as a defect affecting the enhancement of strength, particularly in particle reinforced MMC. The presence of porosity decreased the mechanical properties of cast MMC as the failure process is initiated from the void formed.

The composite behaviour is characterized by pitting attack in the presence of H_2SO_4 . This is in support of the finding of [13]. Therefore, it is likely

that in the homogenous structure of metal matrix composite (MMC) are responsible and must be considered in designing a corrosion protection system. This inhomogeneous tendency is made obvious by the presence of SiC particles as a reinforcement material. [13] study has shown that sliding wear, slurring, erosive wear and corrosive wear of an aluminium-based metal matrix reinforced with SiC particles resistance were considerably improved with the addition of SiC particles whereas composite corrosion resistance decreased.

Emphasis on SiC addition becomes strong, giving the submission of the findings of [1] that after metal matrix composite reduced corrosion by 50%. Therefore, in the present study, it can be submitted in line with [13] that the observed decrease in composition resistance of the composite was a direct consequent of SiC addition which gives rise to porosity and formation of the remarkable void which reduced cohesion and inter mechanical failures.

4. CONCLUSION

The study of the corrosion behaviour of aluminium-iron (Al-Fe) metal matrix composite (MMC) reinforced with silicon carbide (SiC) particles in various concentrations of H_2SO_4 showed a decrease in corrosion resistance of the composite with the addition of SiC. This suggests that the SiC addition enhanced porosity formation, creating a void which leads to easy mechanical failure.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Anyalebechi O, Owate IO, Avwiri G. reduction of corrosion in carious concentration of hydrochloric acid by compositional design. Academic Journals. 2013;8(27):1328-1333.
2. Koch HG, Moser M, Schimz KL, Muller M. The Integration of YidC into the Cytoplasmic membrane of Escherichia coli requires the signal recognition particles, SecA and SecYEG. J. Biol. Chem. 2002; 277:5715-5718.
3. Winston R. Revie, Uhlig H. Herbert. Corrosion and corrosion control: An introduction to corrosion science and

- engineering. John Wiley & Sons Inc. Publication; 2008.
4. Ihom AP, Nyior GB, Nor IJ, Segun S, Ogbodo J. Evaluation of the corrosion resistance of aluminum alloy matrix 12.5% particulate glass reinforced composite in various media. *International Journal of Science and Technology*. 2012;1(10):560-568.
 5. Fontana G. Mars. *Corrosion engineering*. McGraw-Hill Book Company; 1987.
 6. Ogbonna AI, Asoegwu SN, Okebanama PC. Corrosion susceptibility of squeeze cast Al-Based metal composites. *J. Corrosion Science Technology*. Vol. 1.1 nCA Press. University of South Florida, Florida; 2004.
 7. Darvishi A, Maleki A, Alabaki MM, Zargami M. the mutual effect of iron and manganese on microstructure and mechanical properties of Aluminum- silicon Alloy. *Mjom*. 2010;16(1):11-24.
 8. Owate IO, Ezi CW, Awiri G. Impact of environmental condition on sub-surface storage tanks. *Journal of applied Science and Environmental Management*. 2012; 6(2):79-83.
 9. Adesosun SO, Akpan EI, Sekunowo OI, Ayoola WA, Balogun SA. Mechanical characteristic of 6063 aluminum steel dust composite. *ISSN Mechanical Engineering*; 2012. Article ID 461853. DOI: 5402/2012/461853
 10. Asuke F, Yaro SA, Oloche OB. Propargyl as corrosion inhibitor for Al-5%Si/15%SiC composite in 0.5 molar sodium hydroxide. *Eurasian ChemTech Journal*. 2009;11: 141-147.
 11. Bobic B, Mitrovic S, Babic M, Bobic I. corrosion of metal-matrix composite with aluminum alloy substrate. *Tribology in Industry*. 2010;32(1):11.
 12. Aqida SN, Ghazali MI, Hashim J. Effect of porosity on mechanical properties of metal matrix composite. *An Overview Journal Teknologi*. 2014;400(A):17-32.
 13. Ramachandra S, Bartrip K, Mancuso S. Important Considerations for Corrosion Inhibitors in the Laboratory and in the Prediction of Field Performance Based on Laboratory Data. Paper No. 08627 presented at CORROSION 2008. New Orleans, 16-20 March; 2008.

© 2017 Onyebuchi et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:

The peer review history for this paper can be accessed here:
<http://www.sciencedomain.org/review-history/23423>