Original Research Article

CORROSION BEHAVIOUR OF ALUMINIUM-IRON (Al-Fe) METAL MATRIX COMPOSITE (MMC) REINFORCED WITH SILICON CARBIDE (SiC) PARTICLES IN VARIOUS MEDIA CONCENTRATION OF TETRAOXIOSULPHATE IV ACID (H_2SO_4)

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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.

Keywords:- corrosion, iron, analysis, regression, statistics

INTRODUCTION

1.0 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 (Anyalebechi, et al. 2013, Koch, et al. 2002, Ross and Lott 2001).

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 John, (1994). 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 (Koch *et al, 2002*). 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 (Uhlig, 2008).

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 (Anyalebechi et al, 2013, Ihom, et al, 2012). Considering the importance of composite, Fontana (1987) 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. Anyalebechi et al, (2013) 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%. Ihom et al (2012) 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. Ogbonna et al (2004) 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; Darvishi et al. (2010), Owate et al. (2012), Adeosun et al. (2012), Asuke et al (2009) and Bobic et al (2010).

1.1 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.

MATERIAL AND METHOD

2.0 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.

Figure 1.1: Electronic weighing machine

Figure 1.2: Electric sandpaper machine

2.1 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^{0}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^{0}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 H_2SO_4 of 0.1m, 0.5m and 1.0m respectively.

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

RESULTS AND DISCUSSION

The results of this work are as presented in the tables 1-3 and figures 2.1-2.6

Table 1: Specimen (2.5%wt sic/ 10%wt Al/ 87.5%wt Fe) in 0.1m H_2SO_4

Time(hours)	Initial weight (g) wi	Final weight (g) wf	Weight loss Δw=wi-wf	%weight loss $\frac{\Delta w}{wi}x100$	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

Time(hours)	Initial weight (g) wi	Final weight (g) wf	Weight loss Δw=wi-wf	%weight loss $\frac{\Delta w}{wi} x100$	Change in weight wi-Δw	Log (wi-Δw)
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

Log = 1.536 - 0.000249 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			

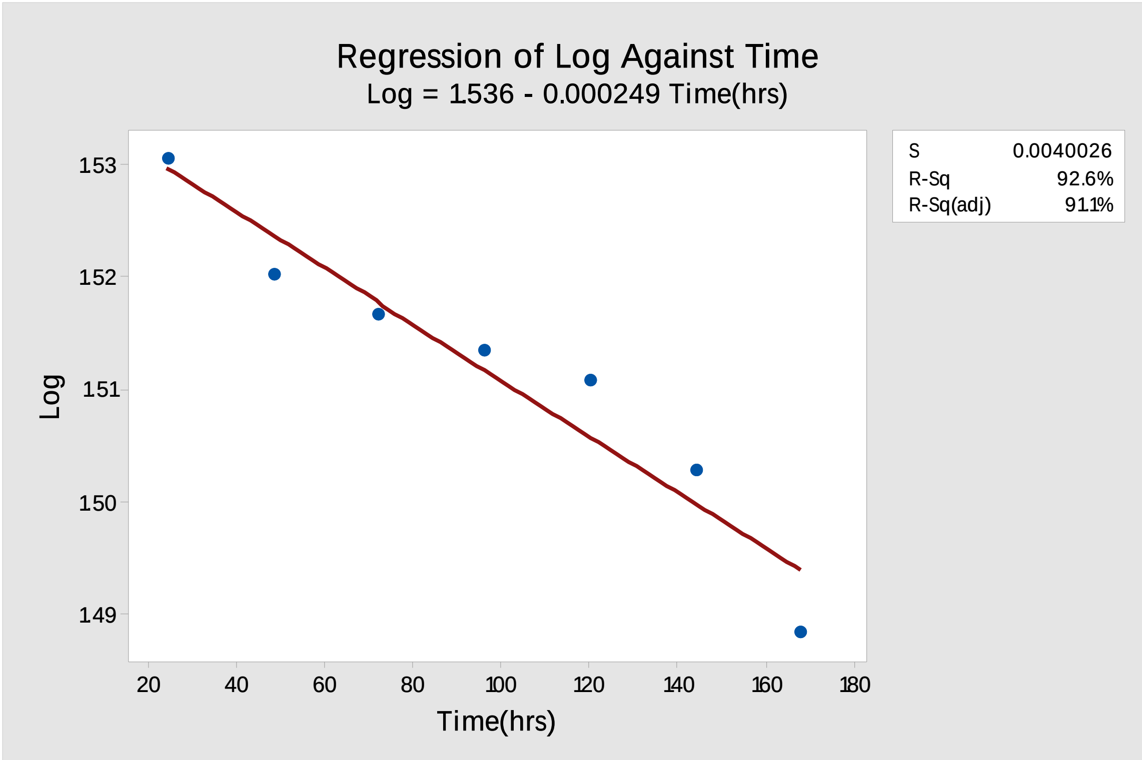

Figure 2.2: Regression of Log Versus Time (hrs)

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			

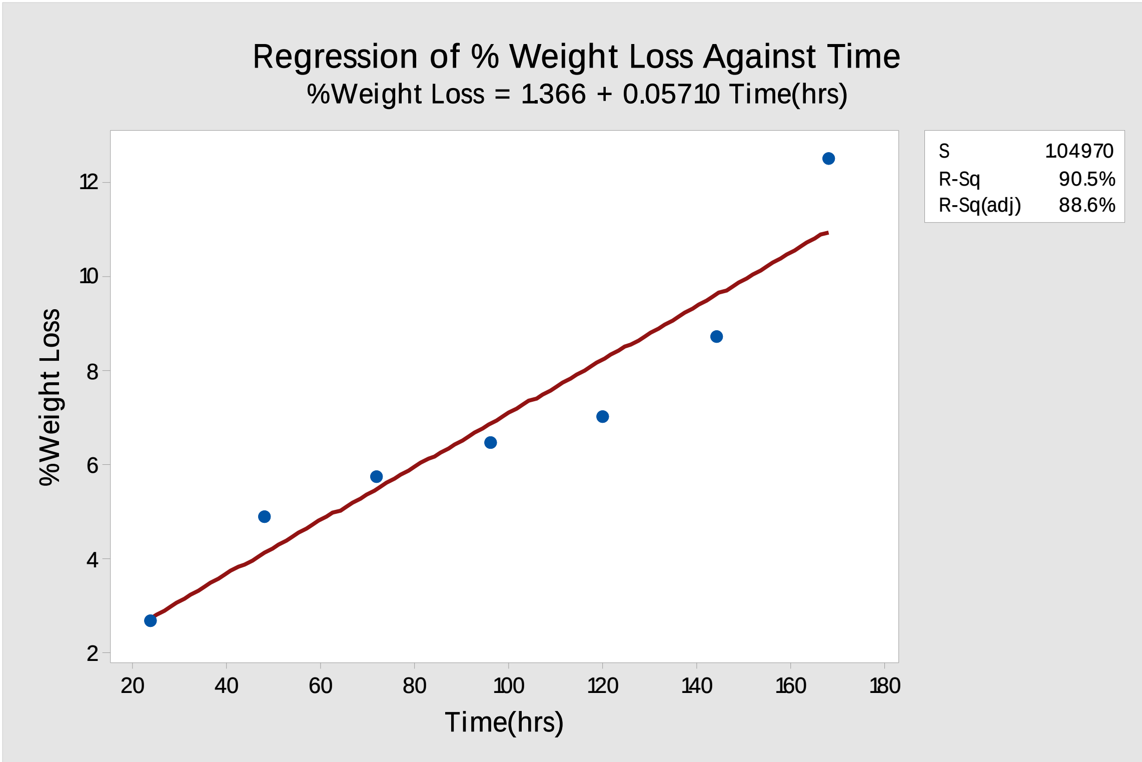

Figure 3.2: Regression of %Weight Loss Versus Time (hrs)

Table 2: Specimen (2.5%wt sic/ 10%wt Al/ 87.5%wt Fe) in 0.5m H_2SO_4

Time(hours)	Initial weight (g) wi	Final weight (g) wf	Weight loss Δw=wi-wf	%weight loss $\frac{\Delta w}{wi} x100$	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

Time(hours)	Initial weight (g) wi	Final weight (g) wf	Weight loss Δw=wi-wf	%weight loss $\frac{\Delta w}{wi}x100$	Change in weight wi-Δw	Log (wi-Δw)
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

Log = 1.442 - 0.000228 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			

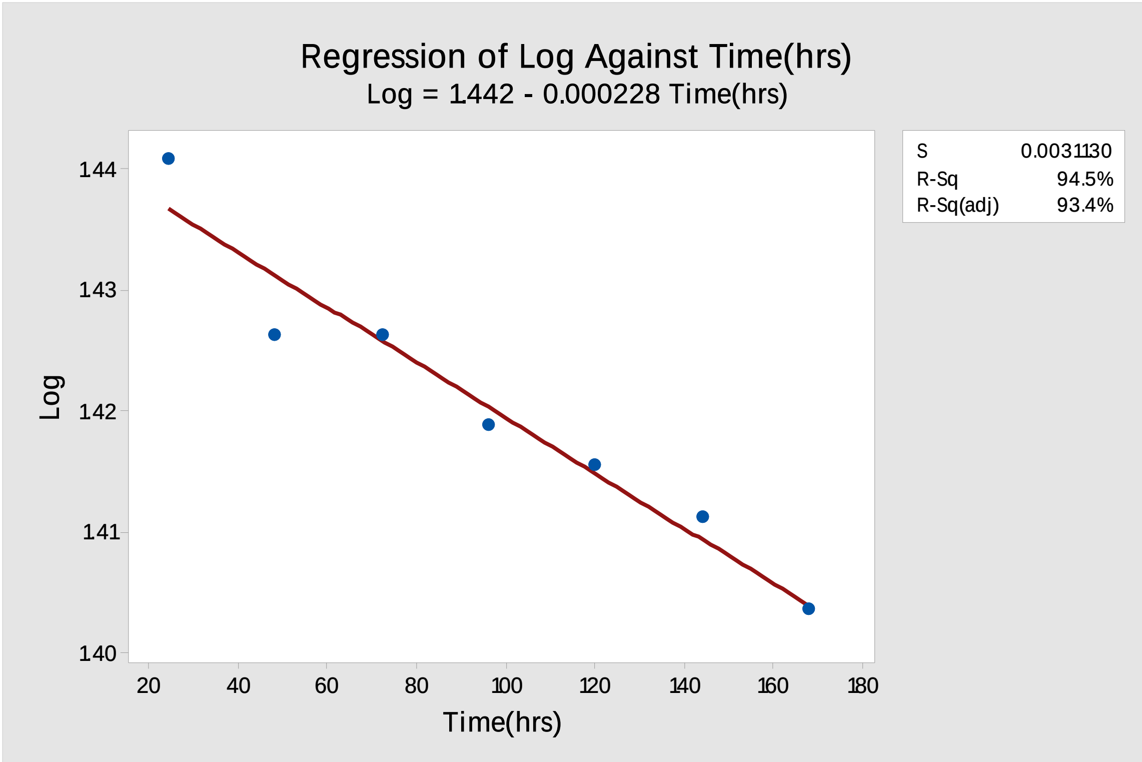

Figure 2.4: Regression of Log Versus Time (hrs)

Regression Analysis: %Weight Loss versus Time(hrs)

The regression equation is

%Weight Loss = 2.257 + 0.05223 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			

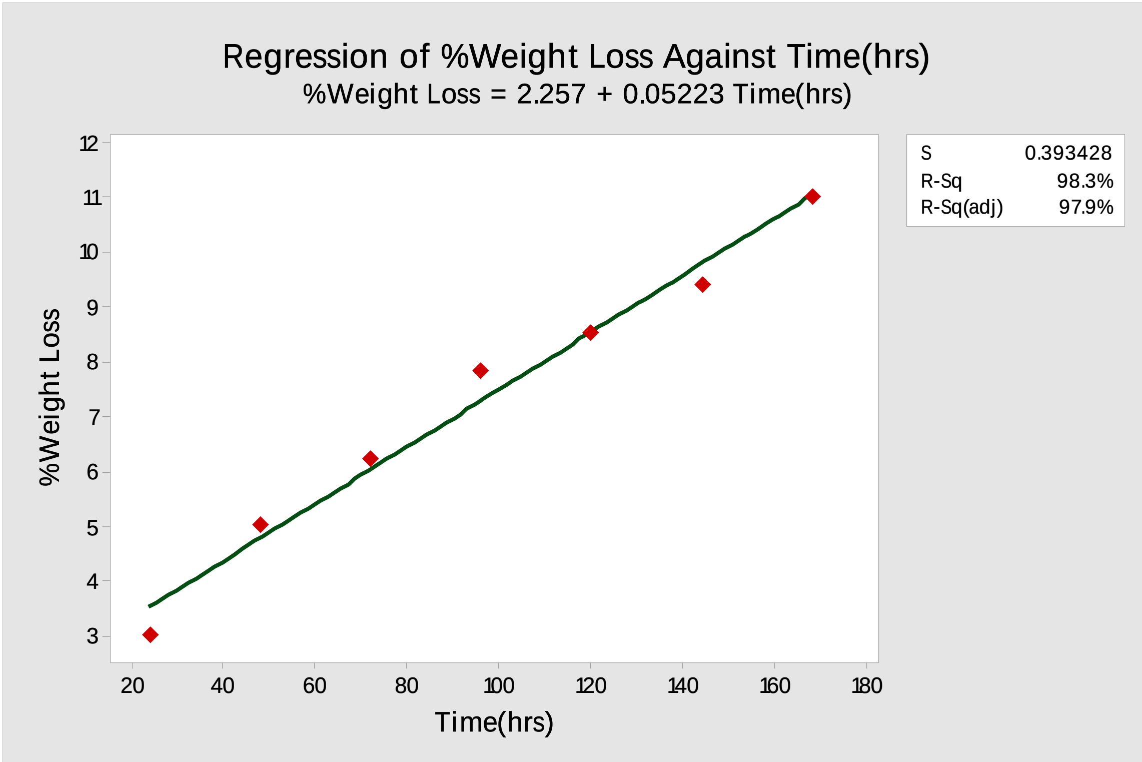

Figure 2.5: Regression of %Weight Loss Versus Time (hrs)

Table 3: Specimen (2.5%wt sic/ 10%wt Al/ 87.5%wt Fe) in 1.0m H_2SO_4

Time(hours)	Initial weight (g) wi	Final weight (g) wf	Weight loss Δw=wi-wf	%weight loss $\frac{\Delta w}{wi} x100$	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

Time(hours)	Initial weight (g) wi	Final weight (g) wf	Weight loss Δw=wi-wf	%weight loss $\frac{\Delta w}{wi} x100$	Change in weight wi-Δw	Log (wi-Δw)
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

Log = 1.516 - 0.000277 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			

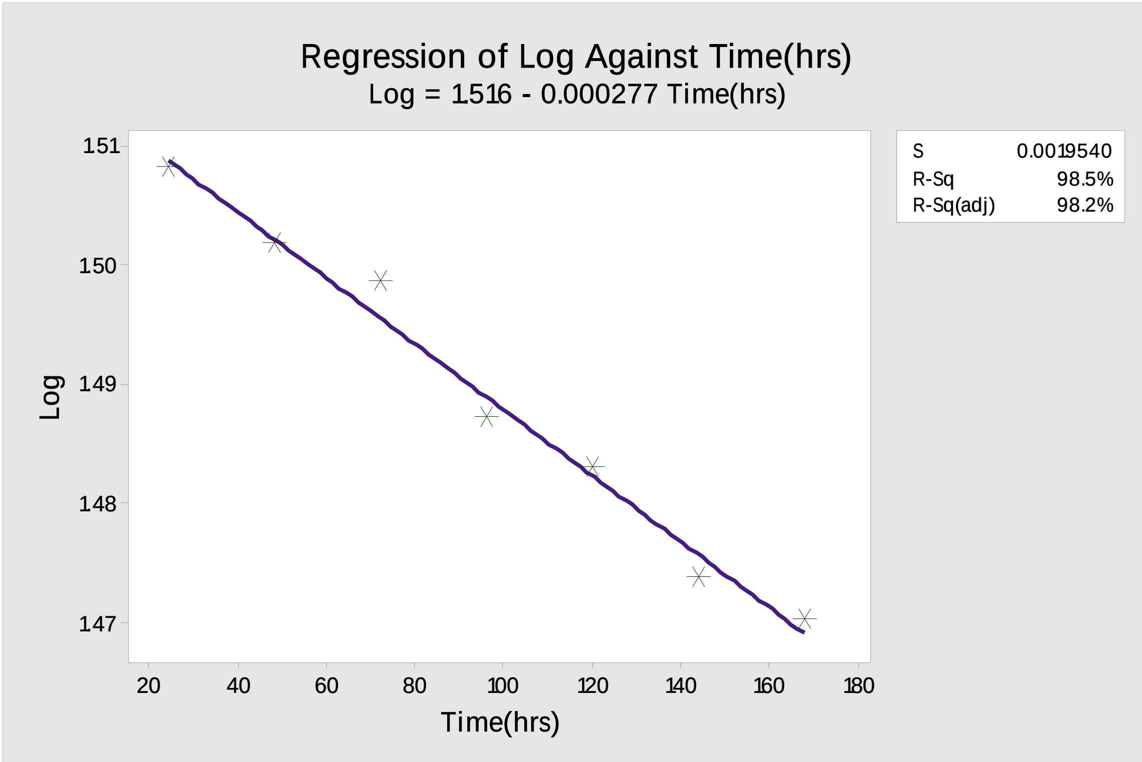

Figure 2.6: Regression of Log Versus Time (hrs)

Regression Analysis: %Weight Loss versus Time (hrs)

The regression equation is

%Weight Loss = 3.286 + 0.04747 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			

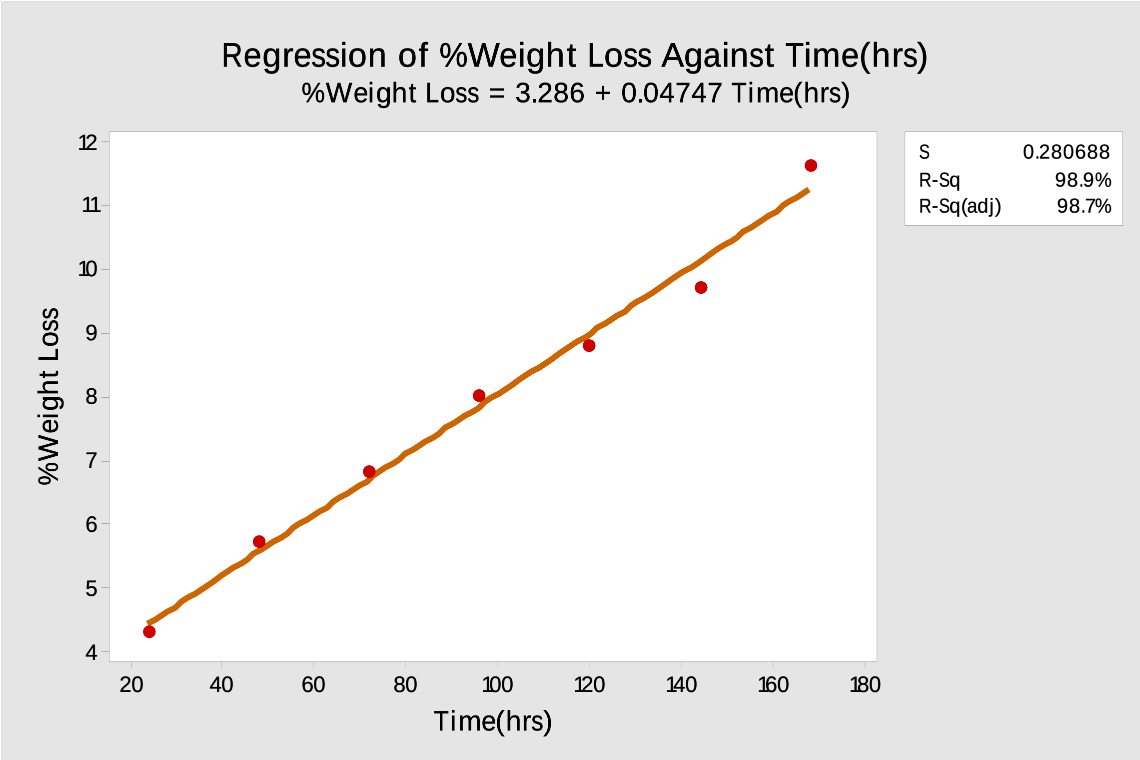

Figure2.7: Regression of %Weight Loss Versus Time (hrs)

DISCUSSION

The graphs of log (w_1-Δw) plotted against time as shown in ***figures 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-Δw) with time which gave a regression of equation of:

$$y = 1.536 - 0.000249x \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; eqn. 3.1$$

Indicating that reactivity was reducing with time. The reaction rate depends on the composition and the temperature of the reacting mixture (Atkin 2008, Veltegreen et., al 2003, Owate et., al 2008). This observed trend did not change remarkably throughout the composites. The graph of percentage weight loss i.e. %weight loss ($\frac{\Delta w}{wi} x100$) against time (*see* ***figures 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 Adeosun et al 2012, observation on issue of porosity in metal matrix composite (MMCs). Bobic et al (2010) 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. Cramer et., al (2005). The resolution here is further buttressed by Aqida et al (2004) 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_2S0_4. This is in support of the finding of Ramachandra et., al (2006). 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. Ramachandra et al (2006) 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 Anyalebechi et al (2013) that after metal matrix composite reduced corrosion by 50%. Therefore, in the present study, it can be submitted in line with Ramachandra et al (2006) 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.

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.

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