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Anti-Corrosion and Passivation Potential of AA6063-Type Al-Mg-Si Alloy with Avogadro Natural Oil in HCl Solution

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ABSTRACT

The electrochemical study of the passivation potential of AA6063-type Al-Mg-Si alloy in Avogadro Natural Oil/HCl Interface was studied using weight loss and potentiodynamic techniques. The result shows that the corrosion rate increases with an increase in exposure time but decrease as the concentration of inhibitor increases. The result of both weight loss and potentiodynamic show good agreement as can been seen that the inhibition efficiencies was found to increase as concentration of inhibitor increases. Equally the additive helps to retard the rate of corrosion and increase the polarization resistance thereby lowering the corrosion density of the system. The presence of the additive was also seen to affect both the cathodic and anodic half which shows that the inhibitor acts as a mixed-type inhibitor. The surface morphology of as-corroded samples assessed with scanning electron microscopy show that the attack was severely reduce in the presence of the Avogadro natural oil.

1. Introduction

Aluminium has a versatile application in the industries owing to it numerous characteristics such as: thermal and good electrical conductivities, high ductility, low cost, availability for its fabrication, shiny appearance and excellent properties [1-4]. It has wide application in automobile, roofing, aviation, electronic devices, pipe, machinery and chemical batteries [3].

In most cases, contact between the metal and aggressive medium (such as acid, base and salt) is unavoidable [5]. In view of the industrial facilities exposed to corrosion are often protected against such attack by adopting several options including painting, oiling, cathodic and anodic protections etc. However, the use of inhibitors has been found to be one of the best options available for the protection of metals against corrosion [6-8]. Most of the effective and efficient chemical inhibitors are those compounds containing hetero-atoms such as oxygen, nitrogen, sulphur, and olefins which allowed adsorption on the metal surface. However, using these inhibitors for corrosion control, factors such as cost, toxicity, availability, and environmental friendliness are very important.

Numerous studies have been carried out on the corrosion of metals in different environments and their inhibition and most of the well-known inhibitors suitable for the inhibition of the corrosion of metals in acidic medium are heterocyclic compounds [9-18]. In view of this, environmentally friendly and non-toxic inhibitors have been the focus in recent research. This study is therefore aimed at determining the electrochemical behavior of the passivation potential of AA6063-type Al-Mg-Si alloy in Avogadro natural oil/HCl interface using both gravimetric and potentiodynamic measurement.

2. Experimental Methods

The aluminium alloy specimen was cut into dimension of 20 mm x 10 mm x 3 mm with the chemical composition shown in Table 1. The entire specimen were immersed in ethanol to degrease it dried, weighed and later stored in a desiccator. Each alloy initial weight were taken and recorded. 0.5 M HCl was prepared fresh as required for the experiment. Avogadro oil used for the analysis was obtained from chemical shop in Pretoria, South Africa. The measurements were conducted at room temperature (25 °C) under static condition.

Table 1 Chemical composition of aluminium alloy used

Element	wt%	Element	wt%
Al	99.01	Ca	0.0012
Si	0.157	Na	0.001
Mn	0.025	Fe	0.281
Mg	0.5	Ti	0.0046
Sr	0.0001	P, Cr, Zr,Cu,Zn	0.01
Bi	0.0024	B,Ni,Ag, Co	0.004

2.1 Weight Loss Measurement

Weight loss measurement was carried out on a previously weighed aluminium alloy in the presence and absence of inhibitor at 25 °C. The volume of the solution prepared were 100 mL with and without inhibitor. The Avogadro natural oil as inhibitor concentrations were 1.5, 3.0 and 4.5 g/v in 100 mL of 0.5 M HCl solution. On each sample with Avogadro oil inhibitor using weight loss after the corrosion test, samples were washed, dried and weight taken at interval of 96, 192, 288 and 384 h of immersion. The corrosion rate (mm/day), inhibition efficiencies (IE%) and degree of surface coverage (θ) were determined.

2.3 Potentiodynamic Corrosion Measurement

Potentiodynamic polarization measurement was used to determine the rate of corrosion of the alloy in the presence of the oil-HCl solution. All the measurement was done in an Auto lab frequency response analyzer (FRA) coupled to potentiostat that was connected to a computer system. A glass corrosion cell kit with a platinum counter electrode a saturated Ag/Ag reference electrode and aluminium alloy sample as working electrode. The working electrodes samples were positioned at the glass corrosion cell kit, leaving 1 cm^2 surfaces in contact with the solution. Polarization test were carried out in 0.5 M HCl solution at room temperature under static solution using a potentiostat (model: AuT71791 and PGSTAT 30) with a scan rate of 0.003 V/sec. From the Tafel corrosion results, the inhibition efficiencies, corrosion rate and linear polarization resistance were obtained. The

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sample as-corroded uninhibited and inhibited aluminium alloy surfaces were examined with scanning electron microscopy to analyze the extent of surface damage (Model: Joel 6100).

3. Results and Discussion

Table 2 shows the corrosion rate inhibition efficiencies and degree of surface coverage obtained from gravimetric measurement for aluminium in 0.5 M HCl/Avogadro natural oil environment. Fig. 1 shows the variation of corrosion rate with inhibitor concentrations. While Table 3 present the electrochemical corrosion data for the alloy in 0.5 M HCl-Avogadro natural oil environment. Fig. 2 also present the polarization curve of the inhibition at various concentrations in the acidic medium. The micrograph of as-corroded in uninhibited/inhibited aluminium alloy are presented in Plate 1a-b. Fig. 3 illustrates the Langmuir adsorption isotherm for the inhibitor using different corrosion measurement.

3.1 Weight Loss Measurement

The oil was found to be a good inhibitor of aluminium alloy in HCl medium. The corrosion rate was found to increase as the exposure time increases in the un-inhibited condition, while an increase in inhibitor concentration decreases the rate of corrosion of the alloy. Behaviour of the alloy in the HCl environment containing the inhibitor is attributed to the increase in the element that forms stable oxides as evidence in the SEM. Inhibition efficiencies were also found to increase as the concentration of inhibitor increases but get to a peak at 3.0 g/v after which the efficiencies of the Avogadro oil decreases. As the exposure time increases, the efficiencies of the inhibitor also increase but after 8 days exposure the inhibition efficiencies reduced. Similar reports have been found elsewhere [19].

Table 2 Corrosion rate (CR), degree of surface coverage (θ) and inhibition efficiency for aluminium in 0.5 M HCl solution with and without Avogadro natural oil addition obtained from gravimetric technique at 25 °C

Exposure time (h)	Concentration of inhibitor (g/v)	CR (mm/year)	Degree of surface coverage (θ) in HCl	Inhibition Efficiency (%) in HCl
96	0	0.7876	-	-
	1.5	0.3241	0.5885	58.85
	3.0	0.1693	0.7849	78.49
	4.5	0.2000	0.7460	74.60
192	0	0.6577	-	-
	1.5	0.4354	0.3379	33.79
	3.0	0.2829	0.5699	56.99
	4.5	0.3295	0.9955	99.55
288	0	0.5424	-	-
	1.5	0.4589	0.1538	15.38
	3.0	0.3521	0.3508	35.08
	4.5	0.3593	0.3378	33.78
384	0	0.4549	-	-
	1.5	0.4557	0.0786	07.86
	3.0	0.3436	0.2446	24.46
	4.5	0.4159	0.0858	08.58

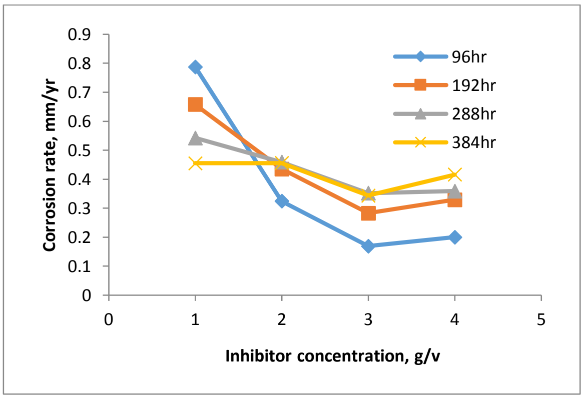

Fig. 1 Variation of corrosion rate with concentration of inhibitor for aluminium in 0.5 M HCl without and with varying concentration of Avogadro natural oil addition at 298 K

Potentiodynamic parameters for the alloy are presented in Table 3. The presence of the inhibitor demonstrated a decrease in corrosion rate and current density. While the polarization resistance (R_p) and corrosion potential (E_{corr}) were found to increase with increase in inhibitor's concentrations. The result is in agreement with previous study [20]. The result also show that both the cathodic and anodic were found to be affected and this shows that the inhibitor behave as a mixed-type inhibitor.

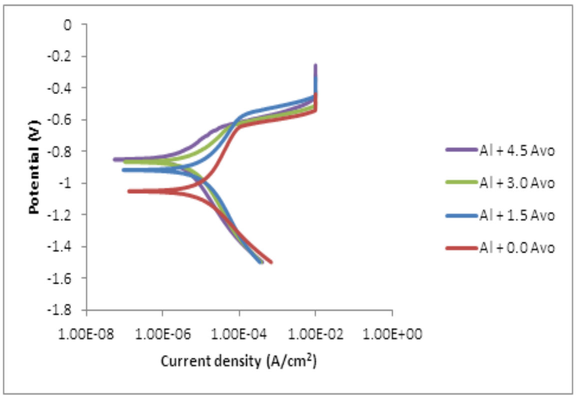

Fig. 2 Linear polarization of aluminium in 0.5 M HCl solution with and without Avogadro natural oil addition at 298 K

Table 3 The electrochemical parameters of aluminium in 0.5 M HCl-Avogadro natural oil environment at 298 K

Samples	ba (V/dec)	bc (V/dec)	Ecorr, Calc (V)	Ecorr, Obs (V)	jcorr (A/cm²) x 10⁻⁶	icorr (A) x 10⁻⁶	Corrosion rate (mm/year) x 10⁻⁶	Polarization resistance (Ω)	E Begin (V)	E End (V)
Al+4.5 Avo	0.122	0.115	-0.85	-0.85	1.12	1.12	2036	22950	-0.91	-0.77
Al+3.0 Avo	0.086	0.119	-0.88	-0.86	1.94	1.94	3525	11175	-0.91	-0.78
Al+1.5 Avo	0.099	0.163	-0.94	-0.92	3.21	3.21	5826	8376.4	-0.96	-0.82
Al+0.0 Avo	0.085	0.142	-1.06	-1.05	3.24	3.24	5895	7104.9	-1.11	-0.98

3.2 Surface Morphology

Surface morphology of the aluminium alloy in uninhibited and inhibited acid was followed by SEM after immersion in the medium for 3 h at 25 °C. As presented in Fig. 3a, corrosion was relatively general with no evidence of localized attack. While Fig. 3b shows that the corrosion damage is visibly reduced, and there is slight evidence of the adsorbate presence on the surface of the metal, also it is seen that the Avogadro oil was able to exhibit some degree of inhibition and this retard the corrosion rate of the alloy in the medium [21].

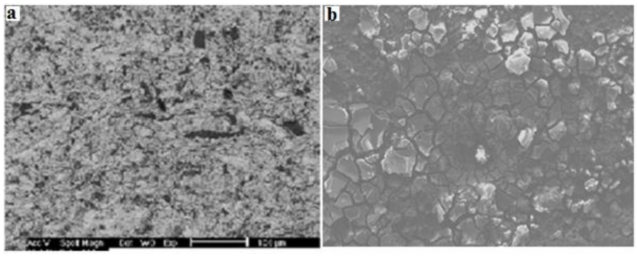

Fig. 3 SEM micrograph of a) as-received and b) as-corroded uninhibited aluminium alloy in 0.5 M HCl solution

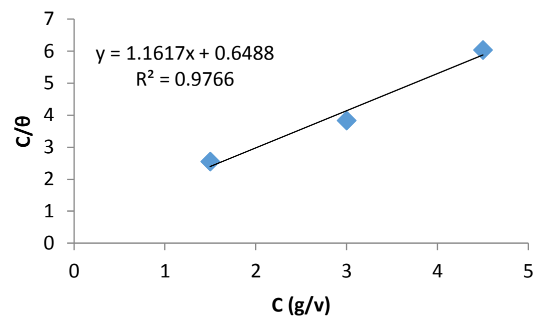

Fig. 4 Langmuir isotherm for the adsorption of Avogadro Oil compounds on the aluminium alloy surface in 0.5 M HCl solution at 25 °C obtained by weight loss methods at 96 h

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The mechanism of inhibition was also determined by fitting data obtained from weight loss into the Langmuir adsorption isotherm as presented in Fig. 4. The plot gives a linear regression with coefficient (R^2) value of 0.976 and the slope 1.161 close to unity. The adsorption behaviour was found to obey the Langmuir isotherms under the study conditions.

4. Conclusion

The results obtained from this study indicate that the Avogadro Oil inhibited the corrosion process by virtue of adsorption on the surface of the aluminium. The corrosion rate was found to increase as exposure time increases and seen to reach a peak at which the rate was found to increase as the concentration of the inhibitor increases. From the electrochemical study, a mixed type corrosion inhibitor exists between the inhibitor and the metal. The mechanism of adsorption of the inhibitor on the surface of the metal supported Langmuir isotherm.

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