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Corrosion Polarization Behaviour of Welded 316 Stainless Steel in Hydrochloric Acid

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ABSTRACT
The specimen samples were MIG also known as gas metal arc welding (GMAW) is themost common industrial welding process. The corrosion resistance of welded 316 austenitic stainless steel was performed at ambient temperature in different concentrations of hydrochloric acid. Potentiostatic polarization method was used for the corrosion investigation. The electrochemical corrosion reactions exhibited both the passive and active corrosion reactions characteristics. The acids at the intermediate concentrations show more obvious active corrosion reactions; while in the concentrated form they were relatively passive – the passivity that was associated with the oxidizing nature of the concentrated acids. In all the tests, however, the magnitude of corrosion could be considered to be low. The experiments were conducted in eight different solutions for each stainless steel sample.

Keywords: Inert Gas welding, corrosion resistance, hydrochloric acid, polarization

I. INTRODUCTION

The International Union of Pure and Applied Chemistry (IUPAC) and European Federation of Corrosion (EFC) define corrosion as an irreversible interfacial reaction of a material with its environment which results in its consumption or dissolution, often resulting in effects detrimental to the usage of the material considered. Corrosion failure is a significant problem in any given type of industry, leading to substantial economic consequences, but also often influencing human health and the environment negatively [1].

Stainless steels are in wide use for resisting corrosion. There are many alloys of this kind and the proper alloy must be selected for its intended purpose. Chromium is the principal alloying element and occurs in percentages from 11.5 to 30. In some alloys nickel is also present in amounts up to 14%. Close control must be exercised on the carbon content of these materials. The chromium forms a layer of chromium oxide (Cr_2O_3) when exposed to oxygen and the layer is not visible contributing to the shiny appearance of the metal surface [2-5]

They are high alloy steels which possess high corrosion and oxidation resistance, making them widely used for resisting corrosion. These characteristics make stainless steel to have numerous applications in nuclear plants, petrochemical industries and food processing units, pulp and paper manufacturing plants. The alloys can be milled into sheets, bars, plates, wire and tubing to be used for cookware, cutlery, surgical instruments and building materials [3].

There are different types of stainless steel giving rise to different degrees of corrosion resistance behavior characteristics of the different grades. There are four categories, these are austenitic, martensitic, ferritic and precipitation hardening stainless steels (duplex stainless steel)

The welded 316 Austenitic stainless steel is a specific type of stainless steel alloy which possess austenite as their primary crystalline structure (face-centered cubic). This austenite crystalline structure is achieved by sufficient additions of the austenite stabilizing elements nickel, manganese and nitrogen. Their crystalline structure prevents austenitic steels from being harden able by heat treatment and makes them essentially non-magnetic [4].

MIG also known as gas metal arc welding (GMAW) is themost common industrial welding process, preferred forits versatility, speed and the relative ease of adapting theprocess even to robotic automation. It is used extensivelyby the sheet metal industry and by extension, theautomobile industry[4].

Hydrochloricacid at varied concentrations are used in this investigation. Apparently, hydrochloric acid is produced at wide range. It is used directly or indirectly in nearly all industries. It is principally used in the production of chemicals and their derivatives, pickling of steel and other metals, manufacture of fertilizers, dyes, drugs, pigments, explosives, synthetic detergents, rayon and other textiles, petroleum refining, and the production of rubbers. In making the acids, the problem of corrosion is significant in the production plants. The acid also causes major problem in consumers' plants when it is utilized under a wide variety of conditions [6-10]

This present investigation looks at the corrosion resistance reactions phenomena of welded type 316stainless steels in varied concentrations of the acids used. The work aims at evaluating the corrosion resistance of welded Type 316 stainless steel at different concentrations of hydrochloric acid.

II. EXPERIMENTAL PROCEDURE

The materials used for the study include;
Specimen of stainless steel rods,
i 0.5M hydrochloric acid,
ii 1M hydrochloric acid,
iii .5M hydrochloric acid
iv 2.0M hydrochloric acid.

2.1 Corrosion polarization tests

The corrosion resistance and/or susceptibility of austenitic stainless steel was separately performed at ambient temperature in different concentrations of hydrochloric acid.Potentiostatic polarization method was used for the corrosion investigation. Theelectrochemical corrosion reactions exhibited both the passive and active corrosion reactionscharacteristics. While in the concentrated form they were relatively passive – the passivity that wasassociated with the oxidizing nature of the concentrated acids. In all the tests, however, themagnitude of corrosion could be considered to be low.

Austenitic stainless steel samples in cylindrical form (10mm diameter and 10mm long) used for this investigation were mounted in araldite resin and connected with a flexible wire connection, ground and polished to fine diamond (1μm), cleaned and rinsed/degreased in an ultrasonic bath using acetone. The samples were immediately kept in a desiccator for subsequent corrosion experimental studies. Potentiostatic polarization experiments were performed using each of the cylindrical specimens in turns, in which 1 cm^2 surface area of the specimen was exposed to the test solution at room temperature. The experiments were performed using a polarization cell of three electrode system consisting of a reference electrode(RE), a working electrode (WE); and auxiliary (AE) made of platinum mesh. The experiments were conducted in eight different solutions for each stainless steel sample.

Plate 1: Rear view of the specimen (Austenitic stainless steel)

Plate 2: Front view of the specimen (Austenitic stainless steel)

Plate 3: Experimental set up of Potentiostat and Polarization cell

Plate 3: Potentiostat and Polarization cell interfaced with computer for data acquisition

III. RESULTS/DISCUSSION

3.1 Corrosion Polarization Behaviour of Welded and Un-Welded Stainless Steel in 0.5M Hydrochloric Acid

Figures1 and 2below show the linear polarization curves for welded and unwelded 316L stainless steel in 0.5M hydrochloric acid. In figure 1, the welded specimen has open corrosion potential (OCP) of -0.402V. It can be said that this high potentials value offered the specimen protection from corrosion [11]. The OCP value reduced to -0.37V as observed in the un-welded specimen in figure 2. Table 1 also shows a summary of the complete corrosion polarization results.It can be observed that the welded specimen in Figure 1 has a higher value of corrosion current 4.019x10 and corrosion resistance 7Ωand a lower value of corrosion rate7mm/year when compared with the un-welded specimen in figure2. It can therefore be deduced from this table that the welded steel exhibits lower resistance to corrosion and higher corrosion rate in low concentrated hydrochloric acid medium than the un-welded one [11].

Table1: Results of Corrosion Polarization of Welded and Unwelded Specimen in 0.5M of Hydrochloric acid

Specimen sample	Icorr(A)	Rp(Ohm)	Ecorr	Corrosion rate(mm/year)
Unwelded	3.119x00	5	-0.4	9
Welded	4.019x10	7	-0.4	7

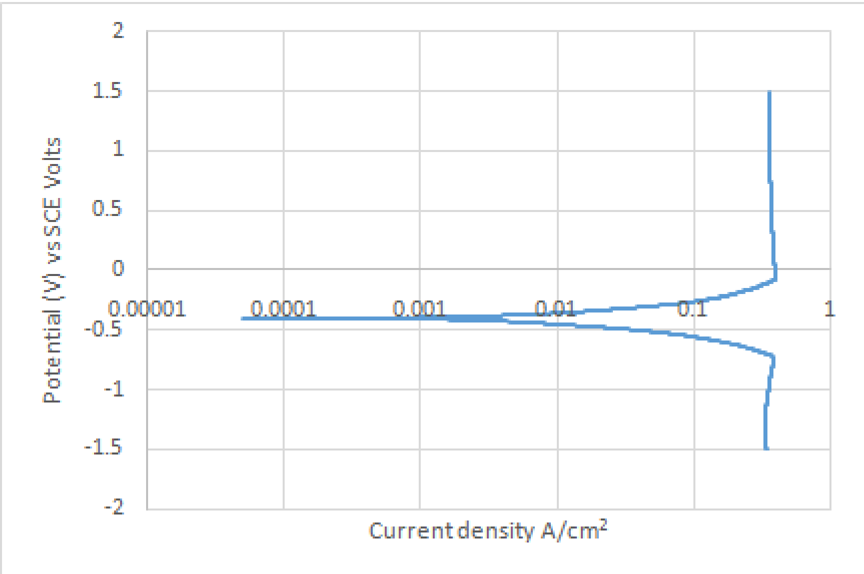

Figure 1: Polarization curves of welded 316L stainless steel in 0.5M HCL

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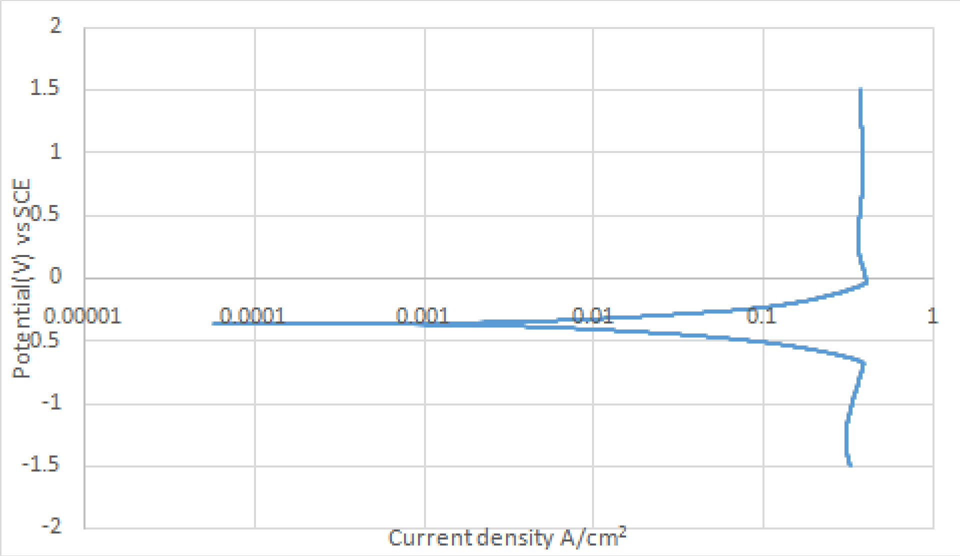

Figure 2: Polarization curves of 316L un-welded stainless steel in 0.5M HCL

3.2 Corrosion Polarization Behaviour of Welded and Un-Welded Stainless Steel in 1.0M Hydrochloric Acid

Figures3 and 4below show the linear polarization curves for welded and u-nwelded 316L stainless steel in 1.0M Hydrochloric acidconcentration. Table 2 also presents a summary of the complete corrosion polarization results. The welded specimen has the same value of corrosion current and corrosion resistance and the same value of corrosion rate.

Table 2: Results of Corrosion Polarization of Welded and Un-welded Specimen in 1.0M of Hydrochloric acid

Specimen sample	Icorr(A)	Rp(η)	Ecorr(V)	Corrosion rate(mm/year)
Un-welded	5.066x00	4	-0.4	1.13
Welded	5.066x00	4	-0.4	1.13

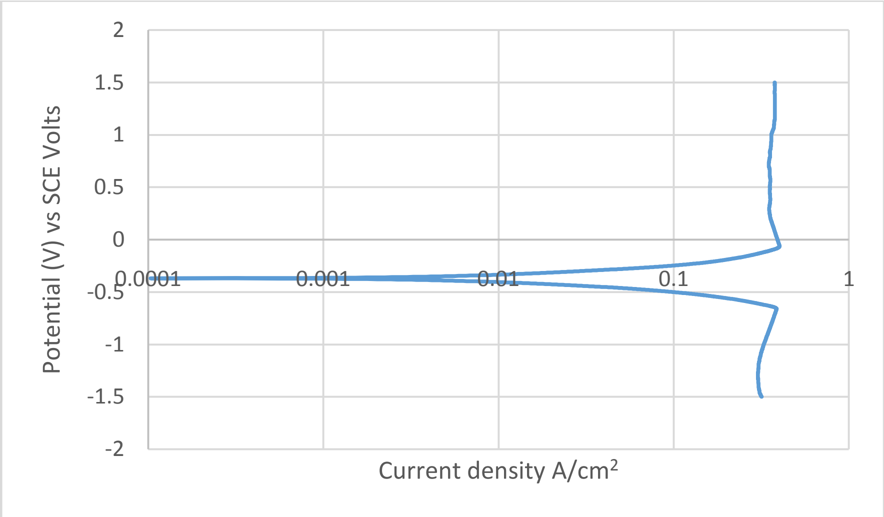

Figure 3: Polarization curve of 316L un-welded stainless steel in 1M HCL

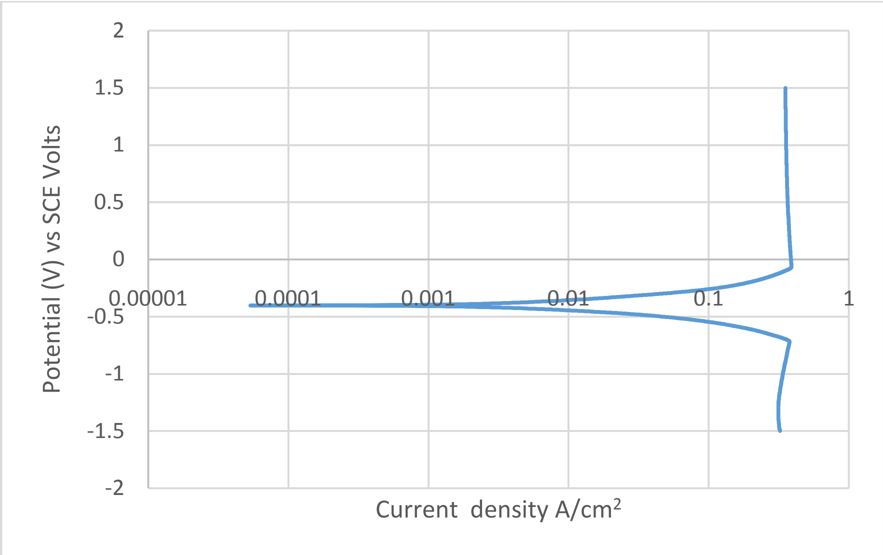

Figure 4: Polarization curves of 316L welded stainless steel in 1M HCL

3.3 Corrosion Polarization Behaviour of Welded and Un-Welded Stainless Steel in 1.5M Hydrochloric Acid

Figures5 and 6below show the linear polarization curves for welded and un-welded 316L stainless steel in 1.5M hydrochloric acidat 1.5M of concentration. The welded specimen illustrated in Figure6 has a higher value of corrosion current and corrosion resistance and a lower value of corrosion rate $1.599x10^2$ mm/year.Table 3also shows the summary of detailed corrosion polarization results.

Table 3: Results of Corrosion Polarization of Welded and Un-welded Specimen in 1.5 of Hydrochloric acid

Specimen sample	Icorr(A)	Rp(ohm)	Ecorr(V)	Corrosion rate(mm/year)
Un-welded	1.248x10-2	3	-0.4	2.805x102
Welded	7.144x10-3	4	-0.42	1.599x102

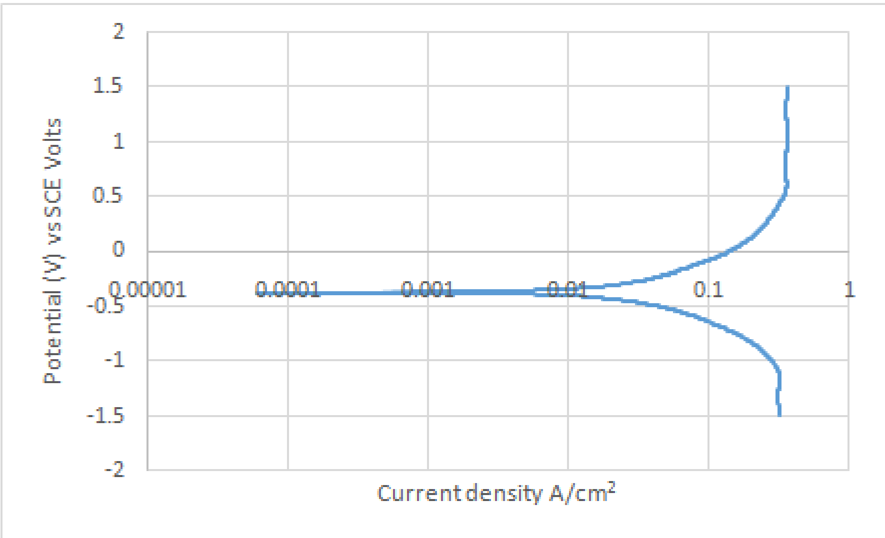

Figure 5: Polarization curves of 316L un-welded stainless steel in 1.5M HCL

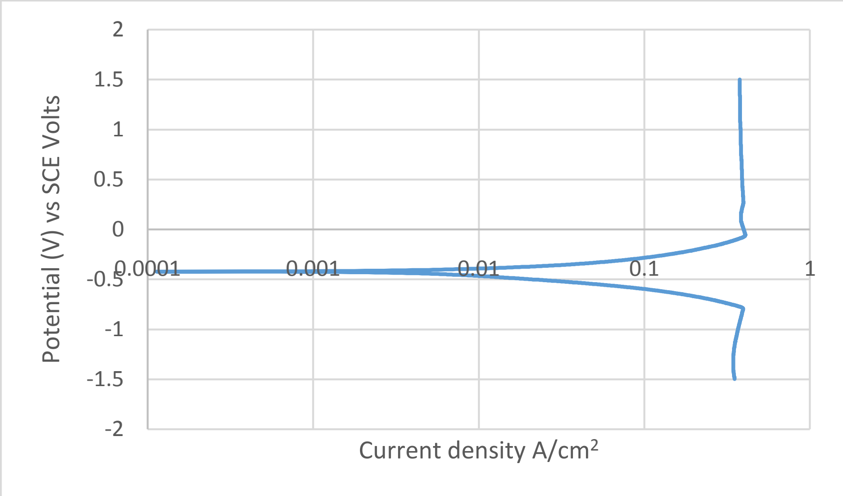

Figure 6: Polarization curves of 316L welded stainless steel in 1.5M HCL

3.4 Corrosion Polarization Behaviour of Welded and Un-Welded Stainless Steel in 2.0M Hydrochloric Acid

Figures 7 and 8below show the linear polarization curves for welded and unwelded 316L stainless steel in 2M hydrochloric acid concentration. Table 4 shows the detailed corrosion polarization results. The un-welded specimen has a higher value of corrosion current and the same corrosion resistance and open corrosion potential and a higher value of corrosion rate of $6.395x10^2$ mm/year indicating high acid rate which can accelerate corrosion.

Table 4: Results of Corrosion Polarization of Welded and Un-welded Specimen in 2.0M of hydrochloric acid

Specimen sample	Icorr(A)	Rp(ohm)	Ecorr	Corrosion rate(mm/year)
Unwedded	2.845x102	1	-0.4	6.395x102
Welded	2.187x102	1	-0.4	4.916102

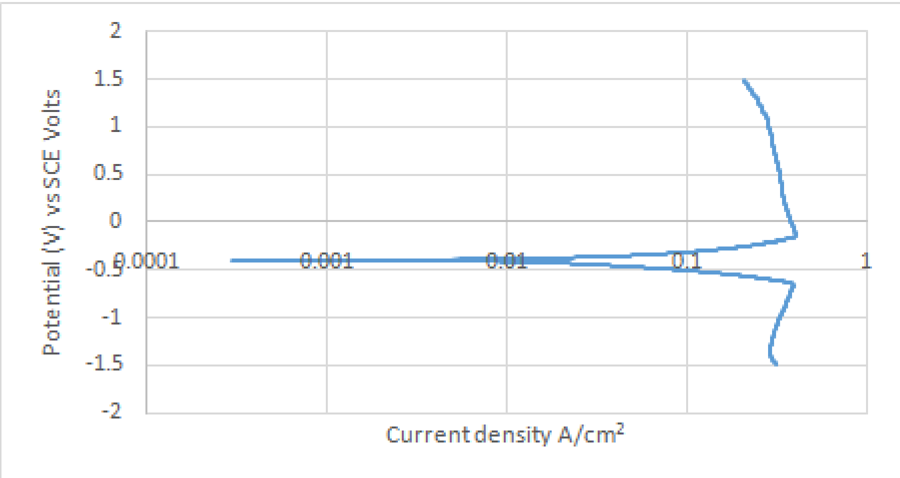

Figure 7: Polarization curves of 316L welded stainless steel in 2M HCL

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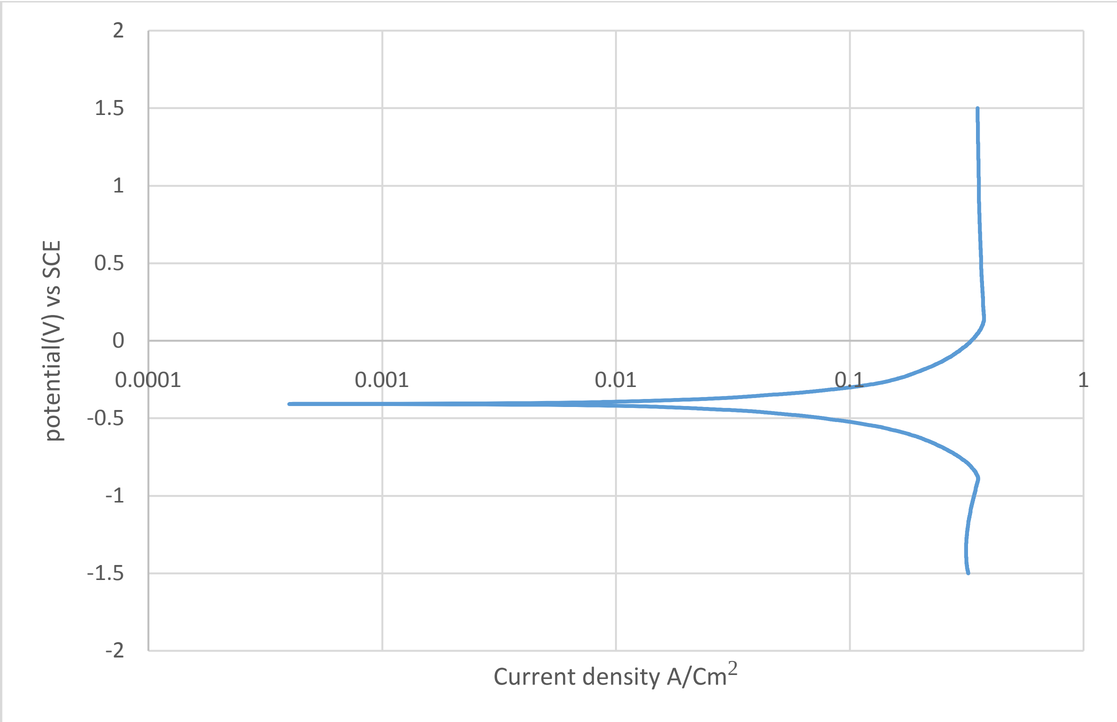

Figure 8: Polarization curves of 316L un-welded stainless steel in 2M HCL

Figures 1 to 8 above show the polarization corrosion curves of the 316L welded and un-welded stainless steel specimens in 0.5M, 1M, 1.5M and 2M. The open corrosion potential (OCP), Ecorr was -0.4V. The specimen can be protected with this potential throughout the experimental period. This medium serves as the control for all the experiment.The polarization corrosion curves of welded 316 stainless steel in 0.5M and 1M of hydrochloric acidshow a slight reduction in the corrosion rate due to the welding effect when compared to the un-welded sample and a slight increase in 2M of hydrochloric acid concentration [11, 12].

IV. CONCLUSION

The polarization corrosion curves of welded 316 stainless steel in 0.5M and 1M of hydrochloric acidshow a slight reduction in the corrosion rate due to the gas metal arc welding (GMAW) effect, when compared to the un-welded sample and a slight increase in 2M of hydrochloric acid of concentration. This show that high acid concentration rate can increase the corrosion rate of a component.

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