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ARTICLE

The Study on the Corrosion Behaviour of Welded and Unwelded Medium Carbon Steel in Sodium Chloride (Nacl) Solutions

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ABSTRACT

The research work was based on the study of the corrosion behaviour of the welded and un-welded medium carbon steel in sodium chloride solutions. The Sodium chloride solutions used are 1ml, 2ml, 3ml and 4ml for both welded and un-welded medium carbon steel in NaCl. The experiments were conducted in two ways, the weight loss analyses of measurements and using the electrochemical analyzer workstation to determine the potential dynamic of the samples. The samples for the weight loss measurements were prepared from rolled products obtained at the foundry shop. Two medium carbon steel materials were sourced with different chemical compositions as sample A and B. The materials were prepared to accommodate the experiments for the determination of welded and un-welded medium carbon steel. A total of sixty-eight (68) samples were produced, prepared and used for the weight loss measurements /analyses the experiments. Thirty-four of the samples each were prepared for both the welded and un-welded experiments. All the samples were produced and prepared through the use of various machining processes with the use of a lathe machine for planning, milling. Thirty-four (34) of the sample preparation were further welded in readiness of the experiments. Sixty -eight breakers were sourced for and used. Ten (10) other samples were used for the determination with the use of the electrochemical analyzer. The chemical compositions of the medium carbon steel were determined with the use of SPECTRO Analytical Instruments. A metallurgical inverted optical microscope was used to determine the microstructures of the materials. The Scanning Electron Microscopy with EDS was used to determine the morphologies of the materials. The thirty-four of the samples were welded this process was performed to determine the effects of welding on the material surrounding the weldments. These materials were made into sizes with the use of power hacksaw (i.e. 2cm by 2cm). Other materials were prepared to 1cm x 1cm thickness from the same materials. The Tafel plot experiments and that of the open Circuit Potential Time (OCPT) were carried out with the use of Electrochemical Analyzer/ Workstation. The Medium carbon steel materials were exposed for fifty-four (54) days, with an interval of 3days. The corrosion rates analyses were determined and the graphs of the corrosion rates (mm/yr.) and other parameters were used plotted against No of days exposed.

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1. Introduction

The tendency of a metal to revert to its native state (or) Metallurgy in reverse, the chemical or electrochemical reaction between a material and its environments that produces a deterioration of the material and its deterioration properties. The destructive attack of a material by reaction with its environment, corrosion of metals is the commonest electrochemical phenomenon encountered in day phenomenon day to day life. Corrosion is the degradation of materials by electrochemical or chemical reaction with its environment. It is also an electrical circuit process where the exchange of electrons is conducted by a chemical reaction in part of the circuit. The chemical reactions occur at the surface of the metal exposed to the electrolyte. Oxidation reactions occur at the surface of the anode and reduction reaction occurs at the surface of the cathode [1]. Metals corrode because they are used in an environment where they are chemically unstable. Only copper and precious metals (gold, silver, platinum, etc.) are found in nature in their metallic state. All the other metals, to include iron, the metal are most commonly used and are processed from minerals or ores into metals which are inherently unstable in their environment [2].

Corrosion allows the pipes and other metallic and associated components to degrade and deteriorate steadily both internally and externally. It can reduce materials' life span by gradually chewing the thickness wall up. Under such circumstances, it could be as short as five years for the decline to cause certain metallic materials to fail [14]. Corrosion may also result in the pipe being encrusted, reducing the pipe's carrying capacity to a point that it needs to be replaced to provide the necessary flow [3,4]. However, like any engineering structure, the best-designed and maintained metallic materials will become defective as it progresses through it design life. One of the major causes of metallic defects around the world is corrosion [5]. The selection of materials for a particular situation is dependent on the materials that may pass through or been used for. In the case of metallic materials made to pipe, in such situation, liquid and gasses may be allowed to pass through the device. In such a scenario, the pressure is allowed to move through and the temperature of the contents. Metallic materials are made from various types of materials to meet precise and stringent requirements with regard to the desired service. Due to its strength, ductility, weldability, the most widely used material for the manufacture of petroleum pipelines is mild steel or medium carbon steel and is suitable for heat treatment with varying mechanical properties [6]. However, carbon steel quickly corrodes when exposed to pure air due to all the common structural metals from surface oxide films, but the oxide produced on carbon steel is ready to be broken down and is not fixed in the presence of moisture [7].

However, despite the current level of industry knowledge, most metallic materials continue to experience a modest but significant number of failure due to corrosion at its weld and entire point. The explanation for this is that the corrosion behaviour of materials such as pipes buried under the earth is much more complex than that of piece steel in a saltwater beaker [8].

Metallic materials built into pipelines play an incredibly important role worldwide as a means of transporting gases and liquids to the ultimate users over long distances from their sources. The general public is not aware of the number of pipelines which as a primary means of transportation are continually in services. A buried operating pipeline is very unobtrusive and seldom makes it present when transportation fluids are constructed with carbon steel materials. This is because metallic materials such as pipes have to be sturdy enough to withstand various conditions that are primarily due to temperature, pressure and fluid [6]. Medium steels can be categorized according to [9].

2. Medium-Carbon Steels

The medium-carbon steels have carbon concentrations between about 0.25 and 0.60 wt. %. These alloys may be heat treated by austenitizing, quenching, and then tempering to improve their mechanical properties. They are most often utilized in the tempered condition, having microstructures of tempered martensite. The plain medium-carbon steels have low hardenabilities and can be successfully heat-treated only in very thin sections and with very rapid quenching rates. Additions of chromium, nickel, and molybdenum improve the capacity of these alloys to be heat-treated, giving rise to a variety of strength-ductility combinations.

These heat-treated alloys are stronger than the low-carbon steels but at a sacrifice of ductility and toughness. Applications include railway wheels and tracks, gears, crankshafts, and other machine parts and high-strength structural components calling for a combination of high strength, wear resistance, and toughness [6].

3. Materials and Methods

3.1 Materials

The material used in this research work is a medium Carbon Steel produced at the Light Section Mill of the

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Ajaokuta Steel Company Limited, Ajaokuta, Kogi State, Nigeria. The chemical compositions of the materials were determined using SPECTRO Analytical Instruments at the Quality Control and Materials Analysis of the Foundry shop section of the Steel Plant. The chemical compositions of the two sourced materials are shown in table 1 and 2 tagged as samples A and B.

Figure 1. SPECTRO Analytical Instruments used for the determination of chemical compositions of Medium Carbon Steel

3.2 Equipment

The equipment used for this research work includes table lathe machine, table vice, bench grinder, electric arc welding machine, polishing machine, digital weighing balance, digital multi-meter, pH meter, and SPECTRO Analytical Instruments and Electrochemical Analyzer workstation.

3.3 Chemical Reagents

Chemical reagents used include sodium chloride, Distilled water.

3.4 Materials Preparation

3.4.1 Welding Operation

The 10mm thickness medium steel was cut by a hacksaw to 2cm by 2cm. Thirty-four (34) of such samples were prepared for the welded and un-welded samples. The types of joints were adopted, which include; Butt joint. Out of the (68) samples of 10mm thickness that was researched on, thirty-four (34) samples were welded, while the remaining thirty-four (34) for un-welded samples including some numbers that were used as the received control samples. All the thirty-four (34) samples of 10mm were abutted leaving a gap of 3 mm between them when the gap was fully filled with welded melt using the same 3.0 mm welding electrode and 2.5 mm welding gages at 12.5A welding current and at the same 70V welding voltage. This experiment was carried out in which the test materials were combined with gas welding, paying attention to the welding pool and the heat-affected gas welding zone.

3.4.2 Gas Welding

The welding operations were performed using oxy-acetylene gas that was held at a temperature of approximately 2200-2400^{o}C with a heat power of approximately 54-56mg / m^{3}. The electrode holder was connected to one terminal of the power source via a welding cable, and the work piece was connected to another terminal of the power source via a second cable. The heart of the coated electrode, the heart wire, conducts the electrical current to the arc and provides filler metals for the joint, the top 1.5 cm of the core wire was bare and retained by the electrode holder for electrical contact. The electrode holder was basically a metal clam with an outer shell that was electrically shielded to keep the welder secure.

3.4.3 Arc Welding

In Arc welding, the sample sizes of the test materials used in gas welding were also used. Using the same operation but the only difference being that the same electrode was used instead of an acetylene gas, and electric current. The version of your electrode is a 3.0 version of the electrode used for carbon steels. The welded samples were allowed to cool and hammer-tipped to remove the slag in order to reveal if the gap is totally filled

3.4.4 Preparation of Sample for Corrosion Test

The samples used for general corrosion studies were medium carbon steel with a thickness of 10 mm and were cut into various sizes of 2cm by 2 cm by power hacksaw. These samples were ground and polished by using emery papers to remove the rust particles on the test materials. A total of sixty-eight (68) specimens were used in all as shown in the table below.

Table 1. Shows Sample A: the chemical compositions of the sourced Medium Carbon Steel

Average	%C	%Si	%Mn	%P	%S	%Cr	%Ni	%Mo
$\bar{x}$	0.335	0.307	0.82	0.0061	0.0081	0.080	0.102	0.038
	%Al	%Cu	%Co	%Ti	%Nb	%V	%W	%Pb
$\bar{x}$	0.036	0.178	0.0085	0.0003	0.0054	0.0016	<0.0001	<0.0001
	%B	%Sn	%Zn	%As	%Bi	%Ca	%Ce	%Zr
$\bar{x}$	0.0007	0.0063	0.0042	0.0005	0.0010	0.0010	0.0023	0.0006
	%La	%Fe						
$\bar{x}$	<0.0001	98.3						

Table 2. Shows Sample B: the chemical compositions of the sourced Medium Carbon Steel

Average	%C	%Si	%Mn	%P	%S	%Cr	%Ni	%Mo
$\bar{x}$	0.347	0.276	1.3	0.027	0.0043	0.015	0.036	<0.0001
	%Al	%Cu	%Co	%Ti	%Nb	%V	%W	%Pb
$\bar{x}$	0.033	0.015	0.0013	0.001	0.042	0.0007	<0.0001	<0.0001
	%B	%Sn	%Zn	%As	%Bi	%Ca	%Ce	%Zr
$\bar{x}$	0.0006	0.0008	0.0021	<0.0001	0.001	0.0018	0.0019	0.0002
	%La	%Fe						
$\bar{x}$	<0.0001	98.1						

Table 3. Shows: The Identification and Description of Test Pieces in the solution of various Concentrations

S/No	Sample	Concentration Solution 1ml, 2ml, 3ml and 4ml of NaCl
1	Parent material	
2	Weld assembly for gas welding	
3	heat-affected zone for gas welding	
4	weld pool for gas welding	
5	weld assembly for arc welding	
6	weld pool for arc welding	
7	heat-affected zone arc welding	
8	Electrochemical Analyzer CHI600	Open Circuit Potential Time (OCPT), Tafel plots

3.4.5 Preparation of Solutions and Testing for the Corrosion

(a) The NaCl solutions were prepared using distilled water. The Electrochemical Analyzer was used for the determination of the corrosion tests. About 20ml of distilled water in volume was poured a big conical flask. These solutions were put into sixty -eight (68) small plastic beakers for the weight loss experiments. The processes were determined for 54 days at an interval of 3 days. The other experiments for the determination of the corrosion rate, log (iA) Currents and potentials etc., were performed with the aid of the Electrochemical Analyzer. The solutions were prepared as stated below in table 4.

Table 4. Sample preparation and methods of analyses

S/NO	Sample	Sample Size	Materials	Concentration	Remarks
1	A	10mm	Welded	Control sample 1-4 ml	Weight Loss
2	B	10mm	Un-welded	Control Sample 1-4 ml	Weight Loss
3	A	1cm x 1cm	Welded	The control sample, 1-4 ml	Electrochemical Analyzer
4	B	1cm x1cm	Un-welded	Control Sample 1-4 ml	Electrochemical Analyzer

The medium carbon steel rod of the thickness of 16mm by 12mm and length of 45mm by 6mm thickness was obtained from Light section Mill of the Ajaokuta Steel Company Limited, Ajaokuta, Kogi State, Nigeria. The materials were thoroughly clean and taken to the lathe machine for removing unwanted parts until the sample sizes were 10mm in thickness for both the welded and un-welded. The materials were cut into the required sizes with the use of a cutting disc to 10mm x 10mm for all the samples. A total of sixty-eight (68) samples were prepared in all for the experiments performed for weight loss measurement/analyses. Sixty-eight beakers were used for these experiments. Each of the beakers contained various quantities of Sodium Chloride (NaCl) solutions [12]. Each of the prepared samples was properly labelled for proper identification. During the cause of the experiments, both materials were kept side by side with reference to the welded and un-welded samples. The experiments were conducted for fifty-four (54) days. Before the experiments commenced all the weights of the samples were taken with the aid of a digital weighing balance. The immersed sample materials were removed from the sodium chloride at an interval of three (3) and the new weights were taken with the same weighing balance. The differential in the initial and final weights was used for the determination of corrosion rate measured in mm/yr.

3.4.6 Characterization of Medium Carbon Steel

Metallographic analyses took place with the use of Optical Microscopy at Material Science Laboratory, in the Department of Metallurgical and Materials Engineering, University of Nigeria Nsukka, the SEM and EDS analyses were carried out in South Africa. Below are the results of the analyses:

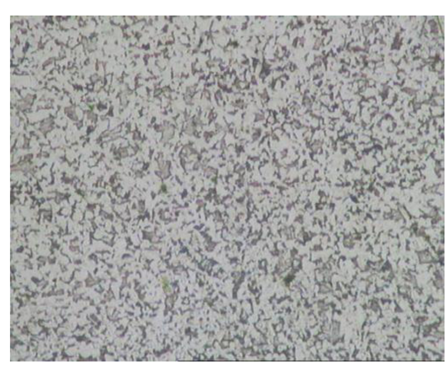

Figure 2. Optical micrograph of Medium Carbon Steel

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From the micrograph of figure 2 above, it can be seen that the parent material contains ferrites and cementite. The ferrites are more compared to cementite which shows that cementite will corrode first before the ferrites.

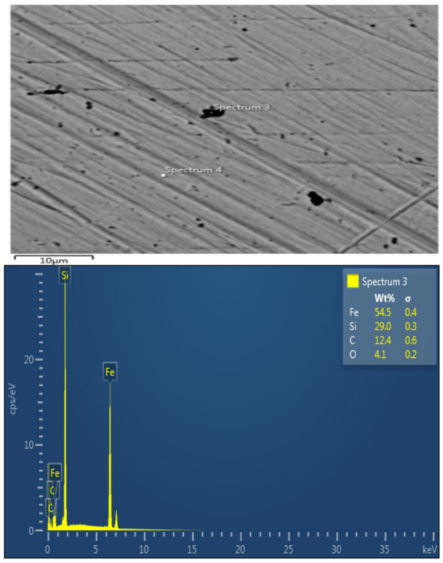


Figure 3. SEM/EDS for parent material

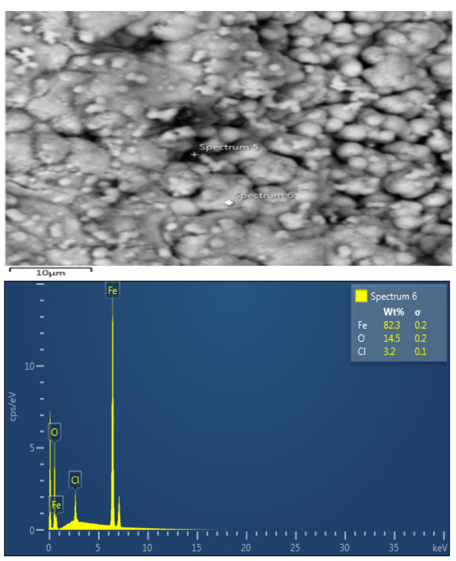
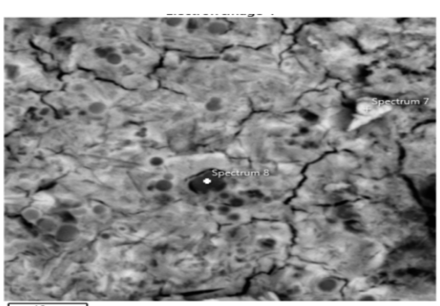


Figure 4. SEM/EDS for the control Sample A



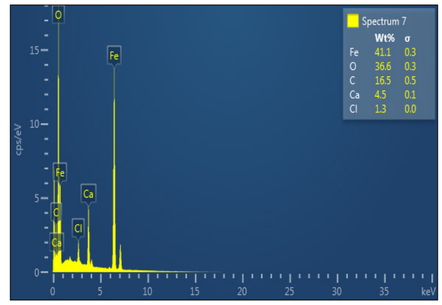


Figure 5. SEM/EDS for coupon Sample A of medium carbon steel immersed in NaCl on 4ml

From the above micrograph of Figure 1, it indicates that the parent material contains ferrites and cementite. The ferrites compared to cementite, which shows that cementite will corrode first before the ferrites.

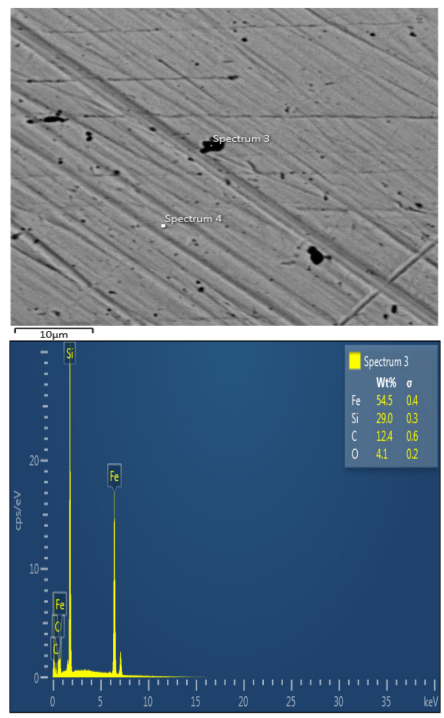
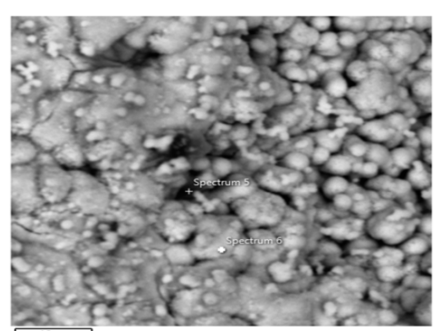


Figure 6. SEM/EDS for parent material



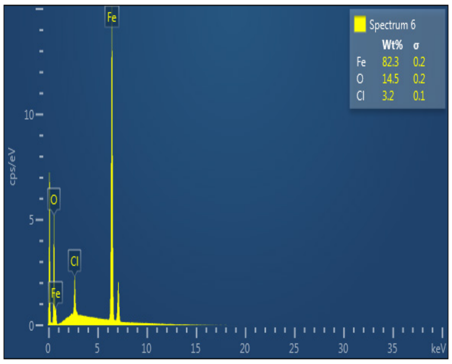


Figure 7. SEM/EDS for the control Sample B

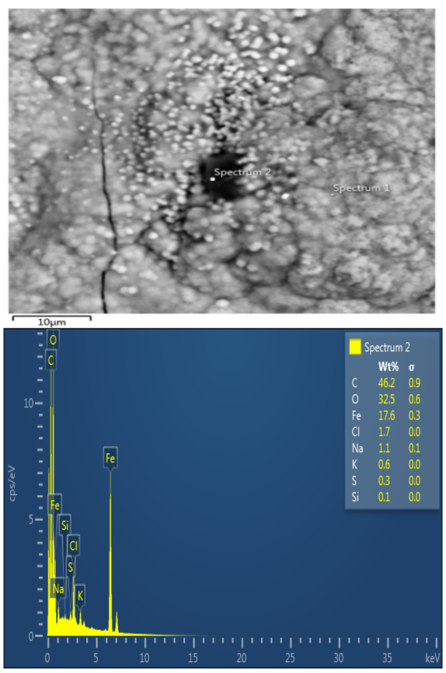


Figure 8. SEM/EDS for coupons for Sample B immersed in NaCl for 6 days on 4ml for un-welded Medium carbon steel

The optical microscopic examination, SEM/EDS for the parent material (coupon) viewed and discovered that iron was the major element present in the sample. These tests took 9 days before the morphological analyses. The sample with 4ml of welded materials shows that there was cathodic protection, which shows there was an increase in carbon content than that of the iron in the parent material. That is, the iron, which was 100wt%, reduced from 100 to 17.6wt% and carbon with 12.4wt% increased to 46.2wt%. These results show that the protection took place on the carbon whereas iron was degraded.

3.5 Corrosion Monitoring

Weight loss: The surface area mass of all specimens used for this was measured before immersion into a different solution. At every 3days interval, the immersion samples were collected, kept with the aid of a spatula within a bowl of water and with two white ankles to extract any corrosion products that may have come into contact with the test material. The specimens were then weighted digitally to achieve weight loss as part of the corrosion result in the setting under analysis. The calculation of corrosion rate was determined using the form below. Calculation of Corrosion Rate

The average corrosion rate may be obtained as follows:

$$Corrosion\,Rate = \frac{K\,x\,W}{A\,x\,T\,x\,D}[13]$$

Millimeters per year (mm/yr.) 8.76 x 10^4

Where K is a constant (varies with the unit)

T is the time of exposure in hours to the nearest 0.01 h, A is the area in cm to the nearest 0.01 cm^2t

W is the mass loss in grams to the nearest 1 mg g

D is the density in g/cm. D cm3

Several units are used to express corrosion rates s rates

Using the above-mentioned units for T, A, W, and D, the corrosion rate can be calculated in a variety of units, with an appropriate value of K

Millimeters per year (mm/yr) 8.76 x 10^4

$$Corrosion\,Rate = \frac{Weight\,Loss\,(CR)}{\frac{A\,x\,T}{365}} - - - - - Equation\,3.2\ [10]$$

W = Weight loss (mg)

A = Total Surface area (mm²)

$$\frac{T}{365} = Exposure\,time\,in\,days\,extrapolated\,to\,a\,year$$

A = 2Π²1

Where

L is the length (mm)

R = radius (mm)

(b) Weight Loss Measurement

The experiments with 1ml-4 ml NaCl solutions took a period of 54 days. The Medium carbon steel on welded joints was used in the corrosion environment for the testing corrosion safety efficiency. The optical multi-meter (model 84280) was used to examine the weight loss of the samples in the sodium chloride atmosphere at an interval of three (3days). The obtained values were converted to a saturated calomel electrode (SCE) values using the following relation:

$E_m V$(SCE)=E_{zin} -1030… Equation (3.1), where 1030 is a constant value.

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4. Results and Discussion

4.1 Results

The values and data generated from the weight loss measurement/ analyses tabulated from table 4.1 to 4.8. It could be seen that each data are specifically for welded and un-welded samples Nevertheless, tables 4.1 to 4.4 are located to welded samples, while tables 4.5 to 4.8 are located to un-welded samples. Also figures 9- 13 shows the description and distributions of the analyses various parameters with the no of days for A1-10mm samples of welded medium carbon steel immersed in 1 ml of sodium chloride solution. A similar trend was observed of figures 14 -18 shows the description and distributions of the analyses various parameters with the no of days for B1-10mm samples of welded medium carbon steel immersed in 2 ml of sodium chloride solution. Also figures 19-23 followed the pattern shown description and distributions of the analyses various parameters with the no of days for A1-10mm samples of welded medium carbon steel immersed in 3 ml of sodium chloride solution and figures 24- 28 shows the same trend for the description and distributions of the analyses various parameters with the no of days for A1-10mm samples of welded medium carbon steel immersed in 4 ml of sodium chloride solution. Also figures 29- 33 shows the description and distributions of the analyses various parameters with the no of days for A1-10mm samples of un-welded medium carbon steel immersed in 1ml of sodium chloride solution. A similar trend was observed of figures 34 -38 shows the description and distributions of the analyses various parameters with the no of days for B1-10mm samples of un-welded medium carbon steel immersed in 2 ml of sodium chloride solution. Also figures 39-43 followed the pattern shown description and distributions of the analyses various parameters with the no of days for A1-10mm samples of un-welded medium carbon steel immersed in 3 ml of sodium chloride solution and figures 44- 48 shows the same trend for the description and distributions of the analyses various parameters with the no of days for A1-10mm samples of un-welded medium carbon steel immersed in 4 ml of sodium chloride solution.

Table 4.1 A1- 10mm samples welded immersed in 1ml NaCl

No of days	Initial weights g	Final weights g	Weight loss g	Cumulative weight loss g	Corrosion rate $g/cm^2/yr$	Potential (mV)	pH
1	26.94	26.94	0	0	0	-488	7.35
4	26.94	26.93	0.006	0.006	0.359	-726	7.66
7	26.93	26.93	0.002	0.007	0.236	-755	7.89
10	26.93	26.92	0.011	0.018	0.208	-712	8.19
13	26.92	26.91	0.011	0.029	0.252	-686	7.45
16	26.91	26.9	0.008	0.037	0.215	-703	7.11
19	26.9	26.89	0.008	0.044	0.178	-621	7.31
21	26.89	26.89	0.006	0.05	0.085	-532	8.7
24	26.89	26.87	0.014	0.064	0.065	-710	7.8
27	26.87	26.86	0.015	0.079	0.079	-650	7.25
30	26.86	26.86	0.005	0.084	0.099	-735	7.1
33	26.86	26.85	0.59	0.09	0.058	-611	8.2
36	26.85	26.84	0.009	0.099	0.067	-680	8.1
39	26.84	26.84	0.007	0.105	0.088	-725	7.7
42	26.84	26.83	0.111	0.116	0.097	-740	8.1
45	26.83	26.82	0.007	0.124	0.065	-510	7.7
48	26.82	26.81	0.007	0.131	0.054	-620	8.15
51	26.81	26.8	0.009	0.139	0.035	-630	7.65
54	26.8	26.8	0.006	0.1454	0.026	-525	8.30

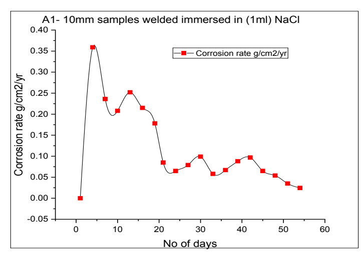

Figure 9. Weight loss g vs No of days

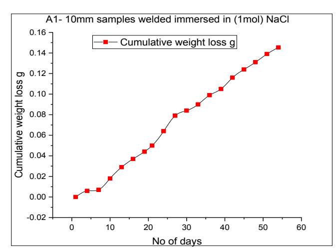

Figure 10. Cumulative weight loss g vs No of days

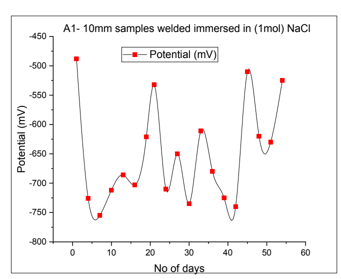

Figure 11. Corrosion rate $g/cm^2/yr.$ vs No of days

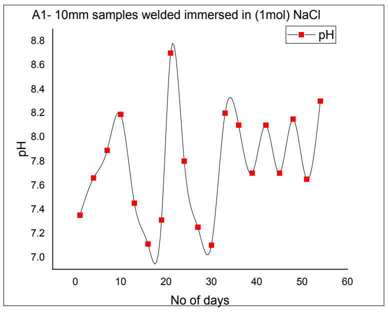

Figure 12. Potential (mV) vs No of days

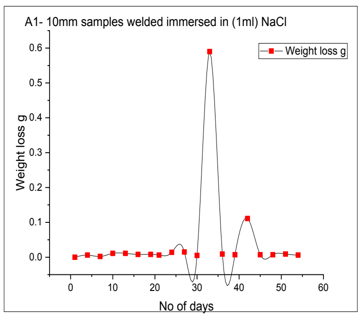

Figure 13. pH vs No of days

Table 4.2 B1- 10mm samples welded immersed in (2ml) NaCl

Nos. of days	Initial weights g	Final weights g	Weight loss g	cumulative weight loss g	Corrosion rate g/cm2/yr	Potential (mV)	pH
1	26.34	26.3361	0	0	0	-539	7.21
4	26.34	26.331	0.005	0.005	0.233	-805	8.06
7	26.33	26.3283	0.003	0.008	0.071	-395	7.64
10	26.33	26.3204	0.008	0.016	0.145	-577	8.3
13	26.32	26.3182	0.002	0.018	0.031	-790	7.35
16	26.32	263,102	0.008	0.026	0.091	-780	7.31
19	26.32	26.3085	0.002	0.028	0.016	-637	7.42
21	26.31	26.3002	0.008	0.036	0.072	-690	8.05
24	26.3	26.2965	0.004	0.04	0.028	-660	7.2
27	26.3	26.2911	0.005	0.045	0.037	-621	8.1
30	26.29	26.286	0.005	0.05	0.031	-635	8.19
33	26.29	26.28	0.006	0.056	0.033	-605	7.9
36	26.28	26.2742	0.006	0.062	0.029	-570	8
39	26.27	26.2702	0.004	0.066	0.019	-745	8.35
42	26.27	26.2662	0.004	0.07	0.017	-660	7.4
45	26.27	26.2601	0.006	0.076	0.025	-615	8.7
48	26.26	26.2554	0.005	0.081	0.018	-520	9.08
51	26.26	26.2494	0.006	0.087	0.022	-642	8.55
54	26.25	26.2419	0.008	0.094	0.025	-673	9.35

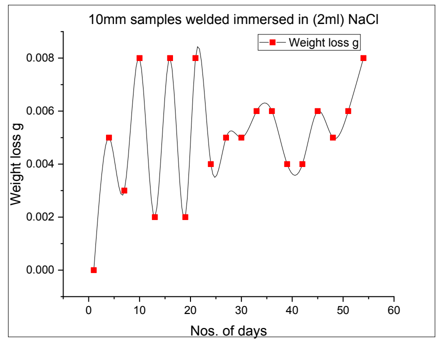

Figure 14. Weight loss g vs No of days

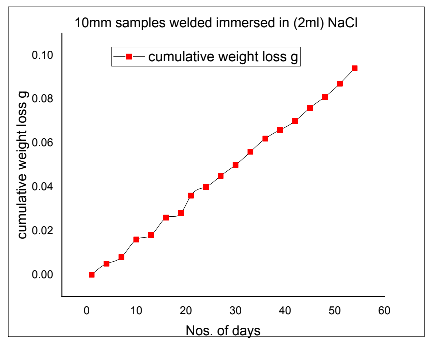

Figure 15. Cumulative weight loss g vs No of days

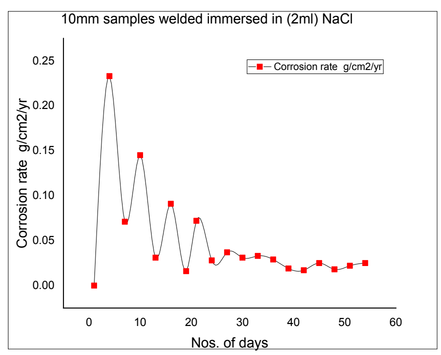

Figure 16. Corrosion rate g/cm^2/yr vs No of days

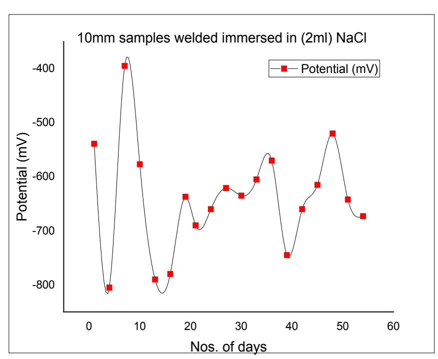

Figure 17. Potential (mV) vs No of days

DOI: https://doi.org/10.30564/jmmr.v3i2.2400

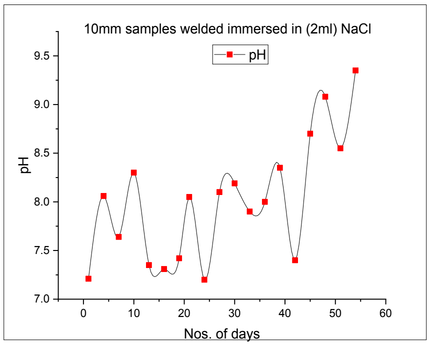

Figure 18. pH vs No of days

Table 4.3. A1- 10mm samples welded immersed in (3ml) NaCl

Nos. of days	Initial weights g	Final weights g	weight loss g	Cumulative weight loss g	Corrosion rate g/cm2/yr	Potential (mV)	PH
1	15.32	15.32	0	0	0	-676	7.13
4	15.32	15.31	0.01	0.01	0.39	-456	7.11
7	15.31	15.31	0	0.01	0.29	-484	7.91
10	15.31	15.3	0.01	0.02	0.26	-776	7.21
13	15.3	15.3	0	0.02	0.17	-655	7.31
16	15.3	15.29	0.01	0.03	0.14	-674	7.44
19	15.29	15.29	0.01	0.03	0.05	-467	7.85
21	15.29	15.28	0.01	0.04	0.02	-678	7.36
24	15.28	15.27	0.01	0.05	0.04	-784	8.16
27	15.27	15.27	0	0.05	0.05	-657	7.64
30	15.27	15.27	0	0.05	0.03	-784	8.47
33	15.27	15.26	0.01	0.06	0.01	-467	8.09
36	15.26	15.25	0.01	0.07	0.03	-475	8.1
39	15.25	15.25	0.01	0.07	0.03	-657	7.5
42	15.25	15.23	0.01	0.09	0.03	-873	8.06
45	15.24	15.23	0.01	0.09	0.02	-674	8.24
48	15.23	15.22	0.01	0.1	0.02	-793	7.97
51	15.22	15.22	0.00	0.1	0.04	-674	7.46
54	15.22	15.21	0.01	0.10	0.02	-567	8.25

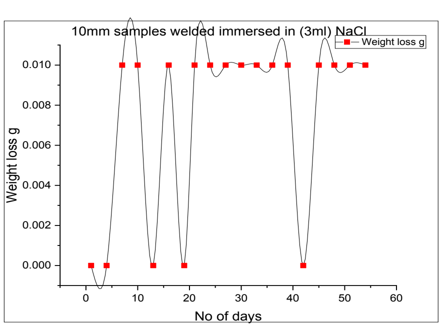

Figure 19. Weight loss g vs No of days

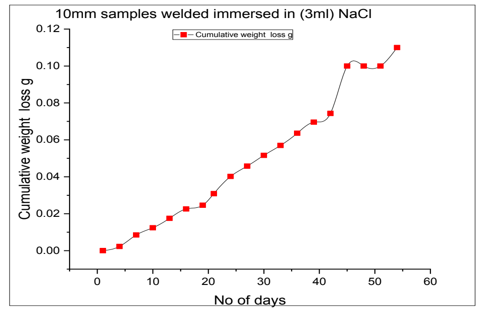

Figure 20. Cumulative weight loss g vs No of days

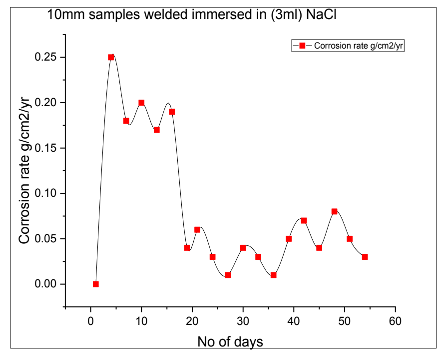

Figure 21. Corrosion rate g/cm^2/yr vs No of days

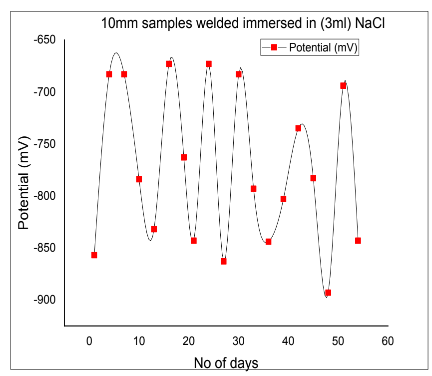

Figure 22. Potential (mV) vs No of days

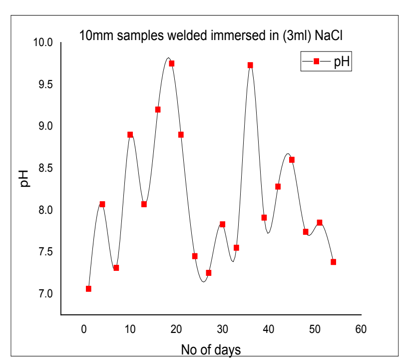

Figure 23. pH vs No of days

Table 4.4. B1- 10mm samples welded immersed in (4ml) NaCl

No of Days	Initial weights g	Final weights g	weight loss g	Cumulative weight loss g	Corrosion rate g/cm2/yr	Potential (mV)	pH
1	21.65	21.65	0	0	0	-672	7.91
4	21.65	21.65	0	0.0018	0.37	-675	7.23
7	21.65	21.64	0.01	0.0102	0.24	-564	7.43
10	21.64	21.64	0	0.0145	0.16	-647	8.15
13	21.64	21.63	0.01	0.0205	0.19	-567	8.25
16	21.63	21.63	0	0.0235	0.04	-563	8.19
19	21.63	21.53	0	0.0266	0.03	-567	7.91
21	21.63	21.62	0	0.0302	0.03	-475	8.06
24	21.62	21.62	0	0.0335	0.03	-485	7.78
27	21.62	21.61	0.01	0.0416	0.06	-784	8.11
30	21.61	21.61	0	0.0436	0.01	-683	8.03
33	21.61	21.6	0.01	0.0496	0.04	-567	8.02
36	21.6	21.59	0.01	0.0636	0.08	-683	7.8
39	21.59	21.58	0.02	0.0807	0.09	-794	7.52
42	21.58	21.58	0	0.0827	0.01	-684	8.88
45	21.58	21.56	0.02	0.0997	0.07	-783	7.19
48	21.56	21.56	0	0.1006	0	-467	7.4
51	21.56	21.56	0	0.1037	0.01	-683	8.1
54	21.56	21.55	0.01	0.1118	0.01	-647	8.22

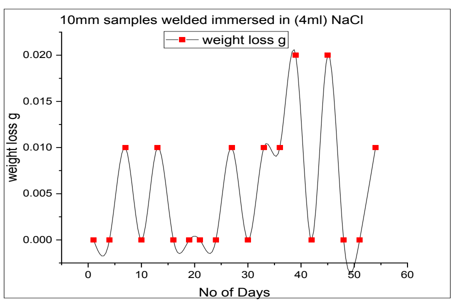

Figure 24. Weight loss g vs No of days

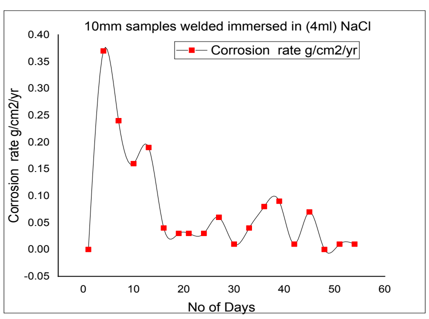

Figure 25. Cumulative weight loss g vs No of days

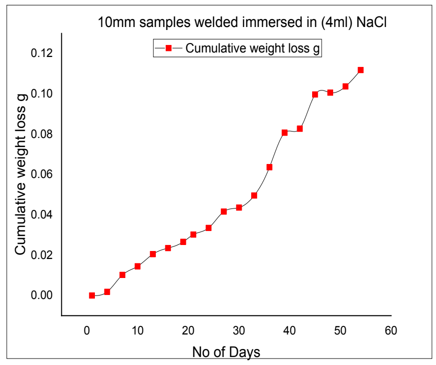

Figure 26. Corrosion rate g/cm^2/yr. vs No of days

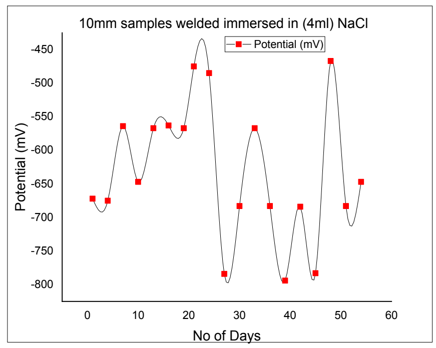

Figure 27. Potential (mV) vs No of days

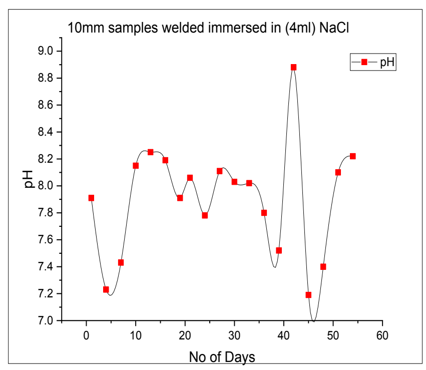

Figure 28. pH vs No of days

Table 4.5 A1- 10mm samples unwelded immersed in (1ml) NaCl

Nos. of days	Initial weights g	Final weights g	Weight loss g	Cumulative weight loss g	Corrosion rate g/cm2/yr	Po-tential (mV)	PH
1	15.06	15.06	0	0	0	-459	7.09
4	15.06	15.06	0.001	0.001	0.578	-465	7.13
7	15.06	15.05	0.002	0.003	0.355	-567	7.2
10	15.05	15.05	0.002	0.005	0.312	-647	7.32

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13	15.05	15.05	0.002	0.007	0.213	-563	7.25
16	15.05	15.05	0.002	0.008	0.029	-742	7.31
19	15.05	15.05	0.001	0.01	0.02	-645	7.37
21	15.05	15.05	0.003	0.012	0.024	-456	7.22
24	15.05	15.04	0.001	0.013	0.017	-598	8.1
27	15.04	15.04	0.001	0.014	0.088	-843	8.03
30	15.04	15.04	0.002	0.017	0.022	-658	7.99
33	15.04	15.04	0.002	0.018	0.038	-653	8.13
36	15.04	15.03	0.003	0.027	0.023	-793	8.08
39	15.03	15.02	0.002	0.035	0.036	-465	8.15
42	15.02	15.02	0.002	0.041	0.016	-753	7.35
45	15.02	15.01	0.005	0.046	0.033	-675	7.6
48	15.0116	15.01	0.0027	0.0484	0.034	-773	8.24
51	15.0089	15	0.0041	0.0525	0.034	-333	8.15
54	15.0048	15	0.0047	0.0572	0.029	-544	7.45

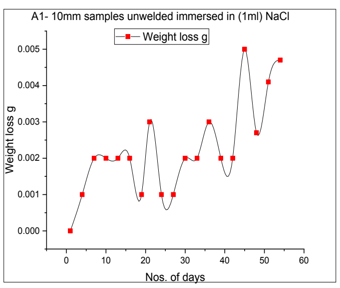

Figure 29. Weight loss g vs No of days

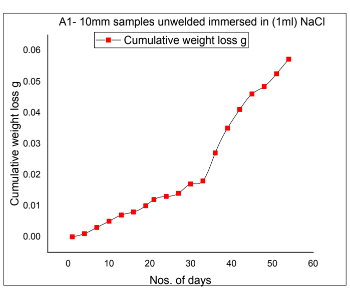

Figure 30. Cumulative weight loss g vs No of days

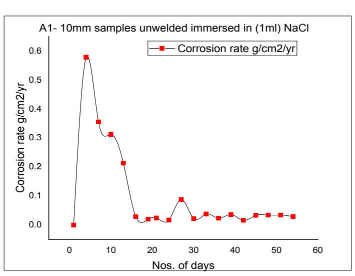

Figure 31. Corrosion rate g/cm^2/yr. vs No of days

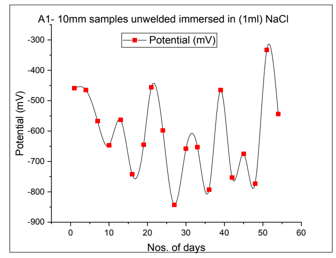

Figure 32. Potential (mV) vs No of days

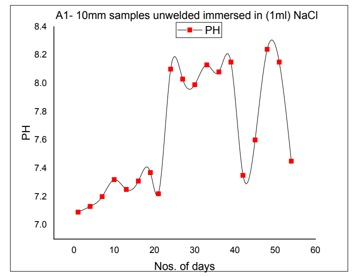

Figure 33. pH vs No of days

Table 4.6 B1- 10mm samples unwelded immersed in (2ml) NaCl

Nos. of days	Initial weights g	Final weights g	weight loss g	Cumulative weight loss g	Corrosion rate g/cm2/yr	Potential (mV)	PH
1	15.32	15.32	0	0	0	-676	7.13
4	15.32	15.31	0.01	0.01	0.39	-456	7.11
7	15.31	15.31	0	0.01	0.29	-484	7.91
10	15.31	15.3	0.01	0.02	0.26	-776	7.21
13	15.3	15.3	0	0.02	0.17	-655	7.31
16	15.3	15.29	0.01	0.03	0.14	-674	7.44
19	15.29	15.29	0.01	0.03	0.05	-467	7.85
21	15.29	15.28	0.01	0.04	0.02	-678	7.36
24	15.28	15.27	0.01	0.05	0.04	-784	8.16
27	15.27	15.27	0	0.05	0.05	-657	7.64
30	15.27	15.27	0	0.05	0.03	-784	8.47
33	15.27	15.26	0.01	0.06	0.01	-467	8.09
36	15.26	15.25	0.01	0.07	0.03	-475	8.1
39	15.25	15.25	0.01	0.07	0.03	-657	7.5
42	15.25	15.23	0.01	0.09	0.03	-873	8.06
45	15.24	15.23	0.01	0.09	0.02	-674	8.24
48	15.23	15.22	0.01	0.1	0.02	-793	7.97
51	15.22	15.22	0.00	0.1	0.04	-674	7.46
54	15.22	15.21	0.01	0.10	0.02	-567	8.25

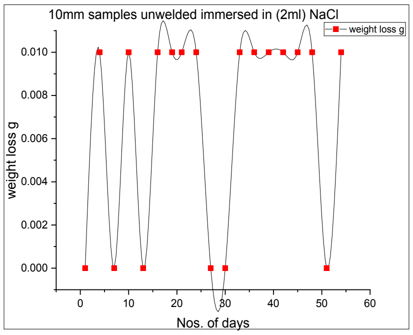

Figure 34. Weight loss g vs No of days

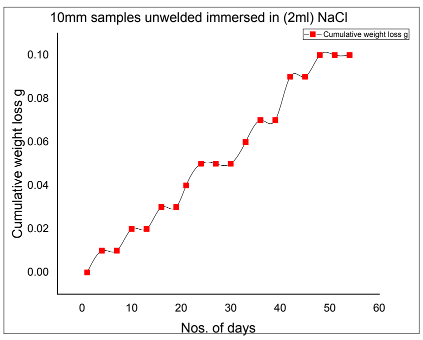

Figure 35. Cumulative weight loss g vs No of days

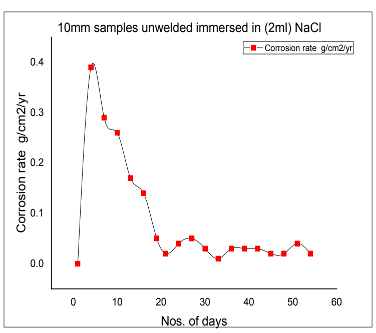

Figure 36. Corrosion rate g/cm^2/yr vs No of days

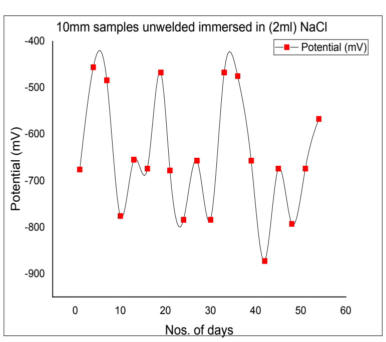

Figure 37. Potential (mV) vs No of days

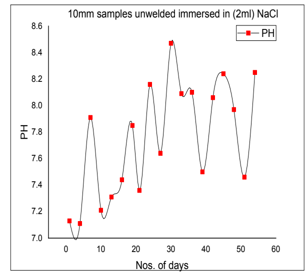

Figure 38. pH vs No of days

Table 4.7. A1- 10mm samples unwelded immersed in (3ml) NaCl

Nos. of days	Initial weights (g)	Final weights (g)	Weight loss (g)	Cumulative weight loss (g)	Corrosion rate g/ cm2/yr	Potential (mV)	PH
1	15.35	15.35	0	0	0	-528	7.2
4	15.35	15.34	0.01	0.0062	0.37	-678	7.3
7	15.34	15.34	0	0.0094	0.28	-765	7.42
10	15.34	15.34	0	0.0119	0.29	-567	7.16
13	15.34	15.33	0.01	0.0177	0.14	-763	7.3
16	15.33	15.33	0	0.0206	0.15	-647	7.21
19	15.33	15.32	0.01	0.0284	0.05	-503	7.11
21	15.32	15.32	0	0.0308	0.06	-674	7.78
24	15.33	15.31	0	0.0345	0.05	-783	7.14
27	15.31	15.31	0.01	0.0418	0.07	-573	7.38
30	15.31	15.3	0.01	0.0494	0.05	-564	7.36
33	15.3	15.29	0.01	0.0559	0.06	-673	7.23
36	15.29	15.29	0.01	0.0637	0.04	-764	7.5
39	15.29	15.28	0.01	0.0688	0.03	-863	7.18
42	15.28	15.27	0.01	0.0752	0.07	-673	7.52
45	15.27	15.27	0.01	0.0835	0.06	-753	7.12
48	15.27	15.26	0.01	0.0914	0.05	-573	7.86
51	15.26	15.25	0.01	0.0979	0.04	-792	7.84
54	15.25	15.25	0.00	0.1014	0.04	-783	7.86

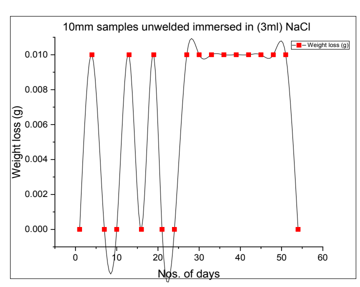

Figure 39. Weight loss g vs No of days

 DOI: https://doi.org/10.30564/jmmr.v3i2.2400

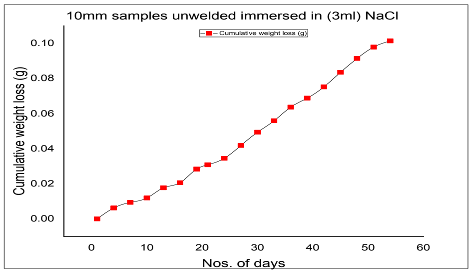

Figure 40. Cumulative weight loss g vs No of days

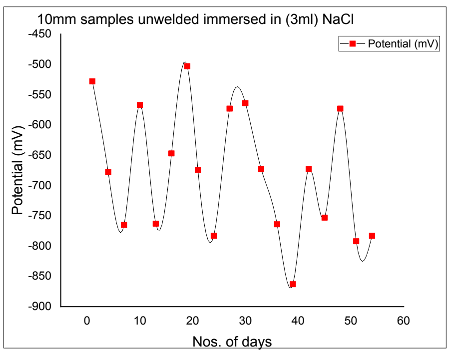

Figure 41. Corrosion rate g/cm^2/yr. vs No of days

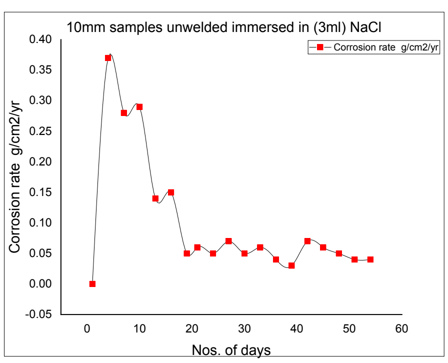

Figure 42. Potential (mV) vs No of days

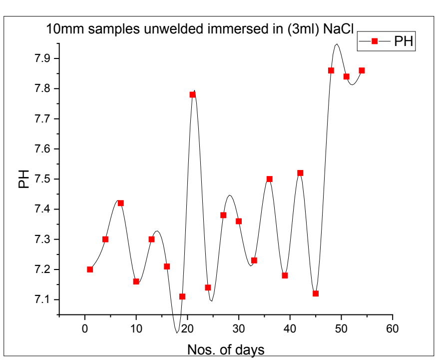

Figure 43. pH vs No of days

Table 4.8 B1: 10mm samples unwelded immersed in (4ml) NaCl

Nos. of days	Initial weights (g)	Final weights (g)	Weight loss (g)	Cumulative weight loss (g)	Corrosion rate g/cm2/ yr.	Potential (mV)	pH
1	14.61	14.61	0	0	0	-635	7.44
4	14.61	14.61	0	0.0004	0.48	-654	7.47
7	14.61	14.6	0.01	0.0068	0.27	-708	7.56
10	14.6	14.6	0	0.0113	0.13	-535	8.36
13	14.6	14.59	0.01	0.0174	0.14	-660	8.49
16	14.59	14.59	0.01	0.0225	0.09	-672	8.44
19	14.59	14.58	0	0.0269	0.07	-541	8.39
21	14.58	14.58	0.01	0.0033	0.08	-709	8.4
24	14.58	14.57	0.01	0.0386	0.07	-660	8.06
27	14.57	14.56	0.01	0.0458	0.08	-567	8.39
30	14.56	14.56	0.01	0.0517	0.06	-428	8.34
33	14.56	14.55	0.01	0.0571	0.05	-812	7.36
36	14.55	14.55	0	0.0613	0.03	-517	8.07
39	14.55	14.54	0.01	0.0664	0.04	-708	7.62
42	14.54	14.54	0	0.0702	0.03	-765	7.41
45	14.54	14.54	0.01	0.0776	0.05	-678	7.45
48	14.54	14.52	0.01	0.0822	0.04	-578	7.54
51	14.52	14.52	0.01	0.089	0.04	-688	8.3
54	14.52	14.51	0.01	0.0967	0.04	-656	7.61

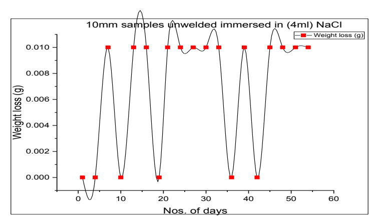

Figure 44. Weight loss g vs No of days

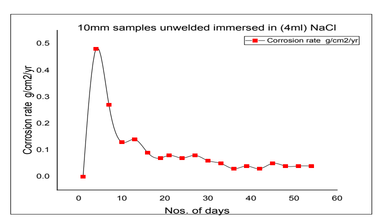

Figure 45. Cumulative weight loss g vs No of days

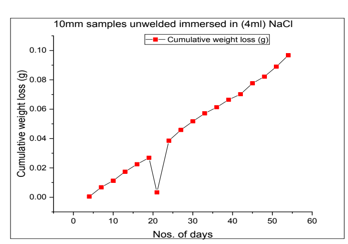

Figure 46. Corrosion rate g/cm^2/yr. vs No of days

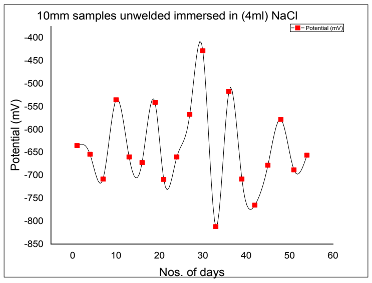

Figure 47. Potential (mV) vs No of days

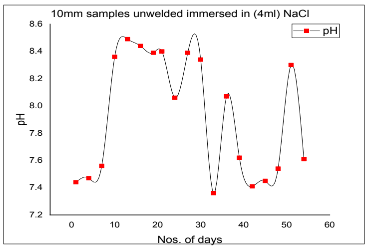

Figure 48. pH vs No of days

4.2 Electrochenical Test

(b) The corrosion test was conducted with the use of Electrochemical Tester Model: CHI604E. The tests were conducted in accordance with ASTM G199 - 09 (2014 Standard Guide for Electrochemical Measurement). An electrochemical cell containing the potential inhibitor solutions were used as the electrolyte, consisting of three electrodes, the working electrode (sample), counter electrode (graphite rod) and silver/silver chloride electrode was used as a reference electrode (Ag/AgCl). The tests were performed from -1.0V to +1.0V. The Open Circuit Tests were allowed to run for 3600 seconds while the Tafel tests were allowed to run for the same duration in seconds after which the graphs were plotted.

The samples used for the experiments were prepared in such a way that they were in the same sizes and dimensions of 1cm x 1cm. A total number of ten samples were prepared and five samples each for the samples A and B. Each of the sample have one control sample while the remaining four samples each were used to prepared samples 1-4ml solution of sodium chloride. Immediately the samples were mounted on the system. An Open Circuit Potential Time (OCPT) was carried out. The working and reference electrodes are connected in the Open Circuit Potential-Time technique (OCPT), and the potential difference across them was reported as a function of time. Since the counter electrode was not attached to the external cell, there was no current passing through the working electrode except for the bias current of the measuring amplifiers in the range of picoamperes. [11]. The values/data generated from the experiments were used to plot graphs. These graphs are shown in figures 49-58. Figures 49 -50 show the OCPT for welded and un-welded the medium carbon steel, while figures 51 -58 indicate the plot of Log(iA) against Current (A) for welded and un-welded medium carbon steel.

Interpretation of the Tafel plots for welded and un-welded samples for 1-4ml in sodium chloride.

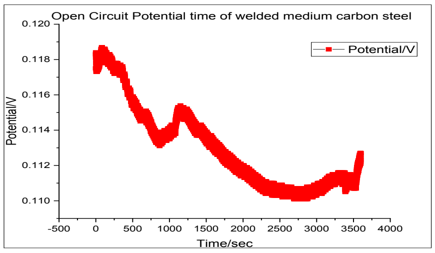

Figure 49. Potential vs time (OCPT) welded medium carbon Steel

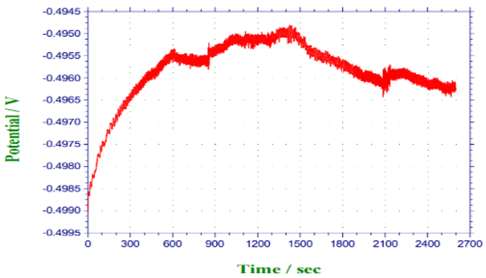

Figure 50. Potential vs time (OCPT) unwelded medium carbon Steel

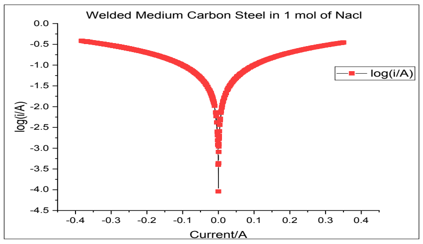

Figure 51. Log(i/A) for welded material in 1 ml NaCl solution

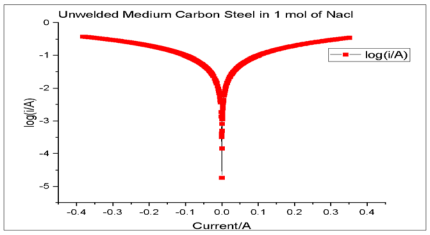

Figure 52. Log(i/A) for un-welded material in1 ml NaCl solution

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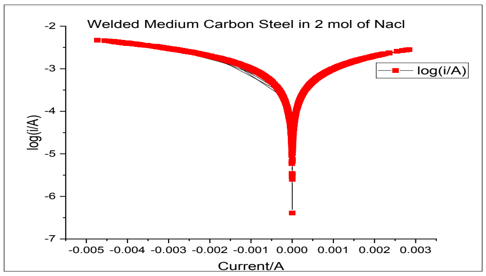

Figure 53. Log(i/A) for welded material in 2 ml NaCl solution

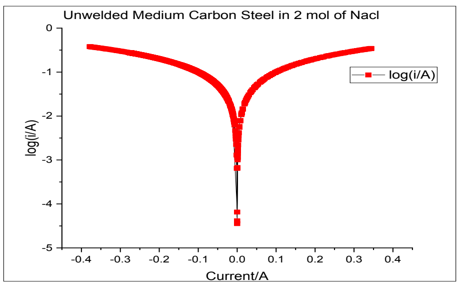

Figure 54. Log(i/A) for un-welded material in 2 ml NaCl solution

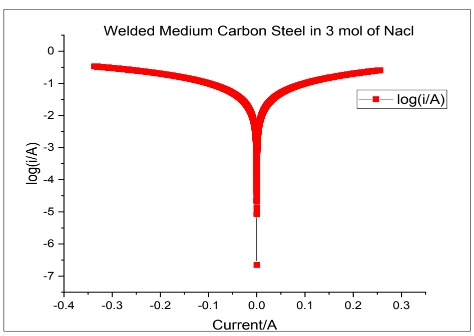

Figure 55. Log(i/A) for welded material in 3 ml NaCl solution

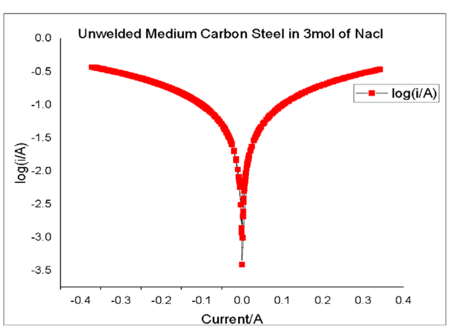

Figure 56. Log(i/A) for un-welded material in3 ml NaCl solution

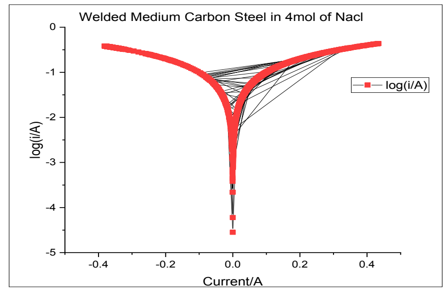

Figure 57. Log(i/A) for welded material in 4 ml NaCl solution

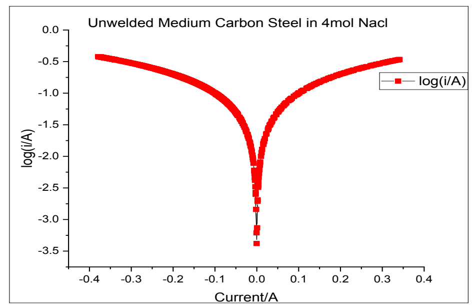

Figure 58. Log(i/A) for un-welded material in 4 ml NaCl solution

5. Conclusion

The Study on the Corrosion Behaviour of Welded and un-welded medium carbon steel in sodium chloride (NaCl) solutions were successfully performed. The experiments were in two parts, the first part took care of the weight loss measurement/analyses and the second part studied was based on the use of the electrochemical Analyzer/workstation. The materials used for the study was sourced from the Ajaokuta Steel Company Limited, Ajaokuta. Kogi State, Nigeria with references to the Light Section Mill. The obtained medium carbon steel materials were analyzed at the Quality Control and Materials Analyses unit of the Foundry Shop. These materials were identified and labelled as sample A and B. The experiments were performed under very strict environment as regards to corrosion science and engineering. 20ml of distilled water was used to prepare sodium chloride solutions. The obtained medium carbon steel materials were prepared for both experiments. The inverted Metallurgical Microscope was used to determine the microstructure of the samples, the samples were taken to South Africa for SEM and EDS analyses. The data generated were used to plot the graphs as shown in the various figures. It can be concluded that the welded medium carbon steel has better corrosion resisting tendency than the un-welded medium carbon steel.

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