

# Behavioural Corrosion Mechanism of Hot Worked Mild Carbon Steel Immersed in various Acidic Environments

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## ABSTRACT

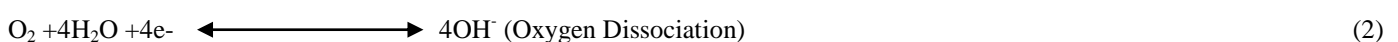
Heat treatment of metals is an important operation in the final fabrication process of many engineering components. Hot working help to improve the mechanical properties of the affected metals. In this research work, behavioural corrosion mechanism of hot worked mild steel carbon immersed in various acidic environments were evaluated mainly to determine the weight loss and corrosion rate of the material. In evaluating the corrosion rate of the mild steel in acidic environment, weight loss approach was adopted. The coupons were measured prior to immersion and different weight measurements were taken at interval of 24 hours, over the period of 168 hours. The difference in weight between the original weight and the final weight at each 24 hour interval (weight loss), was estimated and used for the calculation of the corrosion rates. The results obtained reveal an increased in weight loss as concentration of acids increases and this resulted to increase in corrosion rate as experienced by coupons immersed in five samples of acid environment used in this research work. Besides, nitric acid proved to be more aggressive, and this was followed by hydrochloric acid, tetraoxosulphate (VI) acid, phosphoric acid, and acetic acid was the least. Therefore, if acid must be used with mild steel, nitric acid should not be used.

**Key Words:** Hot Work, Mild Carbon Steel, Weight Loss, Corrosion Rate, Acidic Environment.

## 1. INTRODUCTION

Mild carbon steels account for a large proportion of the total output of steel [1-2]. Mild carbon steel is a vital alloy used in petroleum and petrochemical industries and it account for over 98% of the construction materials [3]. The wide application of mild carbon steel range from chemical, oil gas storage tanks and transportation pipelines is due to its moderate strength, good weld-ability and formability [4]. Deterioration of materials produced from mild carbon steel as a result of corrosion has come to be accepted worldwide as an unavoidable fact of life. The present degradation of infrastructures particularly in acidic medium has continued to generate a lot of worries to researchers across the world in view to procure lasting solution to the problem. Corrosion remains one of the most severe limitations to the use of mild carbon steel in the chemical, petrochemical industries construction, and manufacturing.

Corrosion is the damage of material due to chemical reaction of the material with its environment. Usually, this destruction takes place on its surface in the form of material dissolution or redeposit ion in some other forms. Mild carbon steel just like every other metals and alloys are generally prone to corrosion because most of them occur naturally as ores, which is the most stable state of low energy and there is a net decrease in free energy, ( $\Delta G$ ) from metallic to oxidized state [5]. The corrosion of mild carbon steel in natural environments such as acidic medium is of practical importance. Generally, the chemistry of corrosion processes is shown in equation (1), and equation (2) [6].



The corrosion characteristic of mild carbon steel in acidic medium is the formation and growth of compact and thick layers composed of oxides, insoluble salts and organic materials [7]. The exchange of various species (ions, molecules, gas) between

acidic ion and the rust layers or the metal depends both on the kinetics of the Faradaic reactions of the entities with either the oxides or the metal, as well as on their transport properties through the different strata of the rust layers [8-9]. Corrosion is a complex electrochemical process involving the interaction between metallic materials and their environment, which produces corrosion products and leads to the degradation of the materials [10]. Various factors affect the corrosion process, such as the type of material, design, water vapour, anions in the environment, such as sulphate, chloride and carbonate. It is the deterioration of material and loss of its properties as a result of reactions and interactions with its environment. Materials corrode at various rates and the extent of corrosion damage depends on interrelated variables involved [11]. Materials often have a natural tendency to combine with other chemical elements to return to their lowest energy state. In order to return to lower energy states, materials frequently combine with oxygen and hydrogen ion, both of which are present in most natural environments, to form hydrated oxides and in the case of iron, the iron oxide is referred to as rust.

Heat treatment is a heating and cooling operation applied to metals and alloys in solid state to impart desirable properties to the metal or alloy. Heat treatment of metals is an important operation in the final fabrication process of many engineering components. Heat treatment is of various forms which include annealing, normalizing, tempering, hardening and isothermal operations [12-13]. Heat treatment improves the microstructure of the metal, and this is what gives the metal desired properties for different service conditions. Hot work is the process in which the metal is subjected to forces above recrystallization temperature to give it a desired shape. Above recrystallization temperature, the metal becomes plastic and causing growth in grains. By hot working the grains broke up and forms small new crystals which is refinement of grains. The various methods of hot working are as same as cold working. Hot working is a high temperature thermo mechanical treatment consisting of deforming a metal above its transformation temperature and cooling at a rate to preserve same or all of the deformed structure. It is an activity performed on metals at a temperature high enough to permit recrystallization and strain hardening does not occur. The ingots are preheated in soaking – pits or furnaces in order to bring them to the required temperature which is somewhere in the region between 100-200°C below the melting point. So at such temperature the metal is much more plastic and requires smaller deformation forces than would be necessary at low temperature. The coarse, as-cast structure of the work piece or ingot, would be broken up and distorted during the first stages of hot deformation, however, almost immediately, recrystallization can be carried out. Therefore, a sequence of rolling passes or forging bellows will generally be planned so that final deformation takes place at the temperature close to recrystallization temperature in order without excessive grain growth occurring. Considering the usefulness of hot work on mild carbon steel mainly to improve its mechanical properties and the effect of corrosion on it, it became necessary to study and emulate the effect of hot work and corrosion of mild carbon steel in acidic medium.

## **2. MATERIALS AND METHODS**

### **2.1 Materials Used**

The mild steel used was obtained from Vinupet Steel Company, Warri, Delta State, Nigeria. The elemental composition percentage was carried out at Delta State Company Limited, Ovia-Aladja, Delta State, Nigeria.

### **2.2 Experiment Overview**

The experiment involved the use of 25 pieces of hot worked mild carbon steel coupons in studying their corrosion rate when immersed in various environment of acidic solution: the various acids used include; hydrochloric acid (HCl) of molar mass 36.5g, percentage purity 36%, specific gravity 1.17, and relative density of 1.17g/ml or 1170g/l, nitric acid (HNO<sub>3</sub>) of molar mass of 63.01g/mol, percentage purity 68%, specific gravity 1.42 and relative density 1420g/l, acetic acid (CH<sub>3</sub>COOH) of molar mass 60.05g/mol, percentage purity 99.7%, specific gravity 1.04, relative density 1040g/l, phosphoric acid (H<sub>3</sub>SO<sub>4</sub>) of molar mass of 98.0g, percentage purity 85%, specific gravity 1.685g/mol or 1685g/l and hydrogen tetraoxosulphate (VI) acid (H<sub>2</sub>SO<sub>4</sub>) of molar mass 98g/mol, percentage purity 98%, specific gravity 1.305, relative density 1830.5g/l, with different concentration varying from 0.5 to 2.5 mole per dm<sup>3</sup>. The method employed for this research was simply the weight loss method, which involve the difference in weight of the coupon before and after exposure to the various corrosion medium at a given time interval and at room temperature. Different tags were used to ensure that the experiment was not mixed-up.

### **2.3 pH Meter**

This enables the acidity and the basicity of the solution to be known.

### **2.4 Mettler PM II Sensitive Balance**

It was used to measure the variation in weight of the coupon at different stages (Figure 1).



Figure 1: Weight Loss Measurement

## 2.5 Preparation of Standard Corrosion Solution

The various stock solution used for the experiment were prepared using Equation (3) to Equation (5).

$$\text{Amount of stock solution in g/dm}^3 = \text{percentage purity} \times \text{relative density}/100 \tag{3}$$

$$\text{Number of moles} = \text{mass of substance in g per dm}^3/\text{molar mass in g per} \tag{4}$$

After knowing the concentration of the stock solution, the volume of the stock solution required to prepare each of the environment was calculated using the dilution formula as shown in Equation (3).

$$V_1M_1=V_2M_2 \tag{5}$$

where,

$M_1$  = Concentration of stock solution

$V_1$  = Volume of stock solution required to make environment.

$M_2$  = Concentration of environment to be prepared.

$V_2$  = Volume of environment to be prepared

For HCl acid

Molar mass of HCl = 36.5g

Percentage purity = 36%

Specific gravity = 1.17

Relative density = 1.17g/ml or 1170g/L

To calculate the amount of the stock solution:

$$\text{Percentage purity} \times \text{relative density} = 36/100 \times 1170 = 421.2\text{g/l}$$

$$\text{Amount of stock in mol./dm}^3 = 11.54\text{MHCL}$$

Thus, 36% of hydrochloric acid contains 11.54M of undiluted HCl

For concentration of 0.5M HCl using the dilution formula

$$V_1 = M_2V_2/M_1$$

$$M_1 = 11.53$$

$$M_2 = 0.5$$

$$V_2 = 200\text{ml}$$

$$V_1 = ?$$

Hence,

$$V_1 = 0.5 \times 200 / 11.53 = 8.67\text{ml}$$

Then, Volume of distilled water, 200ml – 8.67ml = 191.33ml

Thus, 8.67ml of concentrated HCl acid was dissolved into 19.33ml of distilled water to give an environment of 200ml to 0.5M.

Same procedures were adopted for all reagents used. Table1 shows the volume of the stock solution (acid) required to prepare each concentration of the different environment.

**Table1. Volume of the Stock Solution (Acid) required for each Concentration of the different Environment**

Concentration (M)	Volume of Acids ml				
	H <sub>2</sub> SO <sub>4</sub>	HCl	HNO <sub>3</sub>	CH <sub>3</sub> COOH	H <sub>3</sub> PO <sub>4</sub>
0.5	8.67	6.53	5.79	6.84	5.46
1.0	17.35	13.05	11.58	13.69	10.92
1.5	26.02	19.58	17.37	20.53	16.38
2.0	34.69	26.11	23.16	27.38	21.85
2.5	43.37	32.64	28.95	34.22	37.31

## 2.6 Experimental Procedures

Fifty (50) sets of clean beakers were tagged with the name of the various acids, with HW, denoting hot worked specimen. Each of the five (5) corrosion environment having ten (10) beakers each with various concentration ranging from 0.5M to 2.5M. Prior to immersion, the approximate pH value of each solution was taken using a pH meter, and the value obtained recorded. The specimens were properly washed with distilled water, dried with clean piece of cloth, and then the initial weight was taken, using the Meter PM II Sensitive Digital weigh balance, and then recorded. Total immersion in 200ml test solution of the specimens into the various environment, was aided with the use of a nylon rope tied to a clean to a clean flattened steel rod of about 3mm diameter, placed on top of each beaker, for support. The experimental setup is shown in Figure 2.



Figure 2: Experimental Setup

## 3. RESULTS AND DISCUSSION

The carbon mild steel material elemental composition from the spark test analysis result is as follow; 0.15% C, 0.22% Si, 0.5% Mn, 0.66% P, 0.057% S, 0.02% Mo, 0.25% Cr, 0.1% Ni, 0.26% V, 0.001% Al, 0.021% Sn, 0.001% Ti and 98.34% Fe. Table 2 Table 6 shows the weight in grams (g) obtained from the measurement taken at twenty four (24) hours intervals.

Table2. Weight (g) of Hot Worked Coupons in Hydrochloric Acid (HCl) Environment

Time (hrs.)	Concentrations (M)				
	0.5M	1.0M	1.5M	2.0M	2.5M
Wi	18.3262	18.2074	18.2683	17.9454	18.3917
24hrs.	18.2146	18.0759	18.0480	17.8351	17.9327
48hrs.	18.1267	17.9470	17.9656	17.7248	17.3978
72hrs.	18.0422	17.8180	17.7832	17.3390	17.0230
96hrs.	17.9814	17.6021	17.4813	17.2143	16.9565
120hrs.	17.7769	17.4427	17.2143	16.5377	16.5980
144hrs.	17.6700	17.1719	16.9143	16.3188	15.4899
168hrs.	17.5615	17.0010	16.8315	16.1215	15.4009

Table3. Weight (g) of Hot Worked Coupons in Nitric Acid (HNO<sub>3</sub>) Environment Weight

Time (hrs.)	Concentrations (M)				
	0.5M	1.0M	1.5M	2.0M	2.5M
Wi	18.0997	18.4112	18.2103	18.1467	18.2078
24hrs.	17.0409	15.3155	11.9924	11.2612	9.9744
48hrs.	15.9758	15.1864	11.5498	10.7876	9.5696
72hrs.	15.7106	14.0378	11.2072	10.1139	9.0648
96hrs.	15.5116	14.0378	11.0880	9.40720	8.2307
120hrs.	15.5116	14.0378	10.7139	8.98720	9.5109
144hrs.	15.4106	13.6888	10.4199	7.16180	7.4966
168hrs.	15.3458	13.3345	9.92580	8.26710	6.5577

Table4. Weight (g) of Hot Worked Coupons in Acetic Acid (CH<sub>3</sub>COOH) Environment Weight

Time (hrs.)	Concentrations (M)				
	0.5M	1.0M	1.5M	2.0M	2.5M
Wi	17.9890	17.8517	18.1358	18.4135	18.3773
24hrs.	17.9367	17.7986	18.0745	18.3397	18.3773
48hrs.	17.9195	17.7754	18.0509	18.3076	18.5298
72hrs.	17.9023	17.7521	18.0172	18.2855	18.2376
96hrs.	17.7415	17.9880	17.9562	18.2360	18.1839
120hrs.	17.8664	17.7190	17.9465	18.2253	18.1648
144hrs.	17.8452	17.6856	17.9308	18.2117	18.1389
168hrs.	17.8240	17.6722	17.1193	18.1980	18.1229

Table5. Weight (g) of Hot Worked Coupons in phosphoric Acid (H<sub>3</sub>PO<sub>4</sub>) Environment

Time (hrs.)	Concentrations (M)				
	0.5M	1.0M	1.5M	2.0M	2.5M
Wi	18.3528	17.9893	18.1183	18.6374	18.4238
24hrs.	18.2632	17.8797	17.9936	18.4831	18.2468
48hrs.	18.2262	17.8567	17.9748	18.4758	18.2273
72hrs.	18.1891	17.8136	17.9359	18.4284	18.1977
96hrs.	18.1385	17.7588	17.8717	18.3772	18.1468
120hrs.	18.0774	17.6908	17.7754	18.2765	18.0484
144hrs.	18.0256	17.6413	17.7414	18.2392	17.9990
168hrs.	17.9737	17.5918	17.7074	18.1918	17.7995

Table6. Weight (g) of Hot Worked Coupons in Hydrogen Tetraoxosulphate (VI) Acid (H<sub>2</sub>SO<sub>4</sub>) Environment

Time (hrs.)	Concentrations (M)				
	0.5M	1.0M	1.5M	2.0M	2.5M
Wi	18.2418	18.1092	18.3087	18.0717	17.8058
24hrs.	18.1482	17.9533	18.1209	17.9264	17.6050
48hrs.	18.0726	17.8540	18.0127	17.7463	17.4409
72hrs.	18.0069	17.7946	17.8624	17.6862	17.2167
96hrs.	17.9063	17.6998	17.7342	17.2557	16.3842
120hrs.	17.8164	17.6134	17.6254	17.2557	16.0350
144hrs.	17.6915	17.4926	17.3765	16.7995	15.6858
168hrs.	17.4218	17.4058	17.3654	16.5653	15.6858

The measured weight depicted in Tables 2 to Table 6 shown the weight loss of coupons as calculated which is the difference between the initial weight before immersion and the final weight after immersion at a given time. From the normal weight obtained, the normalized table was formed as shown in Table 7-Table 11, the normalized is the ratio of the weight at a particular time to the original weight.

Table7. Normalized Values for Hot Worked Coupons in HCl Environment

Time (hrs.)	Normalized Values for Hot Worked Coupons in HCl Environment				
	0.5M	1.0M	1.5M	2.0M	2.5M
24hrs.	0.9940	0.9928	0.9879	0.9843	0.9750
48hrs.	0.9891	0.9895	0.9834	0.9782	0.9632
72hrs.	0.9845	0.9786	0.9734	0.9722	0.9460
96hrs.	0.9812	0.9668	0.9569	0.9510	0.9256
120hrs.	0.9700	0.9580	0.9423	0.9300	0.9083
144hrs.	0.9642	0.9431	0.9259	0.9070	0.8862
168hrs.	0.9583	0.9337	0.9214	0.8950	0.8422

**Table8. Normalized Values for Hot Worked Coupons in HNO<sub>3</sub> Environment**

Time (hrs.)	Normalized Values for Hot Worked Coupons in HNO <sub>3</sub> Environment				
	0.5M	1.0M	1.5M	2.0M	2.5M
24hrs.	0.9415	0.8318	0.6586	0.6206	0.5478
48hrs.	0.8827	0.8248	0.6342	0.5945	0.5256
72hrs.	0.8680	0.7635	0.6154	0.5573	0.4979
96hrs.	0.8570	0.7624	0.6089	0.5241	0.4520
120hrs.	0.8550	0.7573	0.5883	0.5184	0.4117
144hrs.	0.8514	0.7435	0.5722	0.4953	0.3933
168hrs.	0.8478	0.7242	0.5451	0.4556	0.3602

**Table9. Normalized Values for Hot Worked Coupons in CH<sub>3</sub>COOH Environment**

Time (hrs.)	Normalized Values for Hot Worked Coupons in CH <sub>3</sub> COOH Environment				
	0.5M	1.0M	1.5M	2.0M	2.5M
24hrs.	0.9971	0.9970	0.9966	0.996	0.9949
48hrs.	0.9961	0.9957	0.9953	0.9942	0.9936
72hrs.	0.9957	0.9944	0.9935	0.9930	0.9924
96hrs.	0.9952	0.9938	0.9919	0.9904	0.9895
120hrs.	0.9940	0.9926	0.9901	0.9898	0.9884
144hrs.	0.9932	0.9907	0.9896	0.9890	0.9870
168hrs.	0.9908	0.9899	0.9887	0.9883	0.9862

**Table10. Normalized Values for Hot Worked Coupons in H<sub>3</sub>PO<sub>4</sub> Environment**

Time (hrs.)	Normalized Values for Hot Worked Coupons in H <sub>3</sub> PO <sub>4</sub> Environment				
	0.5M	1.0M	1.5M	2.0M	2.5M
24hrs.	0.9951	0.9939	0.9931	0.9917	0.9904
48hrs.	0.9931	0.9926	0.9921	0.9913	0.9893
72hrs.	0.9911	0.9902	0.9899	0.9888	0.9877
96hrs.	0.9883	0.9872	0.9864	0.9860	0.9850
120hrs.	0.985	0.9834	0.9811	0.9806	0.9796
144hrs.	0.9822	0.9807	0.9792	0.9786	0.9769
168hrs.	0.9793	0.9779	0.9773	0.9786	0.9661

**Table11. Normalized Values for Hot Worked Coupons in H<sub>2</sub>SO<sub>4</sub> Environment**

Time (hrs.)	Normalized Values for Hot Worked Coupons in H <sub>2</sub> SO <sub>4</sub> Environment				
	0.5M	1.0M	1.5M	2.0M	2.5M
24hrs.	0.9949	0.9914	0.9898	0.9920	0.9887
48hrs.	0.9795	0.9907	0.9859	0.9838	0.9821
72hrs.	0.9871	0.9826	0.9801	0.9787	0.9669
96hrs.	0.9816	0.9774	0.9756	0.9675	0.9433
120hrs.	0.9767	0.9726	0.9686	0.9548	0.9202
144hrs.	0.9698	0.9660	0.9627	0.9422	0.9005
168hrs.	0.9646	0.9593	0.9491	0.9296	0.8809

Tables 12 to Table 16 represent the weight loss for the various environments. The total surface area of the coupon was calculated using the formula stated below owing to its geometry as shown below;

$$A = 2(LW + Wt + Lt)$$

where,

(6)

A = Total surface area of the coupon,

L = Length of Coupon

W = Width of coupon

t = Thickness of coupon, and

The coupons used for the research were of the following dimension:

L= 50millimeter (mm) = 1.960 inches (in)

W = 19.5mm = 0.768in

T = 2.5mm = 0.098in

Therefore;

$A = 2[(1.969 \times 0.768) + (0.768 \times 0.098) + (1.969 \times 0.098)] = 3.561$  sq. inch

Density of mild steel = 7.85g/cm<sub>3</sub>

The corrosion rate was calculated using Equation (7)

$$CR = \frac{87.6W_l}{DAT} \tag{7}$$

where,

CR = Corrosion Rate (mm/y); W<sub>l</sub> = Weight loss (mg); D = Density of Low Carbon Steel = 7.85g/cm<sub>3</sub>; A = Area

T = Exposure time (hrs.)

**Table12. Weight (mg) Loss of Hot Worked Coupons in HCl Environment**

Time (hrs.)	Concentrations (M)				
	0.5M	1.0M	1.5M	2.0M	2.5M
24hrs.	0.1098	0.1315	0.2203	0.2871	0.2998
48hrs.	0.1995	0.2604	0.3027	0.3974	0.5172
72hrs.	0.2840	0.3894	0.4851	0.5077	0.8347
96hrs.	0.3448	0.6530	0.7870	0.8935	1.2095
120hrs.	0.7647	1.0540	1.2760	1.5264	1.6435
144hrs.	0.6554	1.0355	1.3915	1.6948	1.9345
168hrs.	0.7643	1.2064	1.4368	1.937	2.7426

**Table13. Weight (mg) Loss of Hot Worked Coupons in HNO<sub>3</sub> Environment**

Time (hrs.)	Concentrations (M)				
	0.5M	1.0M	1.5M	2.0M	2.5M
24hrs.	1.0588	3.0967	6.2179	6.8855	8.2334
48hrs.	3.2258	6.6605	7.3591	8.6382	8.8878
72hrs.	2.3891	4.3550	7.0031	8.0328	9.1430
96hrs.	2.5581	4.3744	7.1223	8.6358	9.9711
120hrs.	2.6244	4.4691	7.4964	8.7395	10.711
144hrs.	2.6891	4.7234	7.1904	9.1595	11.046
168hrs.	2.7539	5.0777	8.2845	9.8796	11.650

**Table14. Weight (mg) Loss of Hot Worked Coupons in CH<sub>3</sub>COOH Environment**

Time (hrs.)	Concentrations (M)				
	0.5M	1.0M	1.5M	2.0M	2.5M
24hrs.	0.0523	0.0531	0.0613	0.0738	0.0944
48hrs.	0.0695	0.0763	0.0849	0.1059	0.1175
72hrs.	0.1078	0.1102	0.1478	0.1775	0.1934
96hrs.	0.0867	0.0996	0.1186	0.1280	0.1397
120hrs.	0.1226	0.1327	0.1796	0.1882	0.2125
144hrs.	0.1438	0.1661	0.1993	0.2018	0.2384
168hrs.	0.1650	0.1795	0.2050	0.2115	0.2544

**Table15. Weight (mg) Loss of Hot Worked Coupons in H<sub>3</sub>PO<sub>4</sub> Environment**

Time (hrs.)	Concentrations (M)				
	0.5M	1.0M	1.5M	2.0M	2.5M
24hrs.	0.0896	0.1096	0.1247	0.1543	0.1773
48hrs.	0.1266	0.1326	0.1435	0.1616	0.2261
72hrs.	0.1637	0.1757	0.1824	0.209	0.2261
96hrs.	0.2143	0.2305	0.2466	0.2602	0.2770
120hrs.	0.2754	0.2985	0.3429	0.3609	0.3754
144hrs.	0.3272	0.3480	0.3769	0.3983	0.4248
168hrs.	0.3272	0.3975	0.4109	0.4456	0.6243

**Table16. Weight (mg) Loss of Hot Worked Coupons in H<sub>2</sub>SO<sub>4</sub> Environment**

Time (hrs.)	Concentrations (M)				
	0.5M	1.0M	1.5M	2.0M	2.5M
24hrs.	0.0936	0.1559	0.1878	0.1953	0.2008
48hrs.	0.1692	0.2552	0.2760	0.3254	0.3648
72hrs.	0.2349	0.3146	0.3643	0.3855	0.5891
96hrs.	0.3355	0.4094	0.4463	0.5873	0.0087
120hrs.	0.4254	0.4958	0.5745	0.8160	0.4216
144hrs.	0.5503	0.6166	0.0833	0.0441	1.7708
168hrs.	0.6452	0.7375	0.9322	1.2772	2.1200

Table 17 shows the summary of the corrosion rate of hot worked coupons.

**Table17. Summary of the Corrosion Rate of Hot Worked Coupons in Acidic Environment**

Time (hrs.)					
	HCl	HNO <sub>3</sub>	CH <sub>3</sub> COOH	H <sub>3</sub> PO <sub>4</sub>	H <sub>2</sub> SO <sub>4</sub>
24hrs.	238.6	6553.4	75.1	140.9	159.8
48hrs.	205.8	3437.8	46.8	78.2	145.2
72hrs.	221.5	2425.8	37.1	60.0	156.3
96hrs.	240.8	1985.3	38.5	55.1	200.7
120hrs.	243.0	1705.1	33.8	59.8	226.3
144hrs.	230.1	1465.4	31.6	56.4	234.9
168hrs.	311.9	1324.7	28.9	70.9	241.1

From Table 12-Table 16, the calculated weight losses obtained for hot worked coupons increases with increasing acid concentration for all five acids. This was equally reflected in the normalized results (Table 7-Table 11), indicating accelerated behaviour for the metal dissolution. This result is expected because, with increasing acid concentration, both acidity and Cl<sup>-</sup> ion concentration will also increase. Also, there was increased in weight loss as concentration of used acids increases and this resulted to increase in corrosion rate as experienced by coupons immersed in five samples of acid environment used in this research work. Comparing the corrosion rate in the different acidic environment shown that nitric acid proved to be more aggressive, and this was followed by hydrochloric acid, tetraoxosulphate (VI) acid, phosphoric acid, and acetic acid was the least. Considering the corrosion rate with time, the corrosion rate for nitric acid decreases with time, while that of the other four acids show a trend of decreasing and increasing corrosion rate. This can be attributed to environmental factors such as, fluctuation in temperature with time.

#### 4. CONCLUSIONS

In this research work, behavioural corrosion mechanism of hot worked mild carbon steel immersed in various acidic environments was investigated to ascertain the corrosiveness of the acid used and its effect on mild steel. The outcome of the research work revealed that corrosion rates increased with increased in acid concentration and with nitric acid (HNO<sub>3</sub>) proved to be a more corrosive among the five acids considered in this research work. This was followed by hydrochloric acid (HCl), hydrogen tetraoxosulphate (VI) acid (H<sub>2</sub>SO<sub>4</sub>) and phosphoric acid (H<sub>3</sub>PO<sub>4</sub>). However, acetic acid (CH<sub>3</sub>COOH) proved to be the least corrosive acid. Visual inspection of the coupons after immersion in the various acidic solution environments of different concentrations showed general and pitting corrosion, and the latter became more pronounced at higher level of the various acidic solution environment concentrations.

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