The International Journal of Engineering and Science (IJES)
|| Volume || 7 || Issue || 5 Ver. I || Pages || PP 25-30 || 2018 ||
ISSN (e): 2319 – 1813 ISSN (p): 23-19 – 1805

Corrosion Of Mild And Medium Carbon Steels In Federal Polytechnic, Unwana Environment

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ABSTRACT

Corrosion of mild and medium carbon steels is reported. Steels were exposed to water fetched in Polytechnic Unwana environment and distilled water (control) environment. The corrosion rates were evaluated at intervals of fourteen days for a period of 84 days using weight loss and electrochemical methods. The corroded specimens were visually examined and majorities were found to have undergone general corrosion in all environments investigated. The mild steel was found to corrode more than the medium carbon steel in the entire environment. Mild steel had $2.77x10^{-4}$mpy and -0.74mV, due to high rate of permeability and diffusion of corrosion inducing ions. It also has -0.53mV in the distilled water (control). The medium carbon steel has $2.72x10^{-4}$mpy and -0.69mV in water fetched in polytechnic Unwana environment and -0.63mV in distilled water (control).

KEYWORDS: *Corrosion, Environment, Carbon Steels.*

Date of Submission: 28-04-2018 Date of acceptance: 14-05-2018

I INTRODUCTION

The corrosion of metals and alloys immersed in aqueous solution occurs through local cells operation on their surface. The metals or alloys are subsequently destroyed if this process is not in one way or the other counter-acted. Several factors including the composition of the metals and alloys and their surface finish to mention just a few.

The driving force that makes metals corrode is a consequence of their temporary existence in the refined state contrary to their natural stable forms as ores. Corrosion is therefore a reversion or partial reversion of materials from the metallic state to the more stable mineral state. Considering steel in pipeline, boilers, crude oil storage tanks etc, parts of the steel at a relatively lower electrical potential will act as the cathode and are protected. The surrounding soil or water or even the oxygen of the air will then act as the electrolyte, thereby completing the electrochemical cell (Avwiri and Tay, 1998).

Ovri (1998) stated that the existence of passive layer has been confirmed by electrochemical measurements as well as by visual microscopic examination. Little is known about the chemical and minerlogical composition of these passivating layers, that rate at which they thicken and their ionic and electronic transport properties. However, it has been shown that the presences of certain aggressive agents are known to either inhibit formation of or destabilize the previously-formed passive layers. Carbonation has been observed to interfere with passivation, but it is not known what specific mechanisms are responsible. Aggressive agents such as chloride, nitrates and sulphate are especially liable to interfere with passivation, even though their presence may not significantly affect the pH. It has not been fully established how these agents affect the stability of passivating layers (Avwiri G.O and Tay G, 1998).

The effects of the above mentioned aggressive agents on the depassivation of the oxide layers formed on the steel surface and the consequent corrosion of mild and medium carbon steels in aqueous environment is the subject of this paper.

II MATERIALS AND METHODS

The medium carbon steels used was obtained from Delta steel company limited, Ovwian-Aladja, Delta State. While mild steel was obtained from shell petroleum development company (SPDC), PortHacourt. The two grades of steels used have a thickness of 5.0mm and dimensions of 73.0mm by 22.0mm. Two separate and close holes of diameter 7.00mm each were drilled on the steel cupons to enhance easy suspension in the environments.

Table 1: chemical composition of steels used

Steel grades	**C**	**Si**	**Mn**	**Cu**	**P**	**S**	**Cr**	**Ni**	**Sn**	**Fe**
Ms	0.18	0.23	0.80	0.20	0.03	0.04	0.05	0.55	0.02	Bal
Mcs	0.40	0.25	0.52	0.05	0.03	0.02	-	-	-	Bal

Ms = Mild steels
Mcs = Medium carbon steel

ENVIRONMENTS

Two environments were used in this research, Viz

1. Water fetched along ICT in Akanu Ibiam Federal Polytechnic
2. Distilled water (control)

The chemical composition of water fetch along ICT is given in table 2 below:

Element/compound	Ca	Fe	Co_3	So_3^{2-}	No_3	Cl^-	pH
Amount/mgl liter	-	2.0	7.35	7.5	0.45	0.5	5.70

CORROSION MONITORING AND EVALUATIONS

ELECTROCHEMICAL METHOD

Electrochemical corrosion monitoring is based on the premise that corrosion is essentially an electrochemical process that can be monitored through the measurement of the electrical properties of the material (potential, current and resistance). The corrosion potential measurement was made on each coupons exposed to water near ICT and control environment respectively using reference electrode which was connected to a digital multi-meter. They readings were taken at interval of fourteen days for a period of twelve weeks. The negative lead of the meter was made to touch the coupons in the solution while the positive lead of the multimeter was connected to the test lead of the reference electrode which was immersed freely in the solution.

WEIGHT LOSS METHOD

The coupons were removed from the environments at interval of fourteen days. The oxide film formed on the surface of the coupons were brushed with a sponge in tap water and then dipped in acetone and then dried. The final weight of the test specimen removed from the control and other environment were taken and recorded using electronic weighing machine. The coupons were then discarded. The procedure was repeated at intervals of fourteen days for a period of twelve weeks.

Calculation of corrosion rate:

The corrosion rate (CR) is calculated using the relationship;

$$C.\ R = \frac{534W}{DAT}$$

W = weight loss (g)
D = density of metal (g/cm^3)
A = total surface area of coupons (cm^2)
T = exposure time (hrs)

Total surface area:

The total surface area (A) of the rectangular steel coupons used in the research were calculated using the following relationship

$$A = 2(LW + LH + WH) - 2\,(\Pi d^2/_4)$$

Where, A = Total surface area of coupons (cm^2)
L = Length (cm) = 7.30cm
W = Width (cm) = 2.20 cm
H = Thickness (cm) = 0.5cm
D = Diameter of holes (cm) = 0.7cm

$$
\begin{aligned}
A &= 2(7.3 \times 2.2 + 7.3 \times 0.5 + 2.2 \times 0.5) - (3.142 \times (0.7)^2) \\
&= 2(16.06 + 3.65 + 1.10) - 2(0.385) \\
&= 40.85cm^2
\end{aligned}
$$

Example C.R:

$$C.R\ (\text{control 14days MCS}) = \frac{534 \times 0.030}{7.87 \times 40.85 \times 336}$$

$$= 16.02/108020.47$$

Table 3: Electrode potential Results:

Days	0	14	28	42	56	70	84
MCS control	-0.45	-0.63	-0.69	-0.73	-0.74	-0.72	-0.73
MS control	-0.53	-0.65	-0.73	-0.75	-0.77	-0.73	-0.75
MCS	-0.54	-0.69	-076	-0.83	-0.83	-0.73	-0.77
MS	-0.61	-0.74	-0.80	-0.89	-0.88	-0.78	-0.80

EXPERIMENTAL RESULTS

Table 4: Weight Loss and Corrosion Rate

	0days		14 days		28 days		42 days		56 days		70 days		84 days	
	Wt loss (g)	CR (mpy)	Wt loss (g)	CR (mpy)	Wt loss (g)	CR (mpy)	Wt loss (g)	CR (mpy)	Wt loss (g)	CR (mpy)	Wt loss (g)	CR (mpy)	Wt loss (g)	CR (mpy)
Control MCS	0.00	0.00	0.035	1.73	0.055	1.36	0.081	1.33	0.082	1.00	0.082	0.81	0.080	0.66
Control MS	0.00	0.00	0.047	2.30	0.073	1.80	0.091	1.50	0.087	1.07	0.086	0.85	0.084	0.69
Envt. MCS	0.00	0.00	0.055	2.72	0.080	1.98	0.094	1.55	0.104	1.29	0.089	0.88	0.089	0.73
Envt MS	0.00	0.00	0.056	2.77	0.091	2.24	0.111	1.83	0.136	1.68	0.126	1.24	0.120	0.99

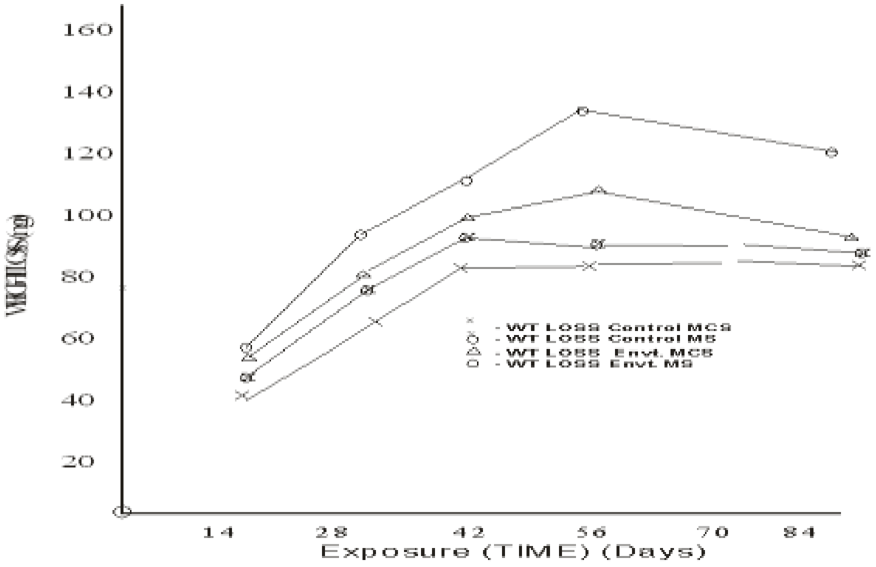

FIG 1: Variation of weight loss in (mg) with exposure time in days for steel coupons exposed to fresh water and control

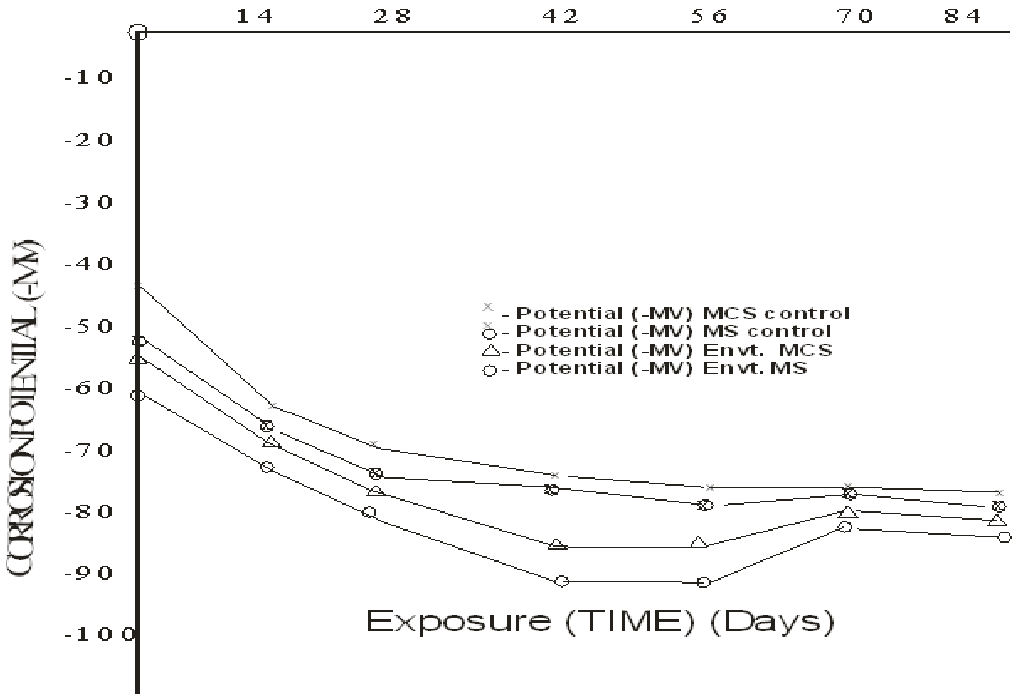

FIG 2: Variation of potential (-mv) with exposure time (days) for steel coupons exposed to fresh water and distilled water environment

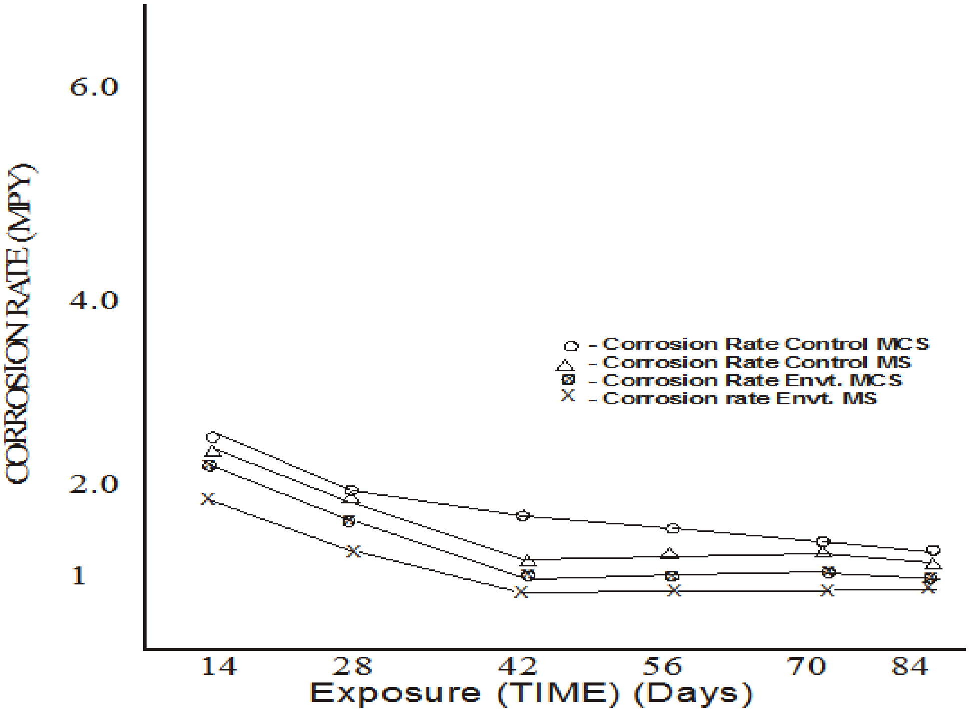

FIG 3: Variation of corrosion (mpy) with exposure time (days) for steel coupons exposed to fresh water and distilled water environment

III RESULTS AND DISCUSSION

The corrosion rate of mild and medium carbon steels depend on several corrosion parameters such as chemical compositions, surface finish and pH. Stream water contains corrosion inducing ions such as Cl^-, OH^- and SO_4^{2-}. Therefore, these environments are considered aggressive and toxic to most engineering materials including steel.

Relating between laboratory test, chemical analysis and visual examination, the results of the investigation are discussed under the following headings; weight loss of samples and electrode potential measurement.

i. Weight loss method

The corrosion rate was higher for mild steel, followed by the medium carbon steel. It was generally observed (fig 3.) that corrosion rate decreased with exposure times in all the environments. This experimental observed behavior was due to the formation of an impermeable protective oxide film on the surface of the steel. In this state, the steel is said to be passive (Ovri, 1998) and does not corrode easily.

Mild steel corrode more than medium carbon steel in the first 56th days due to high rate of permeability of corrosion inducing agents such as OH and So_4^{2-} while after 56th days the aggressive ions in the various environment could not be absorbed by the protective oxide film, hence the decrease in the corrosion rate with higher exposure time for all the environment studied. When steels are exposed to a corrosion environment there is usually rapid corrosion, but this decreases with time due to the formation of corrosion products which may be an oxides, sulphates, carbonates or nitrides. If this product is not removed from the surface of the steel the corrosion rate is reduced. In this study, the corrosion inducing agents (OH^- and So_4^{2-}) could not easily diffuse through the corrosion products formed on the steel surface at exposure times greater than the 56th days. The time taken by the corrosion inducing agents to diffuse through the oxide (corrosion products) to the steel i.e. the base metal contributed significantly to the observed difference in the corrosion rates. These observations are in qualitatively in agreement with Ovri (1998) on steel reinforcement in concrete and ferrite.

ii. Electro-chemical method

The plot of the electrode potentials with exposure times of the steel coupons in all environments investigated is given in fig. 2. It was observed that the electrode potentials of the steel exposed to all the environments decreased with time during the first 56th days of the investigation and later increased due to corrosion product formed on the steel surface (ovri, 1998 & 2004). Hence, the lower the potential, the more the corrosion.

Mild steel in stream fetch in polytechnic environment recorded the highest decrease in electrode potentials in the first 56th days of the study. It had initial potential of – 0.61mV in the first day and - 0.88mV in the 56th days. This decrease in electrode potential shows increase in corrosion rate and weight loss. However, a sharp increase in electrode potential occurred from the 70th to the 84th days (-0.78mV to -0.80mV), showing a decrease in the corrosion rate. This effect is similar to all results obtained for mild steel in control environment.

Medium carbon steel in stream water environment was next after mild steel. It had -0.54mV in the first day and -0.83mV in the 56th day which is an indication of increase in corrosion rate. However, the electrode potential increased from -075mV to -0.77mV in the 70th to 84th days respectively, showing decrease in corrosion rate and weight loss. This effect is similar to all results obtained for mild steels in all environments.

Medium carbon steel in fresh water fetched in the Polytechnic environment was next after mild steel. It had – 0.54mV in the first day and -0.83mV in the 56th day which is an indication of increase in corrosion rate. However, the electrode potential increase from -0.70mV in the 70th to 84th day respectively, showing decrease in corrosion rate and weight loss. This effect is similar to all results obtained for medium carbon steels in all environments.

The observed increase in electrode potential after 56th day of the test was attributed to the concept of Passivity. This was caused by the formation of protective oxide film on the surface of the steels. Thus, the chemical, physical and electronic properties of these oxide films, metals dissolution are lowered resulting to the decrease in corrosion rate. The mild steel in fresh water environment exhibited lowest electrode potential (highest negative potentials) indicating both high weight losses and corrosion rate: followed by medium carbon respectively.

The results are in agreement with those reported by Owate, et al (2008) for the corrosion of mild and high carbon steels.

NOMENCLATURE

A = Total Surface area of coupons, cm^2
C.R = Corrosion rate, Mpy
$Cu/Cuso_4$ = Copper/copper sulphate reference electrode

D = Density g/cm^3
H_2O = Water
L = Length, cm
OH^- = Hydroxyl ions
pH = Measurement of acidity and alkalinity of a solution
S = Sulphide ions
SO_4^{2-} = Sulphate ions
T = Exposure time, hours
W = Width of specimen, cm
WT = Weight loss, g

ABBREVIATIONS

EP = Electrode Potential
Mcs = Medium Carbon Steel
Mpys = Mill Per Year
Ms = Mild Steel

CONCLUSION

The following conclusion can be drawn from this investigation:

- Mild steel was observed to be more corrosive in the entire environments (2.77×10^{-4}mpy). This is due to high rate of permeability of corrosion inducing agent such as OH^- and SO_4^{2-}. This was followed by medium carbon steel (2.72×10^{-4}mpy) with low rate of diffusion of the corrosion agent.
- It has been shown that corrosion rate tends to decrease with increasing carbon content.
- General (uniform) corrosion was observed for mild and medium carbon steels in the entire environments investigated.

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S.I Okeahialam." Corrosion of Mild and Medium Carbon Steels In Federal Polytechnic, Unwana Environment. " The International Journal of Engineering and Science (IJES) 7.5 (2018): 25-30