

The Effect of the Environment on the Corrosion Penetration Rate of Aisi 1046 Steel

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Abstract

Environment plays a major role in the corrosion of materials. A particular metal will behave differently when exposed to different environment. This project aims at comparing the corrosion penetration rate of medium carbon steel, heat treated and non-heat treated, in Engine oil and Seawater. Twenty four specimens of the medium carbon steel, of length 18mm, were collected for the experiment. Twelve of which were heat treated and the remaining twelve were not heat treated. Six of the heat treated specimens were placed in seawater, while the other six was placed in engine oil. The same thing was done to the twelve non-heat treated specimen. Weight loss and corrosion penetration rate of one specimen from each environment was determined at every ten days interval for a total of sixty days. It was noted that corrosion penetration rate was higher in the seawater environment and the heat treated specimens were rather more corrosion resistant than the non-heat treated specimens. For instance, for the Heat treated 0.46%C steel under study, there was a 0.1% increase in corrosion penetration rate in seawater at the end of the duration of exposure (60 days). Whereas there was no noticeable corrosion of the samples placed in the engine oil until the 40th day. In the engine oil, the weight loss and corrosion penetration rate was negligible.

Keywords:Corrosion, Austenitising, Tempering, AISI 1040 Steel

Nomenclature:

W = Weight loss after exposure time t, in milligrams

t = Exposure time in hours

ρ = Density of specimen in grams per cubic centimeters (gcm^{-3})

A = Area of specimen exposed in square centimeters (cm^2)

K = Constant = 87.6

AISI = America Iron and Steel Institute

1.0 Introduction

Corrosion of materials cannot be discussed without making reference to the environment it is exposed to. It is of great importance for us to understand the rate at which corrosion occurs in different environments in order to achieve a good design. Carbon steel being the most widely used engineering material account for approximately 85% of the annual steel production worldwide [1,2]. Despite its relatively limited corrosion resistance, carbon steel is used in large tonnage in marine application, nuclear power and fossil fuel power plant, transportation and chemical processing, petroleum production and refinery, pipelines mining, construction and metal processing equipment [3]. Medium carbon steels containing 0.25%-0.5% carbon are the heat treatable steels. They are used for the production of machine parts, bolts, crank shafts, gears and railroad rails [4,5,6].

A lot of work has been done on the corrosion of medium carbon steel in various environments. Igwemezie et al [7] investigated the the effect of microstructure on the corrosion susceptibility of medium carbon steel in some environment and discovered that 0.5H₂SO₄ was the most aggressive, followed by 0.5HCL, seawater and lastly effluent water. Xiao et al [8] also studied different steels with varied percentage of carbon content in natural and artificial seawater, and showed that corrosion reduces the ultimate tensile strength of the steels and that the effect is more notable during the corrosion in natural seawater than in the artificial seawater. Danek [9] also discovered that the corrosion rate of medium carbon steel and carbon steel in general, decreases with time as protective barrier films are formed on the carbon steel surfaces, and that these

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protective films may be a rust layer, calcareous deposits, or bio-fouling. It has also been discovered that steel microstructure play an important role in terms of the corrosion rate and mechanism of carbon steel [10].

Details of carbon steel corrosion in stagnant natural seawater are significant because of proposals to remove oxygen from seawater ballast as a corrosion control procedure for carbon steel corrosion in stagnant seawater [11]. Engine oil is oil used for lubrication of various internal combustion engines [12,13 14]. The main function is to reduce wear on moving parts; it also cleans, inhibits corrosion, improves sealing, and cools engine by carrying heat away from the moving parts [15,16,17]. Despite this function, the presence of contaminants such as water droplets, usually give room for corrosion to begin [18,19,20].

Since corrosion is a natural phenomenon and cannot be utterly avoided in most application, it is of interest to talk of the corrosion penetration rate of substance as regards to their subjected environment. This also has led to the study of different medium and how they affect corrosion penetration rate. It is on this basis, that the project has been conducted, but this time, comparing the corrosion-penetration rate of specifically, 0.46% C steel when subjected to seawater and engine oil with a view to contributing additional knowledge to existing literature.

2.0 Materials and Methods

Test Materials. The material used for this study was a 0.46% C steel obtained from Delta Steel Company, Ovwian- Aladja Delta State, and seawater. The chemical composition as supplied by the manufacturer is shown in Table 1.

The corrosive environment was seawater obtained from Ogunala village in Escravos, Delta State, which has its source from Gulf of Guinea. The composition of the seawater was analyzed at Petroleum Training Institute Warri Delta State, using mass spectrometer. The result of the analysis is shown in Table 2

Table 1: Chemical Composition of the Steel

ELEMENT	C	Mn	Si	P	S
CONTENT (wt%)	0.46	0.69	0.24	0.023	0.013

Table 2: Composition of Seawater

S/no	Parameters	Result
1	pH at 28.7 °C	7.41
2	Dissolved Oxygen (mg/l) at 28.6 °C	8.26
3	Salinity in form of Chloride (mg/l)	7122.5
4	Sulphate (mg/l)	2727.0
5	Sodium (mg/l)	6.93

Test Procedure: Twenty Four specimens of length 18mm was used for this experiment. Twelve specimens were subjected to austenizing temperatures at 900°C. They were quenched and tempered at 500°C. The remaining twelve specimens were not heat treated. Six of the treated specimens were exposed to seawater, while the others were exposed to engine oil. Also six of the untreated specimens were exposed to seawater, while the the remaining six others were exposed to engine oil. Every 10days, four specimens, two each from each environment were taken out for weighing for a period of 60days.

The corrosion penetration rate (CPR) were obtained using the formulae in equation (1) and the results are shown in Table 3

$$CPR = \frac{KW}{\rho At} \tag{1}$$

Where

CPR = Corrosion Penetration Rate (mm/yr)

W = Weight loss after exposure time t, in milligrams

t = Exposure time in hours

ρ = Density of specimen in grams per cubic centimeters (gcm^{-3})

A = Area of specimen exposed in square centimeters. (cm^2)

K = Constant = 87.6

Environment Preparation: The seawater and the engine oil obtained was placed in two different containers. The heat treated and the non- heat treated specimens were immersed in these containers.

Specimen Identification: The specimens used for the experiment are identified as follows.

A₁ - A₆ -- Heat treated specimens exposed to seawater.

A₇ - A₁₂ -- Heat treated specimens exposed to Engine oil.

B₁ - B₆ -- Non - heat treated specimens exposed to seawater.

B₇ - B₁₂ -- Non - heat treated specimens exposed to Engine oil

3.0 Results

Table 3: Corrosion Penetration Rate

Time (Days)	Samples	Weight of specimen before exposure (mg)	Weight of specimen after exposure (mg)	Weight loss(mg)	CPR of specimens (mm/yr)
10	A1	26060	26040	20	0.07588
	A7	25580	25580	0	0
	B1	25800	25780	20	0.07635
	B7	25670	25670	0	0
20	A2	25680	25640	40	0.07655
	A8	25340	25340	0	0
	B2	25530	25490	40	0.07696
	B8	25680	25680	0	0
30	A3	25280	25240	40	0.05156
	A9	25460	25460	0	0
	B3	25610	25550	60	0.07680
	B9	25830	25830	0	0
40	A4	26000	25920	80	0.07599
	A10	25460	25450	10	0.00963
	B4	26170	26060	110	0.10394
	B10	26270	26260	10	0.00942
50	A5	25090	24990	100	0.07781
	A11	25980	25970	10	0.007603
	B5	24820	24700	120	0.09402
	B11	24700	24690	10	0.007862
60	A6	25440	25310	130	0.083479
	A12	25600	25590	10	0.006393
	B6	24800	24620	180	0.117729
	B12	25100	25090	10	0.006478

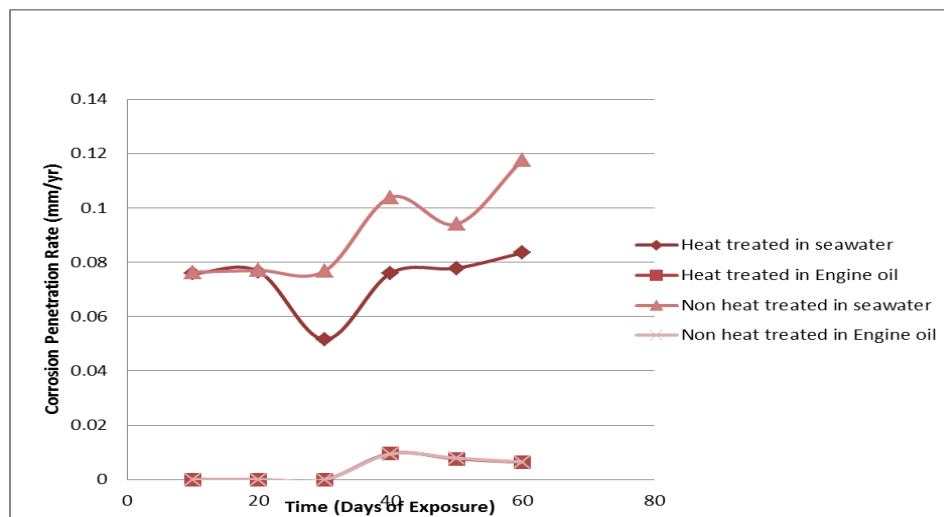


Fig 1: Corrosion penetration Rate vs. Corrosion Exposure Time

4.0 Discussion

Tables 2, gives the corrosion penetration rate for each category of heat treated and non-heat treated samples with exposure time in the seawater and engine oil respectively. The corrosion penetration rate of the heat treated and non-heat treated

samples in engine oil remained at 0mm/yr, in the first 30 days. Meanwhile, the heat treated and non-heat treated samples in seawater started experiencing corrosion even from the first 10days. For example, there was a corrosion penetration rate of 0.07568 mm/yr and 0.07635 mm/yr for the heat treated and non-heat treated samples respectively. The reason for this could be attributed to the fact that engine oil usually has inhibitors that help to reduce corrosion to the greatest minimal level. This is in agreement with [15], [16], and [17], who said that one major function of engine oil is to inhibit corrosion. There was a sudden rise however, in the corrosion penetration rate of samples exposed to engine oil, after 30days. The reason for this could be attributed to contaminants and water droplets that have entered and mixed with the oil due to exposure and has thus aided the corrosion.

In Fig.1, comparing the graph of heat treated and non-heat treated samples in seawater, we observed that the corrosion penetration rate was higher in the case of the non-heat treated samples. This could probably be due to microstructural changes as a result of the heat treatment [11]. The graph of the heat treated samples immersed in seawater showed an approximately equal corrosion penetration rate between the first 10days and the 20th day. Maximum corrosion occurred at the 30th day. After the 30th day, corrosion product (brownish in colour) began to act as protective barrier films, leading to gradual decrease in corrosion. This is in agreement with [6] who observed that the corrosion rate of medium carbon steel and carbon steel in general decreases with time as protective barrier films are formed on the steel surfaces.

5.0 Conclusion

The result show that corrosion penetration rate was higher in the seawater environment and that the heat treated specimens were rather more corrosion resistant than the non-heat treated specimens in both seawater and engine oil. For instance, for the Heat treated 0.46%C steel under study, there was a 0.1% increase in corrosion penetration rate in seawater at the end of the duration of exposure (60 days). Whereas there was no noticeable corrosion of the samples placed in the engine oil until the 40th day. In the engine oil, the weight loss and corrosion penetration rate was negligible.

6.0 References

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