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Corrosion Analysis of the Effects on Automobiles in Niger Delta Region

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ABSTRACT

This project analyses the effects of corrosion in automobiles in the Niger Delta region, in Nigeria. Identification of corrosion and corrosion prone areas in automobile chassis were discussed, as well as its prevention and control. An experiment was carried out with the use of medium carbon steel buried in soils with ram water obtained from these Niger Delta states in comparison with that obtained from a non-Niger Delta state. It was observed that the rate of corrosion in Yenagoa and Warri was considerably high compared to the other states. The experiment was carried out adhering to Section-333 of the Standards for Construction SCF which stipulates standards and procedures for corrosion experiments. The results obtained from the analysis are reliable and can be used as a tool for corrosion detection and prevention in the affected states.

Keywords: Corrosion rate, Niger Delta Region, Experiment, Medium carbon, coated and un-coated steels

INTRODUCTION

Corrosion in the automobile industry is a widespread problem associated predominantly in the vehicle body and moving parts. Corrosion is a prevailing destructive phenomenon in science and technology with regards to materials. In its broadest sense, corrosion can be defined as the deterioration of a metal or substance or its properties because of reaction with its environment. It is a natural process which can attack any metal or alloy under given conditions. Since metals are widely used in various applications, corrosion is imminent and the effects cannot be far-reaching.

The automobile industry has been plagued by a number of problems which one of it is corrosion. The durability of automobiles is a function of an efficient maintenance program embarked upon not only to enhance the reliability of the engine but also to enhance the strength and beauty of the chassis. Therefore, special attention has to be paid on corrosion prevention. Corrosion control can be one of the automobile industry's most effective weapons in the quest for maintaining the material strength of vehicles a factor which can greatly affect its lifespan and functionality. If neglected, corrosion can greatly reduce the integrity of a vehicle: making it unsafe and ugly. It is a problem that is not always acknowledged or easily tackled. Hence constant vigilance is necessary.

The metals that make up automobile components are subjected to several different forms of corrosion, a process accelerated by many factors including poor cleaning habits and prolonged exposure to corrosive agents like salts (chloride) and moisture. Compounding the problem associated with corrosion is the age factor. As automobile ages, it is repeatedly exposed to environmental factors that accelerate the effects of corrosion. Even though some corrosion control measures are been embarked upon in a bid to enhancing the functionality and aesthetics of the automobiles now in operation, there are still much that can still be done.

Examining the effects of corrosion on automobiles in Nigeria, it is quite obvious that especially in the Niger Delta region with a high rate of salinity and humidity provides an excellent environment for corrosion. The traffic situation, bad road condition and impatience on the part of most drivers cause dents and scratches from which corrosion can easily begin. When the paint is scraped off, the metal surface becomes exposed and open to aqueous corrosion. The alternation of the rainy and dry season also leads to the development of mechanized stresses which leads to stress corrosion cracking and corrosion fatigue which are very destructive if not checked.

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Corrosion prevention and control measures can be quite expensive. More often than not, attention is given to engine maintenance other than the chassis. Vehicle manufacturers have made frantic efforts over time to forestall corrosion. Many improvements, such as the expanded use of galvanized steel, use of fibres reduces weight, improve fuel efficiency and reduce denting are solely the result of efforts to improve vehicle corrosion resistance. Due to the fact that these improvements were implemented for more than one reason, it is difficult to isolate costs specifically associated with corrosion protection. Manufacturers were asked to identify in general terms the major elements of corrosion protection that have increased the cost of manufacturing vehicles. In response, the cost items listed were primarily special paints, coatings, and materials. Although not exhaustive, the list includes:

- Precoated steels and plastics in the body;
- Electrode position primers;
- Under body splash shields;
- More extensive use of adhesives, deadeners, and scalers, including sealed electrical systems (e.g., connectors, switches, and circuits);
- Special metals and coatings (such as stainless steel and aluminium) for engine and power train items, ignition components (e.g., starters and alternators), and fuel systems; and
- Special bumper support systems and trim metals.

RESEARCH APPROACH

Experimental Materials

The samples used for this study consists of coupons made of medium carbon steel obtained from Motor Manufacturing/Assembly Company in Nigeria. The chemical analysis of the coupons as carried out on a spectrometer. The coupons used for the corrosion study is medium carbon steel (AISI 1040) rectangular in shape 30x25x15mm. The aim of this investigation is to determine the rate of weight loss from metal strips subjected to a corrosion medium. Other materials used are the corroding medium which is a combination of ram water and soils obtained from the various states under consideration, digital weighing balance, plastic brush, plastic containers, degreasing agent (ethanol), spatula and a set-up platform which is a wooden table.

Medium Carbon Steel

Medium carbon steels are also called plain-carbon steel. It is a metal alloy of two elements, iron and carbon with other elements present in small quantities too small to affect the properties. It contains approximately 0.35% to 0.44% carbon content with 0.6 to 0.90% manganese. This balances its ductility, strength and wears resistance hence making it a preferred choice for large parts, forging and car parts [3]. The coupons cut into sizes with a hack saw to desired measurements in a machine shop.

Soil and Water

The soil and water samples were investigated in a laboratory for the following parameters such as the pH, resistivity, Redox potential, chloride / sulphate contents. The Total Heterotrophic Bacteria / Fungal Counts were also determined.

Corrosion Environment and Specimen Preparation

The corrosion media is rainwater and soil collected at a different location. The experiment is set-up and kept at room conditions. Before weight loss measurements, all tested mild steel samples were polished using emery cloth. They were degreased in ethanol, dried and the initial weight recorded. Some samples were coated with a thin coat of lead-free, oil based red oxide. Soil samples at various depths of ½ft (152.4mm) and 1ft (304.8mm) respectively were collected across the respective Niger Delta States, including rainwater samples, the samples were collected as direct rainwater in de-ionized plastic bottles from an open space free from any interfering matter that could contaminate the rainwater.

Experimental Procedure

The metal strips are buried in the setup of soil and rain water in non-flow condition and then subjected to weight loss corrosion test for a period of 97 days. Two different set-ups were prepared for each state: ½ft and 1ft respectively. Readings were collected at three-day intervals (every 72hrs) by removing the metal from the setup, cleaning it with a plastic brush and ethanol to facilitate drying. The metal is then weighed on a sensitive scale to detect weight loss in the metal. The respective reading of the weight loss in each coupon is used to calculate the corresponding corrosion rate in millimetre per year (MPY) calculated according to the corrosion rate formula.

$$Corrosion\ rate,\ C_r = \frac{534\ x\ W}{Atd} \quad (1)$$

Where:

W = weight loss, g

A = surface area of the coupon, in^2

t = exposure time, hr

d = density of the alloy, g/cm^3

C_r = Mills penetration per year (mpy)

7.86 g/cm^3 for steel

534 = constant

Experimental Results

A summary of the result is shown in the table below:

Table1. *Weight Loss in Each State With Soil Depth of ½ft*

State	Metal	Initial Value (g)	Final Value (g)	Difference (g)
Rivers State	MCS1	5.81175	5.67000	0.14175
	MSC2	5.81175	5.78340	0.02835
Bayelsa State	MCS1	5.81175	5.64165	0.17010
	MSC2	5.81175	5.71253	0.09923
Delta State	MCS1	5.81175	5.68418	0.12758
	MSC2	5.81175	5.69835	0.11340
Akwa-Ibom State	MCS1	5.81175	5.75505	0.05670
	MSC2	5.81175	5.76923	0.04253
Cross Rivers State	MCS1	5.81175	5.67000	0.14175
	MSC2	5.81175	5.69835	0.11340
Enugu State	MCS1	5.81175	5.49990	0.31185
	MSC2	5.81175	5.58495	0.22680

Table2. *Weight Loss in Each State with Soil Depth of 1ft*

State	Metal	Initial Value (g)	Final Value (g)	Difference (g)
Rivers State	MCS1	5.81175	5.76923	0.04253
	MSC2	5.81175	5.79758	0.01418
Bayelsa State	MCS1	5.81175	5.64165	0.17010
	MSC2	5.81175	5.64165	0.17010
Delta State	MCS1	5.81175	5.52825	0.28350
	MSC2	5.81175	5.67000	0. 14175
Akwa-Ibom State	MCS1	5.81175	5.69835	0.11340
	MSC2	5.81175	5.72670	0.08505
Cross Rivers State	MCS1	5.81175	5.72670	0.08505
	MSC2	5.81175	5.72670	0.08505
Enugu State	MCS1	5.81175	5.64165	0.17010
	MSC2	5.81175	5.68418	0.12758

Key: *MCS1 - Uncoated medium carbon steel, MCS2 - Coated medium carbon steel, Difference = initial value - final value*

Calculations of Corrosion Rate

The corrosion rate is calculated for each coupon using the initial and final weights, control weight loss, coupon surface area, and density of the alloy and exposure time in the formula from equation 1.

$$Corrosion\ rate,\ C_r = \frac{534\ x\ W}{Atd}$$

Port Harcourt

a) ½ft (uncoated steel strip)

Weight loss, W = O.14175g, Surface area, A = 1. 16254in^2

Exposure time, t = 2328hrs, Density, d =7.86g/cm^3

$$Corrosion \quad rate, C_r = \frac{534 \quad x\,W}{Atd} = \frac{534 \quad x\,0.14175}{1.16254 \quad x\,2328 \quad x\,7.86}$$

$$Corrosion \quad rate, C_r = 0.003558368 \quad mpy$$

b) ½ft (coated steel strip)

Weight loss, *W* = 0. 14175g, Surface area, A = 2.9528in^2

Exposure time, t = 2328hrs, Density, d = 7.86g/cm^3

$$Corrosion \quad rate, C_r = \frac{534 \quad x\,W}{Atd} = \frac{534 \quad x\,0.02835}{2.9528 \quad x\,2328 \quad x\,7.86}$$

$$Corrosion \quad rate, C_r = 0.000712 \quad mpy$$

Following the calculation procedure above,

c) 1ft (uncoated steel strip): Weight loss, *W* = 0.04253g

$$Corrosion \quad rate, C_r = 0.000107 \quad mpy$$

d) 1ff (coated steel strip): Weight loss, *W* = 0.01418g

$$Corrosion \quad rate, C_r = 0.000356 \quad mpy$$

Bayelsa State

a) ½ft (uncoated steel strip): Weight loss, *W* = 0. 17010g

$$Corrosion \quad rate, C_r = 0.004270042 \quad mpy$$

b) ½ft (coated steel strip): Weight loss, *W* = 0.09923g

$$Corrosion \quad rate, C_r = 0.002490983 \quad mpy$$

c) 1ff (uncoated steel strip): Weight loss, W = 0.17010g

$$Corrosion \quad rate, C_r = 0.00427 \quad mpy$$

d) 1ft (coated steel strip): Weight loss, W = 0. 170100g

$$Corrosion \quad rate, C_r = 0.00427 \quad mpy$$

Delta State

a) ½ft (uncoated steel strip): Weight loss, W = 0.12758g

$$Corrosion \quad rate, C_r = 0.003023 \quad mpy$$

b) ½ft (coated steel strip): Weight loss, W = 0.1 1340g

$$Corrosion \quad rate, C_r = 0.002847 \quad mpy$$

c) 1ft (uncoated steel strip): Weight loss, W = 0.28350g

$$Corrosion \quad rate, C_r = 0.00712 \quad mpy$$

d) 1ft (coated steel strip): Weight loss, W = 0.14175g

$$Corrosion \quad rate, C_r = 0.003558 \quad mpy$$

Akwa Ibom State

a) ½ft (coated steel strip): Weight loss, W = 0.05670g

$$Corrosion\ rate, C_r = 0.000142335\ mpy$$

b) ½ ft (uncoated steel strip): Weight loss, W = 0.04253g

$$Corrosion\ rate, C_r = 0.000106764\ mpy$$

c) 1ft (uncoated steel strip): Weight loss, W = 0.11340g

$$Corrosion\ rate, C_r = 0.00285\ mpy$$

d) 1ft (coated steel strip): Weight loss, W = 0.08505g

$$Corrosion\ rate, C_r = 0.002135\ mpy$$

Cross River State

a) ½ft (coated steel strip): Weight loss, W = 0.14175g

$$Corrosion\ rate, C_r = 0.0035583\ mpy$$

b) ½ft (coated steel strip): Weight loss, W = 0.11340g

$$Corrosion\ rate, C_r = 0.0028467\ mpy$$

c) 1ft (uncoated steel strip): Weight loss, W = 0.08505g

$$Corrosion\ rate, C_r = 0.002135\ mpy$$

d) 1ft (coated steel strip): Weight loss, W = 0.08505g

$$Corrosion\ rate, C_r = 0.002135\ mpy$$

Enugu State

a) ½ft (coated steel strip): Weight loss, W = 0.31185g

$$Corrosion\ rate, C_r = 0.0078284\ mpy$$

b) ½ft (coated steel strip): Weight loss, W = 0.22680g

$$Corrosion\ rate, C_r = 0.0056934\ mpy$$

c) 1ft (uncoated steel strip): Weight loss, W = 0.17010g

$$Corrosion\ rate, C_r = 0.00427\ mpy$$

d) 1ft (coated steel strip): Weight loss, W = 0.12758g

$$Corrosion\ rate, C_r = 0.003203\ mpy$$

ANALYSIS AND DISCUSSION OF RESULTS

At the end of the 97 days, the corrosion rate was calculated for the different samples using the equation 1. The weight loss was determined by finding the difference between the original weight of the coupon and the final weight, after 72hours for a period of 2592hours**:** changes were sported in some coupons thereafter. From the results, the uncoated steel showed a considerable increase in corrosion rate compared to the coated steel.

The data is used to plot graphs of the weight loss against time. The graph of the uncoated medium carbon steel buried in the soil mixed with water was taken from the various states at a depth of ½ft depicts a near uniform corrosion between four locations: Yenagoa, Warri, Calabar and Port Harcourt with increased rate of corrosion in Enugu state and the least being Eket. The accelerated rate of weight loss in Enugu can be traced to the acidity of the soil sample as indicated in the laboratory result. This can be as a result of mineral leaching, decomposition of acidic plants (for example coniferous tree needles), acid rain and certain forms of microbiological activity. The resultant effect of the aforementioned factors can increase the acidity of soil hence the acidity of the top soil is more than that of the soil from 1ft. This fact is further corroborated by the laboratory result. The graph of the coated medium carbon steel still has Enugu as the most affected coupon and Port Harcourt the least.

The coupons of the uncoated medium carbon steel buried in the soil taken from the various states at a depth of 1ft show from the graph that Warri has the greatest rate of weight loss followed by Yenagoa and Enugu with Port Harcourt being the least affected state. Reasons for the drastic weight loss in the coupon for Warri are traceable to the laboratory results which have Warri as the most acidic soil and with Total Heterotrophic Bacteria count (THBC) of 30cfu/g. These components can drastically accelerate corrosion rate. The coated medium carbon steel has Yenagoa as the coupon with the greatest amount of weight loss. This can be proven from the laboratory result which shows that Yenagoa has constituents that accelerate corrosion in considerable proportions.

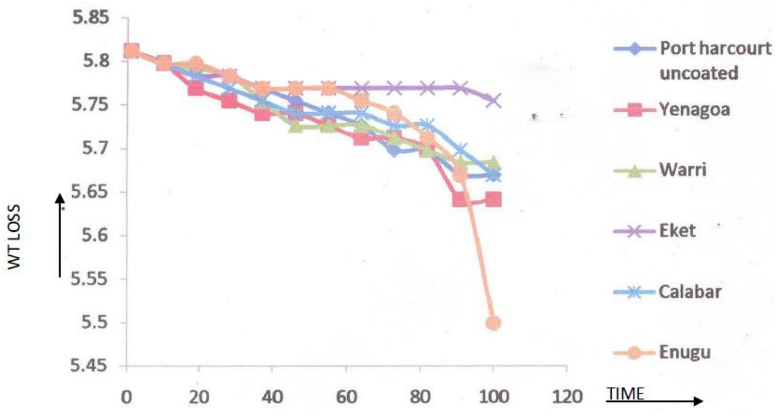

Figure1. *Weight Loss against Time for 1/2ft for all State Uncoated Medium Carbon Steel.*

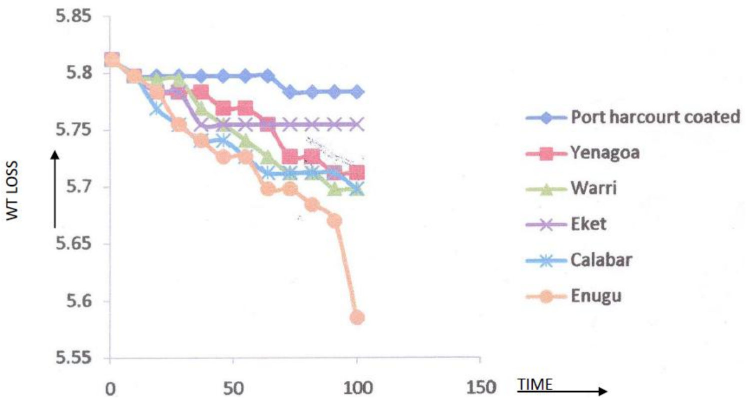

Figure2. *Weight Loss against Time for 1/2ft for all State coated Medium Carbon Steel.*

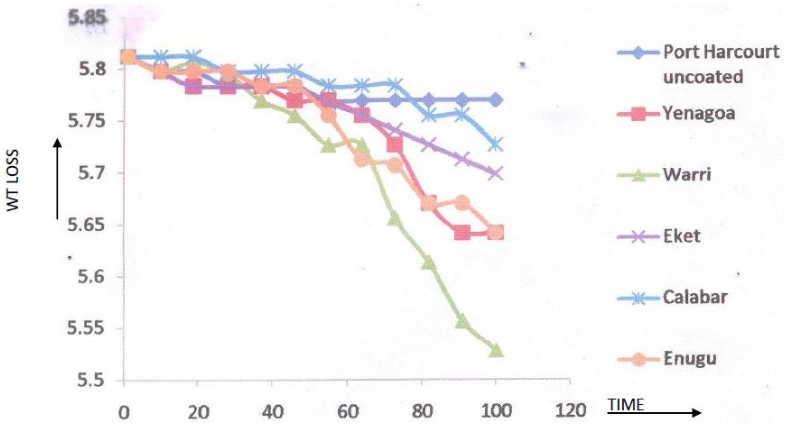

Figure3. *Weight Loss against Time for 1ft for All State Uncoated Medium Carbon Steel.*

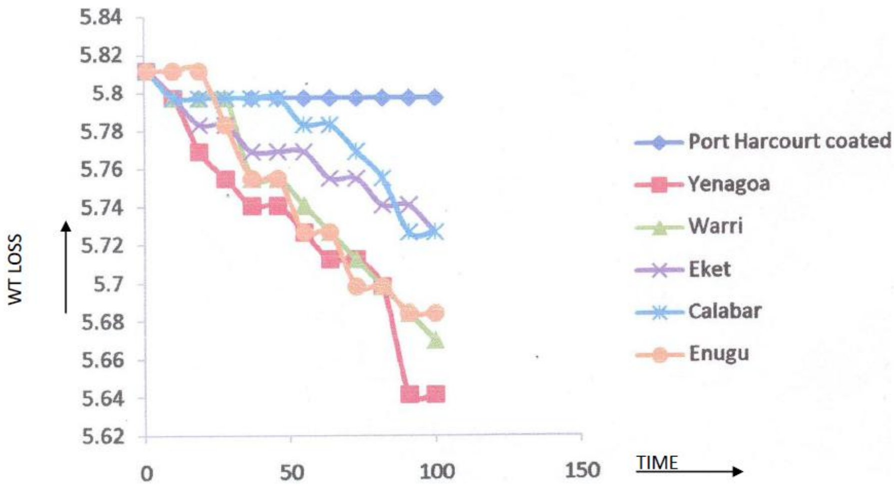

Figure4. *Weight Loss against Time for 1ft for All State Coated Medium Carbon Steel*

CONCLUSION AND RECOMMENDATION

After the 2592hours (i.e. 108days) period of the experiment, it was observed that the various coupons displayed weight loss in varying degrees in both the coated and uncoated medium carbon steels. The corrosion rate was observed to be higher in Warri and Yenagoa compared to the other states under review. From the analysis and conclusion of the results obtained, it is therefore recommended that conscious steps should be taken to reduce the effects of corrosion in these areas by embarking on periodic inspection of corrosion prone areas in vehicles such as the fenders. All tyres should have mudguards to shield the fenders from the impinging action of high-velocity mud slurry. Damaged paint / coating should be properly repaired by qualified personnel to prevent filler / paint undercutting.

The underbodies of vehicles are more prone to corrosion: gravel, chippings, sands and water containing salts are thrown up from the road surface causing mechanical damage. Hence, the under body of vehicles should be coated with a thick protective layer to forestall corrosion, protect against mechanical damage, moisture and reduce thermal stresses.

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