Journal of Inventive Engineering and Technology (JIET)
ISSN: 2705-3865
Volume-3, Issue-3, pp-103-110
www.jiengtech.com
Research Paper Open Access

Corrosion Phenomenon in Diesel Locomotive Engines

Adedotun J. F[1] and Adeyeye P.S.[2]

[1]*Industrial Maintenance Engineering Department, Yaba College of Technology, Lagos Nigeria*
[2]*Segade Engineering Services limited, Lagos Nigeria*

Corresponding Author:* **fjadedotun@gmail.com, +2348038354814

ABSTRACT : *Corrosion is the reactions of materials with their environment, and it represents an enormous loss of material. Corrosion is the destruction, degradation, or deterioration of material resulting from chemical or electrochemical attack by its environment. All metals and alloys corrode or react with their environments. The extent and rate of this interaction are functions of both specific metal and surrounding media. Corrosion forms in Diesel Locomotive Engines auxiliary equipment such as bearings, pumps, turbocharger exhaust manifold, which were principally constructed of ferrous and iron- based alloys were highlighted with emphasis based on visual and theoretical assessment. Corrosion of Diesel Locomotive engine, which was principally constructed of iron and iron-based alloys, is as a result of water attack, air, and fuel, and lubrication oil contaminations. Adequate maintenance will be required to prevent corrosion of principal parts of locomotives used for their operations as corrosion represents an enormous financial loss and wastage of material as metals which have undergone corrosion lose their strength, ductility and other desirable mechanical and physical properties.*

KEYWORDS: *Corrosion, Locomotives, degradation, iron based alloys, mechanical and physical properties.*

Date of Submission: 29-06-2023 Date of acceptance: 04-07-2023

I. INTRODUCTION

Corrosion is the destruction, degradation, or deterioration of material resulting from chemical or electrochemical attack by its environment. All metals and alloys corrode or react with their environments. The extent and rate of this interaction are functions of both specific metal and surrounding media.

Corrosion represents an enormous financial loss and wastage of material as metals which have undergone corrosion lose their strength, ductility and other desirable mechanical and physical properties (ASTM, 1981). There are many types of corrosive media viz.: air, soil, acids, bases, salt solutions and industrial atmospheres with all chemical reactions, the rate of corrosion depends on temperature and concentrations of reactants and products. (Michael, 1985).

Rusting of metal applied to iron or iron-based alloys results in the formation of corrosion products, consisting largely of hydrous ferric oxides $Fe_20_3 \cdot H_20$ (rust), Magnetite, $Fe_3\ 0_4$ and ferrous hydroxide, $Fe(OH)_2$. Both oxygen and water are required for the formation of rust, iron and steel will not rust in a dry atmosphere or when immersed in oxygen free water (Ortom, 1965), Corrosion of diesel locomotive engine, which was principally constructed of iron and iron-based alloys, is as a result of water attack, air and fuel, and lubrication oil contaminations.

Locomotive engines employed in Nigerian Railway Corporation for traction are of diesel electric type. Diesel engine is an internal combustion engine of compression ignition, (C.I), whereby the combustion is initiated spontaneously by virtue of the rise in temperature during the compression process.

The use of untreated (raw) water in cooling system of diesel engine is detrimental to its efficiency of operation, economic and span of usage. Improved design and weight for power ratio in diesel engines, has resulted in smaller cooling chambers and less cooling surface for heat dissipation, any restriction of the flow of the cooling liquid by scale formation or corrosion is critical to the engine. Hence, proper conditioning of water used in the cooling system of an internal combustion engine is as important to the successful operation and life of the engine as the quality of fuel and lubrication oil used in the engine.

To reduce corrosion in diesel engines the four important parameters for efficient operation of engines, viz.: air, water, fuel, and lubrication oil must conform to standard qualities.
Corrosion appears as pitting and results from a chemical or electro-chemical action. Corrosion in diesel engine is a serious condition because it is silent, generally unnoticed, dissolving or eating away of the metal, which is often seen to occur under a layer of sludge or scale
As a result of using "raw water", lubrication oil, fuel and air contamination, the types of corrosion common to Diesel Locomotive Engines are pitting, galvanic, cavitation erosion, velocity erosion (impingement attack), and catastrophic oxidation.

Water in its natural state (raw water), whether it is taken from a river, spring, well or collected rain water contains many impurities in varying amounts. These impurities are limestone ($CaCO_3$), dolomite ($MgCO_3$), gypsum ($CaSO_4$), Epson salts ($MgSO_4$), sand (Si02), common salt (NaCl), Glauber's salt ($Na_2SO_4 \cdot 10H_20$), iron, aluminum. (Herbert ,1963)

Although the water may be suitable for human consumption (free of bacteria or other micro organisms, etc.), but it should be seen as a "Raw product" which must be treated before it is used in an engine cooling system. The disadvantages of using "raw water" in an engine cooling system are formation of sludge, scale formation which eventually resulted into corrosion.

II. MATERIAL AND METHOD

A. Pilling Bedworth Ratio

This determines whether scale formation is protective or non-protective, if volume of scale produced is greater than the volume of metal, the scale tends to be formed in lateral compression and such scales exhibit compactness and protective characteristic peculiar to parabolic growth rate.

Also, if volume of scale produced is less than volume of metal, then scale tends to be formed in lateral tension and such scales are cracked with incomplete coverage of the metal and therefore non protective

$$\text{Volume of scale} = \frac{\text{Molecular weight of scale}}{\text{Density of scale}}$$

$$V_s = \frac{Ms}{Ds} \qquad 1$$

$$\text{Volume of metal} = \frac{\text{Molecular weight of metal}}{\text{density of metal}}$$

$$V_m = \frac{m}{d} \qquad 2$$

For scale to be protective and compact $V_s > V_m$,

$$\text{Implies } \frac{Ms}{Ds} > \frac{m}{d} \quad \rightarrow\rightarrow\blacktriangleright M_s d > mD_s \qquad 3$$

Similarly, for non-protective scale $M_s d < mD_s$ 4

105

Therefore, the expression $\frac{Msd}{mDs}$ = Pilling Bedworth Ratio.

PILLING BEDWORTH RATIO = $\frac{Msd}{mDs}$ 5

B. **Corrosion as an Electro-Chemical Reaction**

Corrosion of metals involves the electrochemical reaction of the metal in an aqueous solution. Corrosion of an iron in oxygenated water may be represented as follows: (ASTM, 1966)

$Fe \rightarrow Fe^{2+} + 2e$ (Anodic reaction) 6

$0_2 + 2H_20 + 4e \rightarrow 40H$ (Cathodic reaction) 7

With the overall reaction,

$2Fe + O_2 + 2H_2O \rightarrow 2Fe^{24-} + 40H^- \rightarrow 2Fe\,(OH)^-_2$ 8

However, ferrous hydroxide, $Fe(OH)_2^-$ is unstable and in the absence of a low oxygen decomposes to magnetite (Fe_30_4) according to

$3Fe\,(OH)_2 \rightarrow Fe_30_4 + 2H_2O + H_2$ 9

If it is adherent and compact, a passivating ensues. And in the presence of oxygen $Fe(OH)_2$ oxidizes to rust by dissolving in oxygen according to

$2Fe(OH)_2 + ½\,O_2 + H_20 \rightarrow Fe_20_3 \bullet H_20$ (reddish brown) (Herbert,1963) 10

The formation of magnetite (Fe_3O_4) in most operation is very important as it determines the passivity or otherwise of the metal. Such oil films may be applied intentionally or may occur naturally, as in the case of metals submerged in sewage or equipment used for the processing of oily substances.

Many different types of reaction may be dependent on potential, pH or the combination of both potential and PH.

$Fe2+ \rightarrow Fe^{3+} + e^-$ (Potential dependent) 11

$Fe^{2+} + 2H_20 \rightarrow Fe(OH)_2 + 2H^+$ (PH dependent) 12

$Fe^{2+} + 3H_2O \rightarrow Fe(OH)_3 + 3H^+ + e$ (Both PH and potential dependent) 13

C. **Methodology**

Different parts of diesel engines as shown in the tables 1and 2 are made of different construction materials e.g. ferrous and non-ferrous, and each reacts to the environment differently. The method applied in the project is to highlight corrosion phenomenon in these parts and suggest ways of reducing the problem and since water is a major corrosive agent, radiator water was analyzed for pH, chloride content and inhibitor concentration.

Table 1: Parts Of The Diesel Engine With Specific Corrosion Forms

S/N	DIESEL ENGINE PARTS		MATERIALS OF CONSTRUCTION	COROSION FORM
1	Cylinder head		grey cast iron, cast iron alloy	Fatigue cracking, cavitations erosion, fretting
2	Cylinder block		High strength cast iron	Catastrophic oxidation, stress corrosion cracking
3	Cylinder liner		Cast iron	Cavitations, impingement attack, rusting, fretting
4	Exhaust valve		Forged nickel-chromium alloy steel with a tip hardened steel head	Pitting, fatigue cracking, cavitations erosion, fretting
5	Piston		Eutectic silicon-aluminum alloy, cast iron	Cavitations erosion, fretting, fatigue, impingement attack, rusting, pitting
6	Connecting rod		Forged-alloy steel	Rusting, impingement attack

7	Crankshaft	Drop forging carbon steel, alloy steel forging, wear resistant cast iron	Corrosion fatigue, stress corrosion cracking
8	Crankcase	Cast iron, Aluminum	Stress corrosion cracking, rusting, Selective leaching
9	Crankshaft thrust	Cooper-lead thrust pads	Fretting
10	Crankshaft	High alloy steel	Stress fatigue
11	Pumps	Cast iron, alloy steel	Erosion , rusting, pitting cavitation
12	Exhaust manifold	Cast iron, steel alloy, stainless steel	Pitting, selective leaching, rusting, cracking, cavitations stress, oxidation
13	Gear	Medium carbon steel, nickel-chromium, molybdenum alloy steel	Corrosive wear, surface fatigue. Fretting, pitting
14	Radiator	Cuprous nickel alloy	Cavitation, pitting impingement attack
15	Oil cooler	Cooper tubing and fins	Pitting, impingement attack, cavitation erosion
16	Bearings (main and connecting rod)	Steel-backed tin-aluminium lead shells, steel-backed lead bronze	Surface erosion, shell fretting, fatigue, cavitation erosion
17	Rings (compression and oil)	Cast iron- chrome plated, stainless steel	Stress corrosion cracking pitting
18	Turbo charger/blower	Cast iron, alloy steel	Pitting, stress corrosion, rusting, erosion corrosion

Table 2: Standard (Specification) Laboratory Analysis Of Fuel Oil, Lube Oil And Coolant Water

Nos.	ANALYSIS	FUEL OIL	NEW LUBE OIL	USED FUEL OIL	WATER COOLANT
1	Specific gravity at 30°C	0.840-0.845	0.835-0.850	-	-
2	Viscosity at 60C	32.0-35.0	200-240	±25% of (200-204) ≥151.6	-
3	PH.	-	8.0-10.5	≥4.5	7.0-9.5
4	Chlorides (ppm) max	-	-	-	≤40
5	Chromates (ppm) max	-	-	-	≤200
6	Sulphate (ppm) max	-	-	-	≤100
7	Water contamination	0.05%	-	≤0.25%	-
8	Fuel dilution	-	-	≤5.0%	-
9	Colour	Clear	Amber	Dark	Yellow with diskro-T
10	Appearance	Liquid	Liquid	Liquid	liquid
11	Total hardness ppm (max)	-	-	-	≤170
12	Sediment deposit	≤0.05	-	-	-

.

IV. RESULT AND DISCUSSION

Various corrosion forms relevant to diesel engines have been highlighted to include erosion corrosion, cavitation, pitting, stress corrosion cracking, catastrophic oxidation, fretting and fatigue wear. Many of these corrosion forms are due to improper maintenance of cooling water treatment, inadequate lubrication oil, high temperature and velocity of filtered or unfiltered air charged to the engine. The study in this section highlights preventive measures against these corrosion forms. Figs. 1-6 show the results obtained from the experiments.

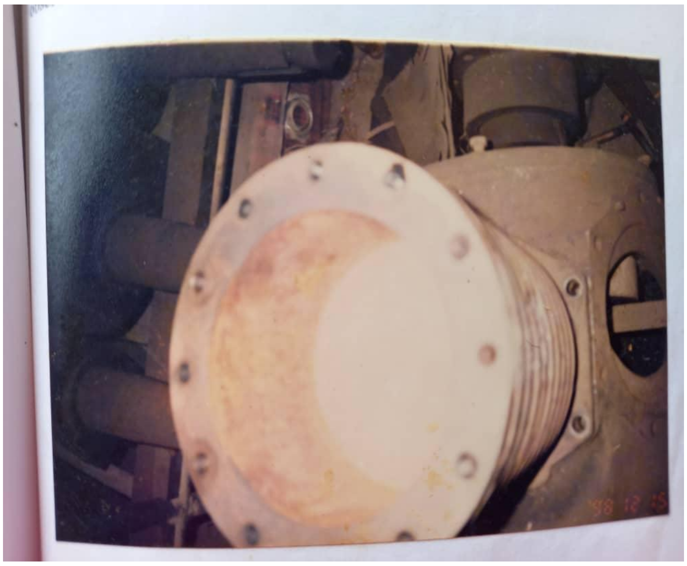

Fig. 1: Corrosion in cylinder liner/piston

Fig. 2 : Corrosion in journal bearing

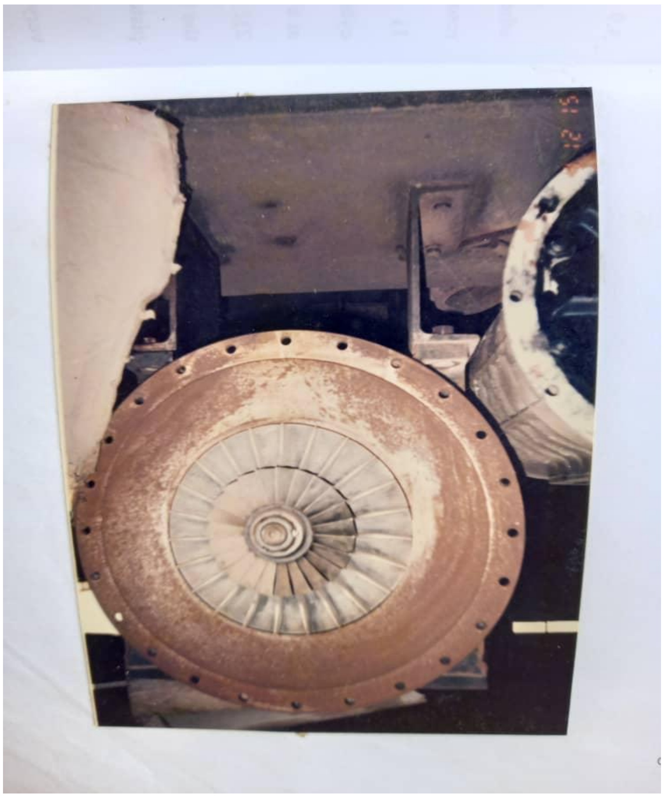

Fig.3: Corrosion in turbocharger assembly

Fig. 4 :Corrosion in crankcase

Fig. 5 : Corrosion in radiator

Fig. 6: Corrosion in exhaust manifold

A. Control of Acidity and Alkalinity

PH ranges from 0 to 14 and the acid or alkaline properties of water are recognized by this series of value. -Iron and steel tend to corrode by acidic waters; aluminum corrodes by alkalis. The control of the PH value of the coolant is very important since most diesel engines employ both ferrous and light alloy metals in the water circuit. A slightly alkaline coolant is best for general use as the effect of mild alkalinity on aluminum can be nullified by a suitable corrosion inhibitor. The PH value of the coolant determines the type of inhibitor and in order to protect the component part of the engine which is in contact with the cooling fluid, the coolant should be treated with a suitable corrosion inhibitor.

B. Corrosion Inhibitors

There are a number of inhibitors available and it should be borne in mind that many otherwise excellent inhibitors must be carefully controlled by chemical tests at regular intervals. If this is not done and concentrations are allowed to vary from the recommended limits the inhibitor may cause more severe corrosion than untreated water. The use of chemical inhibitors can also involve difficulties unless the water is always from the same source, variations in the water supply may affect the recommended concentration of inhibitor (ABB HENSCHEL GERMANY, 1990).

V. CONCLUSION AND RECOMMENDATIOS

A. Conclusion

Corrosion is a single factor that has contributed to uneconomical viability of the operation and running costs of the diesel engines. It is therefore important that adequate education on corrosion be given to industries and government to reduce the resultant economic loss to a minimum.

The use of raw (untreated) water, low quality lube oil and fuel oil, excessive coolant velocity used in diesel locomotive engines is the major cause of corrosion which results in serious and irreparable damage to the engines with high maintenance, repair and replacement cost.

This study will be useful to industry and users of diesel engines for haulage, transportation, marine, electricity, etc. in enabling them to know the different corrosion phenomena and the technologies available for the

prevention of corrosion.
The work will be beneficial to maintenance Engineers and Railway Engineers to stimulate their thinking on the detrimental effects of corrosion and will be helpful in dealing with:

1. Monitoring corrosion progress.
2. Recognizing corrosion defects, damages and failures.
3. Corrosion related maintenance.
4. Application and Selection of process chemicals and materials that is not prone to corrosion damages

B. **Recommendations**

Maintenance engineers are saddled with the responsibilities of ensuring that diesel engines are in acceptable working conditions. It is therefore recommended that the following guide lines are kept to.

i). Ensure adequate cleaning, servicing and maintenance of diesel engines

ii) Make sure that the technical department has the result of the analysis for the composition of cooling water, lubrication oil and fuel, and establish adequate / degree of treatment necessary prior to their use.

iii) Estimate possible effect of corrosion due to scale, sludge formation, untreated water, and poor quality fuel and lube oil.

iv) Ensure adequate training for personnel on the type of corrosion, its effects on equipment and the best way of handling these equipments to prevent corrosion.

v) Furthermore, corrosion study should involve case studies of heavy industrial and marine diesel engines to compare the extent of failures due to corrosion in diesel engines used for traction purposes.

REFERENCES

ABB HENSCHEL GERMANY (1990), " Diesel - Electric locomotive Instructions and Service manual to Nigerian Railway Corporation, Vol. I & II.

AMERICAN SOCIETY FOR TESTING OF MATERIALS, (June 1966),"Journal of materials", P_{346-52}

ANNUAL BOOK OF ASTM STANDARDS, Pt. 10 (1981), " Metals - Physical, Mechanical Corrosion Testing", $P_{829\_58\ 880.917\_25}$•

ASF1WORTH G. V.Corrosion - Industrial problems, Treatment and Control Techniques", Corrosion Consultants, UK, Vol. 2 (KFAS), Pergamon Press.

ENCYCLOPEDIA OF CHEMICAL ENGINEERS TECHNOLOGY, Vol. 6, P28.

EROSION AND WATER, ASTM BV (1985), "Metal Corrosion", Vol. 03. 03, $P_{1\_}$

HERBERT H. UHLIG (1963), "Corrosion and Corrosion control", John Wiley and Son, $P_{3;\ 84-85;\ 246-49.}$

JOHN V. B,, (2nd ed.), " Introduction to Engineering material".

MC GRAW HILL, “Encyclopedia of Science and Technology". Vol. 4, P_{438-45}

MC GRAW HILL, (6th ed.), "Perry's Chemical Engineers Handbook", Perry and Green, P_{23-6}.

MICHAEL B. BEVER, ed. (1986), " Encyclopedia of material science and engineering" , Vol. 2, Pergamon press, $P_{880-92;\ 915-20}$•

ORTUM, G., "2nd ed. (1965), "Treatise on Electrochemistry", P_{598_13}.

RUSTON PAXMAN DIESEL LTD, ENGLAND, "Engine Operating and Maintenance manual", 400 BHP Diesel - Electric locomotives of Nigerian Railway.

ROGERS, G. F. C. and MAYHEW, Y. R. (3rd ed.), “Engineering Thermodynamics", P_{300-14}.