International Journal of Academic Engineering Research (IJAER)
ISSN: 2643-9085
Vol. 9 Issue 3 March - 2025, Pages: 1-6

Analysis of Variance Estimation of Degradation Rate of Coated A36 Steel Pipelines in Environmental Risky Condition

Bani, S. L.

Department of Mechanical Engineering, Rivers State University, Port Harcourt, Nigeria

Email: saturday.bani@ust.edu.ng

ABSTRACT: *Petroleum is a major source of government revenue in Nigeria. The transportation medium of this fundamental source of revenue is through pipelines. The design, installation and sustainability of these infrastructure has consumed large amount of money in dollars from the federation, yet incessant failure of pipelines continues to showcase, majorly due to degradation. The aim of this study is to estimate degradation effects on coated A36 steel pipelines use for transportation of oil and gas in high risky environmental condition. Samples of A36 steel labelled in sample identity delivered to the laboratory for tests. The specimens were segmented into coated and uncoated. The uncoated, labelled A was regarded as the control, while the other three sets labelled B, C, and D were coated with different materials. The samples suspended in hydrogen tetraoxosulphate (vi) acid of varying* P^H *values were observed at every 144 hours for a total of 720 hours and the rate of degradation at each instant was estimated based on mass loss principle. Experimental data were analyzed with analysis of variance at 95% level of confidence using Minitab software. At the end of 720 hours, the degradation rate of the control specimen was 0.706mmpy, while that of the uncontrol was: B 0.055mmpy; C 0.04051mmpy; and D 0.043mmpy. The degradation rate of the samples investigated show higher value for the control (uncoated A) relative to the coated B, C, and D. This show that A36 steel has high rate of degradation and should be coated, especially when use in high risk environment.*

Keywords: Risky condition, ASTM A36 steel, Petroleum, Pipelines, Degradation rate

1.0 INTRODUCTION

Transportation of petroleum and its products through pipelines is considered the most economical and efficient, when compared with other media. However, failure during transmission of products is inevitable, especially in Nigeria. Failure of pipelines in service depend on many factors such as ageing, corrosion, equipment failure, and third-party interference. Chinedu et al. (2015) stated that pipeline corrosion or degradation is a major challenge facing the oil and gas industries today, because of severe downtime associated with corrosion related failures. Corrosion is the degradation of materials through environmental interaction (Akpa, 2013; Ikpesu, 2014), which encompass materials such as plastic, ceramics, and metals and occurs in aqueous environment and is electrochemical in nature. In an attempt to minimize defects of pipelines due to degradation, petroleum pipelines are being coated diversely. According to Anees (1999), FBE is more viable for internal coating of pipes since it composed appropriate composition of properties for the purpose. Choo (2010) carried out investigation on the effect of corrosion of TGIC-free polyester coated and uncoated carbon steel at different pH of seawater and tap water. Weight loss for rate of corrosion and tensile tests were employed. Coating effectively reduced corrosion and increased the tensile strength of steel in different PH solution, as observed.

Nwigbo & Ejimofor (2017) predicted the rate of corrosion of mild steel under paint. The weight loss approach was used for 15 days, at three days interval. Investigation showed maximum deviations of less than 16% of model predicted corrosion rates compared to experimental corrosion rates. It was found that the corrosion rate of mild steel was significantly reduced in the presence of the paint and that it offers good inhibition efficiency at various pH values. Maurren (2012) researched on temperature effects on coating and alloy phase morphology on 1040 steel workpiece. Test samples were by fluorescent microscope, SEM, EPMA, XRD and hardness test. Investigation showed that immersion temperature caused greater thickness of the coating and inter-metallic layer. Ehtera & Aisha (2008) investigated the response of mild steel in HCl through chemical and electrochemical approaches. It was found that mild steel corrodes in hydrochloric acid solution with a reaction constant of 0.56, while the rate of corrosion appreciated with increase in concentration of acid. Wan et al. (2011) examines corrosion behaviour of mild steel in seawater. Both weight loss and potentiodynamic polarization test were utilized for analysis. Results revealed that corrosion rate increased with immersion time. Adetunyi and Aiyedun (2012) studied corrosion behaviour of Zinc alloy coating sheet in cassava juice, maize pulp, and sea water. Weight loss for specific immersion time was observed. Investigation indicated that cassava fluid had the highest corrosion rate of the samples, followed by maize pulp, then seawater.

Anyanwu et al. (2014) assessed the corrosion of API 5L X 42 carbon steel in both Na_2CO_3, Na_2SO_4 and NaCl media using weight loss principle. Investigation showed that 1.0M of Na_2CO_3 solution had the highest corrosive tendency followed by 0.5M NaCl, 1.0M NaCl, 0.5M Na_2CO_3. 0.5M Na_2SO_4 and the least was 1.0M Na_2SO_4 solution. Lee et al. (2024) reported chlorine-induced corrosion and blister formation on steel pipes coated with modified polyethylene powder. Experiments was conducted and data analyzed with SEM-EDX technique. Results showed that no corrosion was observed on modified polyethylene-coated steel pipes at a chlorine concentration range of 0 mg/L to 10 mg/L. Also, no significant changes in specimen weight or iron levels. However, the uncoated samples exhibited significant iron leaching and corrosion. In temperature gradient tests, MPCSPs showed no blisters after 100 days, while ECSPs exhibited severe internal coating layer blisters. Timothy (2019) presented performance characteristics of corrosion resistance coating materials (polyvinyl resin, an organic zinc, epoxy resin, an epoxy polyamide and an epoxy ester) for protection of carbon steel pipeline. For all materials, the same conditions of coating thickness, temperature, pH of corrosion, and exposure time were applied. The studied is for a period of 14-84 days. Results showed that corrosion rate increases with temperature, decrease in pH and increase in duration.

Bani & Dan-Orawari (2023) carried out an experimental studied on the corrosion of coaed mild steel pipelines in different P^H values in acidic environment. The experimental data were analyzed with analysis of variance at a significant level of 0.05. During the process, samples of coated and coated mild steel were suspended in H_2SO_4 solution of different pH (3,4,5, 6) at interval of 120 hours in a total period of 840 hours.

2. MATERIALS AND METHODS

2.1 Materials

Materials utilized in the research include ASTM A36 steel, digital weighing balance, Hydrochloric acid, distilled water, beakers, plastic container, thread, acetone, water, pH meter, hacksaw, caliper, table vice, and steel rule. The test piece, ASTM A36 steel plate is a grade of mild steel used in structural applications. A36 steel contains chemical alloys with properties such as machinability, ductility, and strength that are ideal for use in constructing different structures. The chemical composition of ASTM A36 follows: C 0.26 %, Si 0.26 %, Mn 1.03%, P 0.04%, S 0.05%, Cu 0.20%, and Fe 98%. The physical/chemical properties of A36: yield strength 250Mpa, density 7.85g/cm^3, Modulus of elasticity 200Gpa, shear modulus 79.3Gpa. These properties make A36 steel useful for construction of bridges, storage tank, pressure vessel, grinding, punching, drilling, machinery and tapping.

2.2 Methods

2.2.1 Experimental Procedure

Four different specimens of ASTM A36 steel of specification $3.0 \times 2.2 \times 0.8$ cm were subjected to degradation tests based on different P^H values of hydrochloric acid environment. The container labelled A was uncoated test piece regarded as control, while the rest three labelled B, C, and D were coated test pieces. ASTM A36 steel samples suspended in hydrochloric acid was observed at interval 144 hours for a total of 720 hours and the increase in mass was measured with weighing balance from which mass loss was estimated. The principle of degradation and analysis of variance were utilized for data analysis through Minitab 16 software.

2.2.2 Determination of Change in Mass of A36 Steel Specimens

The loss in nass of ASTM A36 steel was evaluated as expressed in Equation (1) (Bani & Dan-Orawari, 2023).

$$\text{ç™} = \mathrm{M_b} - \mathrm{M_a} \quad (1)$$

where, ç™ is the mass loss, $\mathrm{M_b}$ is the mass (mg) before immersion, and $\mathrm{M_a}$ is the mass (mg) after immersion.

2.2.3 Determination of Degradation Rate

In an attempt to determine the degradation rate for the period investigated, the total surface area of ASTM A36 steel was accordingly estimated using Equation (2).

$$\mathrm{S_A} = 2[(\mathrm{L_w} \times \mathrm{W_w}) + (W_w \times \mathrm{H_w}) + (\mathrm{L_w} \times \mathrm{H_w})] \quad (2)$$

where, $\mathrm{S_A}$ is the surface area of the rectangular workpiece, $\mathrm{L_w}$ is Length (cm) of sample, $\mathrm{W_w}$ is width (cm) of sample and $\mathrm{H_w}$ is the thickness (cm) of sample tested. The total surface area and weight loss already evaluated were used to determine the rate of degradation of the tested samples using Equation (3) according to Bani & Dan-Orawari (2023).

$$\mathrm{R^C} = \frac{87.6 \times \text{ç™}}{\mathrm{S_A} \times \mathrm{E_t} \times\times \rho} \quad (3)$$

where $\mathrm{R^C}$ is Degradation rate in mmpy, $\mathrm{E_t}$ is time during which the sample was exposed to the risky environmental condition in hours and ρ is the density in g/cm^3 of A36 steel samples.

2.2.4 Method of Data Analysis

International Journal of Academic Engineering Research (IJAER)
ISSN: 2643-9085
Vol. 9 Issue 3 March - 2025, Pages: 1-6

Analysis of variance was used to analyzed the data collected based on 95% level of confidence. Minitab 16 software was used for plotting of graphs.

3 RESULTS AND DISCUSSION

Mass Loss and Degradation Rate of A36 Steel Samples

The experimental results of mass loss and degradation rate of A36 steel investigated is presented in Table 1.

Table 1: Results of Mass Loss and Degradation Rate of A36 Steel Samples.

Expt.	ç™ (Uncoated)	ç™ (Coated)	$\mathbf{R}^{C}$(Uncoated)	$\mathbf{R}^{C}$ (Coated)
1	142.20	10.15	0.5197	0.0371
2	217.10	16.00	0.7936	0.0585
3	299.40	23.50	1.0444	0.0859
4	398.00	30.00	1.4549	0.1097
5	602.00	33.22	2.2006	0.1214
6	742.20	41.30	2.7130	0.1509
7	740.50	56.80	2.7050	0.2076
8	138.00	8.83	0.5044	0.0323
9	200.60	14.92	0.7333	0.0542

From Table 1, the average mass loss of the uncoated sample was found to be 386.667, while the average mass loss of the coated sample was found to be 26.08. The observed trend indicates that under the same condition, the uncoated sample of A36 experienced higher loss of mass than the coated sample. Similarly, the average degradation rate of uncoated sample was found to be 1.4076 mg, while that of the coated sample 0.0953 mg.

3.2 Comparison of Mass Loss and Degradation Rate of Uncoated and Coated Steel Specimens

From the experiment conducted, mass loss of both coated and uncoated ASTM A36 steel samples were determined and the degradation rates were plotted against mass loss and presented in Figure 1 and Figure 2, respectively.

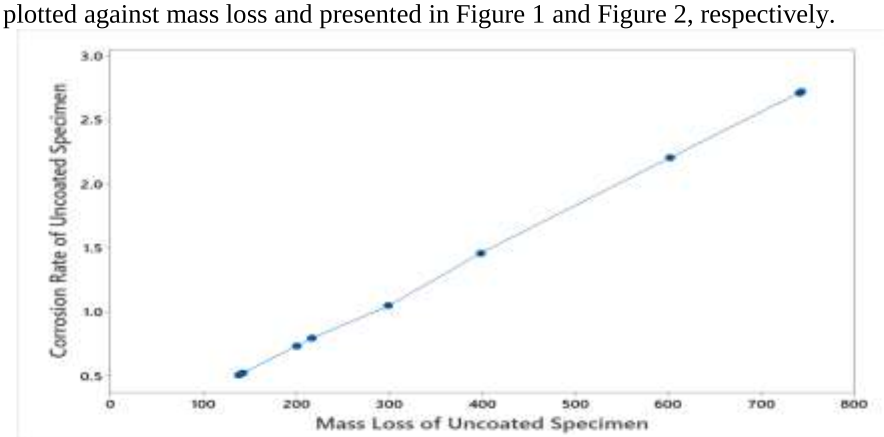

Figure 1: Degradation Rate versus Mass Loss of Uncoated A36 Steel Specimens

Figure 1 shows that degradation rate of the uncoated samples increases approximately as the mass loss increase. However, the observed trend produced a line whose gradient is not constant between all two selected points. The investigation reveals that certain factors were inadequately attended to, and their impacts contributed to the overall outputs. The high degradation rate observed indicate that ASTM A36 Steel can not be used for equipment or infrastructures to be deployed to an acidic environment.

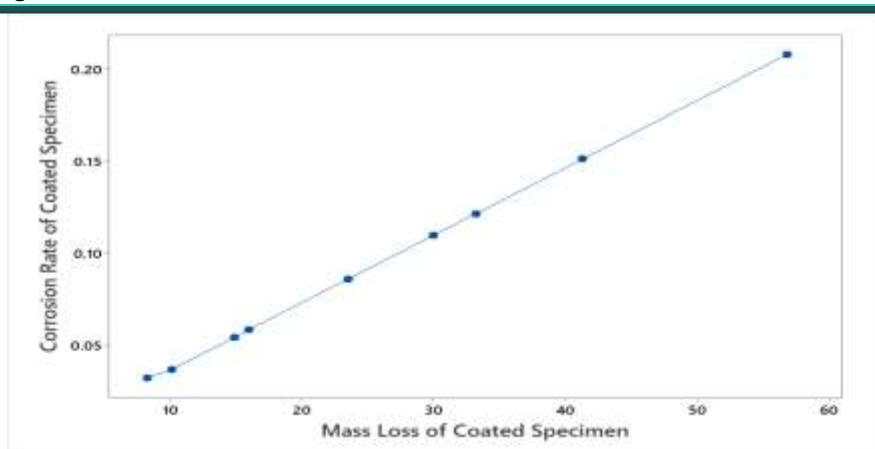

Figure 2: Degradation Rate Versus Mass Loss of Coated Specimen.

It was found premise on Figure 2 that degradation rate of pipelines increases as loss of mass increase. The rate of degradation is directly proportional to mass loss by the system. In furtherance, degradation of coated and uncoated samples was plotted against the experimental runs and reported in Figure 3. Results show that degradation of the uncoated sample tested is far more than that of the coated samples. This observation is significant and represents importance of coating pipelines for oil and gas transportation in acidic environment.

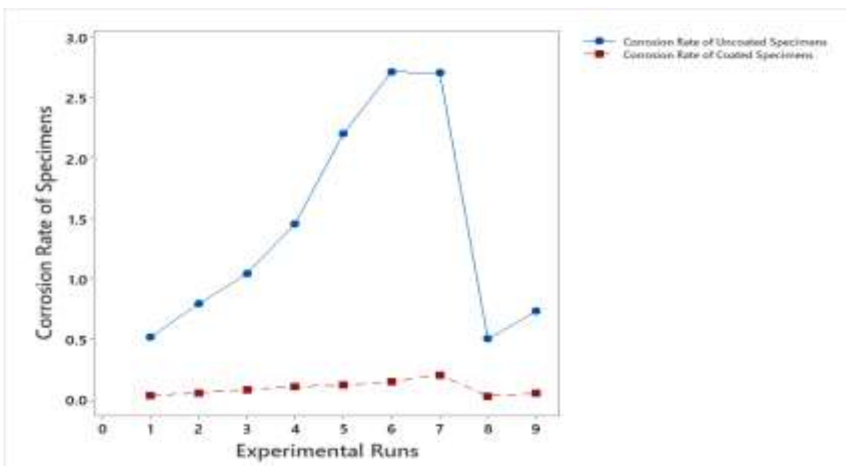

Figure 3: Degradation Rate of Uncoated and Coated A36 Steel Specimens

More so, the mass loss of both coated and uncoated A36 samples investigated was plotted with experimental runs and depicted in Figure 4. It was found that loss of mass of coated sample was very small relative to that of uncoated sample. This position reveal that absolute care needs to be applied to enhance safety and reliability of oil and gas pipeline by avoiding degradation when in service. Hence, pipelines should be properly coated, especially when need in a highly degradable acidic environment.

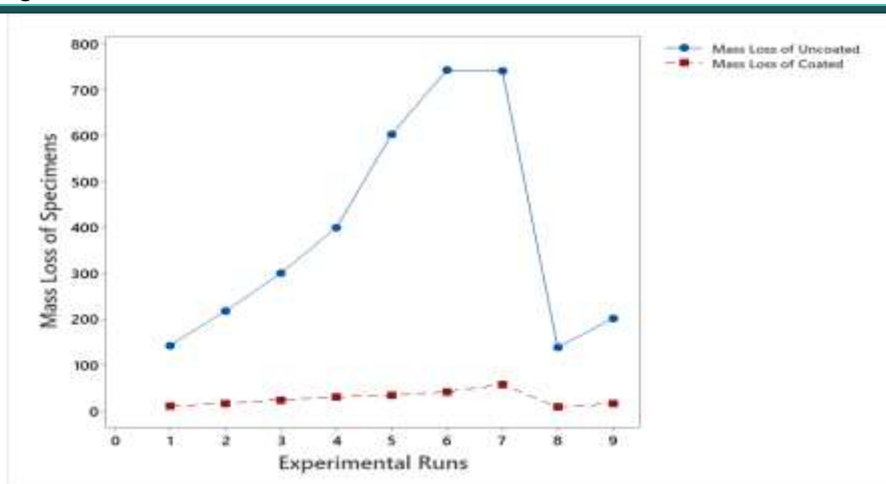

Figure 4: Mass Loss of Uncoated and Coated Steel Specimens

3.3 Analysis of Variance Results

The data acquired from the experiment conducted on A36 steel samples was subjected to analysis of variance investigation. The sources with a probability value < 0.05 show significant effect on mass loss and degradation of workpiece samples. From analysis, p-values of the degradation and mass loss are less than 0.05 which show their significant.

4.0 CONCLUSION

Investigation of degradation of A36 steel in risky condition was carried out and the following were reached:

i. Mass loss of uncoated A36 steel samples in acidic environment is very much greater than the coated sample in the same condition.
ii. Uncoated A36 steel samples degraded much faster than the coated sample in the same environmental condition.
iii. Coated sample of A36 steel is more reliable for transportation of oil and gas in acidic environment.
iv. The degradation rate of coated A36 steel is reasonable so the material is suitable for oil and gas pipeline in risky environment.

REFERENCE

Akpa, J.G. (2013). Modelling of the corrosion of stainless in marine oil environment. *Journal of Engineering and Applied Science*, 8 (8), 656-661.

Anees, U.M; Shahreer, A; Prakash, T. L; Ismail, A. F. & John, O.H. (1999). Corrosion Protection Evaluation of Organic Coating in Transmission Water Line. *Research & Development Centre*, Saudi Arabia.

Anyanwo, I.S; Eseanu, O. & Nwosu, H. U. (2014). Experimental Investigation and Mathematical Modelling of Corrosion Growth Rate on Carbon Steel under The Influence of Soil Resistivity, *International Organization of Scientific Research Journal of Engineering*, 4 (10). 07-18.

Bani, S. L. & Dan-Orawari Gloria, I. F. (2023). Investigating Effects of Corrosion on Industrial Coated Mild Steel Pipelines in Acidic Environment. *Journal of Automation and Automobile Engineering*, 8 (2), 41-56.

Chinedu, O., Boswell, B. & Davies, I. (2015). Pipeline Failure in Corrosive Environments- A Conceptual Analysis of Trends and Effects. *Journal of Engineering Failure Analysis*. 5(3), 36-58.

Choo, L.Q. (2010). Effect of Environmental Factors on Rate of Corrosion of Tgic-Free polyester coated mild steel. Thesis of Department of Civil Engineering. University of Malaysia, Pahang.

Ehteran, A. N. & Asha, H. A. (2008). Corrosion behaviour of Mild Steel in Hydrochloric acid, *International Journal of Electrochemical Science*, 3, 806-818.

Ikpesu, J. E. (2014). Investigation of Weight Loss and Corrosion Rate of Bi-metals and Tri-Metals in Acidic Environment. *Journal of Research in Environmental Science and Toxicology*, 3 (1), 15-20.

Maureen, B. I. (2012). Aluminizing carbon steel temperature effect on coating and Phase Morphology. Master Degree Thesis, Department of Materials Science and Engineering, Norwegian University of Science and Technology.

Nwigbo, M. N., & Ejimofor, R. A. (2017). Corrosion Inhibition of Mild Steel using Organic Coating in Acidic Medium. *World Journal of Innovation and Modern Technology*, 1 (1), 11-21.

Timothy, B. A. (2019). Performance Behavior of Four Corrosion Resistance Coating Materials Applied for protection of pipeline metal. *International Journal of Advanced Academic Research, Sciences, Technology and Engineering*, 7 (2),71-103.

Wan, N.W. B; Zulkifli, F; Rahman, M. M. & Rosliza, R. (2011). Corrosion behaviour of Mild Steel in Seawater from Two different Sites of Kuala Terengganu Costal Area. *International Journal of Basic and Applied Science,* 11(6), 75-80.