The International Journal of Engineering and Science (IJES)
|| Volume || 13 || Issue || 7 || Pages || PP 49-52 || 2024 ||
ISSN (e): 2319 – 1813 ISSN (p): 2319 – 1805

Z*Analysis of the Influence of Viscosity and Coating Thickness on Corrosion rate of steel Pipelines coated with produced metallic paints

OjoyeOlolade Mariam, Danladi King Garba, Thomas N Guma
E-mail: ojoyeololade3d@gmail.com, dkgarba@nda.edu.ng, tnguma@nda.edu.ng
Department of Mechanical Engineering
Faculty of Engineering and Technology, Nigerian Defence Academy
Kaduna, Nigeria.

ABSTRACT
Pipeline failures in Nigeria have been linkedto corrosion caused by old infrastructures. Petroleum pipelines are the most endorsed carriageway of the oil and gas products over competing means such as truck and rail for valid reasons such as being the safest, most convenient,economical, low theft/accident risk and cost-effective means available. These pipelines are susceptible to deteriorate in diverse, extreme climatic and soil conditions which affects their performance and reliability. It is well known that the corrosion resistance of materials can be improved by coating the pipeline to form a protective, dense and stable anti corrosion layer over the material.In order to investigate the influence of viscosity and coating thickness on anti-corrosion resistance of coated 5L X65 steel pipes, the pipes were coated with three produced metallic coatings, copper-metallic, chromium metallic and nickel metallic. Viscosity and ultrasonic thickness tests are performed to investigate the impact on the corrosion degree.

Keywords: *metallic paints, viscosity, coating thickness, corrosion protection, steel pipelines*

Date of Submission: 14-07-2024 Date of acceptance: 31-07-2024

I. INTRODUCTION

Corrosion is extremely old as the history of metals and it has been regarded as a threat to metals and structures. It is well known that the corrosion resistance of materials can be improved by addition of corrosion-resistant elements. The use of protective coatings such as gloss paints, epoxy coatings are definitely not new to corrosion mitigation in the Nigerian oil and gas system. But in continuous research into methods of controlling the degradation and deterioration of pipelines by corrosion and maintenance of existing pipelines, there is need to take mitigation a step further by the introduction of metallic paints.

The corrosion of steel is more aggressive in environments with high humidity, temperature and moisture such as the case of buried pipelines. Therefore, protective measures such as painting and coating must be done to ensure the safety and protection of the steel pipelines. Experimental studies are carried out to investigate the corrosion behavior of steel in different soil and atmospheric environments.

Previous researches have focused on the corrosion mechanisms of varieties of steel as well as the components and properties of corrosion products. Meanwhile, the research on the corrosion rate of coated steel isstill very few. It is not only insufficient for the accurate evaluation of the durability and longevity of pipelines but also for the accurate selection of coating type and thickness. Therefore, it is very important to investigate the corrosion rate of coated steel pipelines.

Corrosion rate is an important parameter in studying the corrosion progression of steel pipelines.

Huang [1] and Zhu [2] pointed out that under the same corrosion cycles, the change rule of corrosion rate of different kinds of carbon steel is basically the same through analyzing the corrosion data. In addition, Schumacher's empirical formula is applied to fit the corrosion data, and it is proposed that the slope of the linear part of the formula can be approximated as the long-term corrosion rate of carbon steel. However, this experimental formula does not consider the influence of rust layer and other factors on corrosion rate.

The corrosion behavior of carbon steel plated with galvanized, aluminum and zinc-aluminum alloy elements/materials has been studied in references [3], [4] and [5]. It is shown that these three plating layers can limit the corrosion rate and have a good anti-corrosioneffect for steel.

In this paper, the corrosion rate of 5L X65 steel coated with four different coatings is studied based on viscosity and thickness of coating. Then the effect of the viscosities and thickness on the corrosion rate is also discussed.

II. EXPERIMENTAL WORK / METHODOLOGY

The alkyd gloss paints and the produced metallic paints were examined for physicochemical parameters such as coating thickness and viscosity to investigate variations in the properties of all paints. The physicochemical properties of paints were determined by different modern instrumental techniques. The four paints (alkyd gloss paint. copper metallic, nickel metallic, chromium metallic) were poured in transparent containers and stirred using HeiDolph RZRI 5000 stirrer for 10 minutes until a homogeneous solution was obtained.

2.1 Viscosity

The viscosity was determined by using the Zahn Viscometer via standard method. This test was carried out at 30^{o}C room temperature. The Zahn cup is a stainless-steel cup with a small hole underneath. The cup was thoroughly cleaned with distilled water, damped with clean cloth and air-dried for ten minutes. 1kg of paint was stirred for 30 seconds in a container to allow any air bubbles dissipate. The cup is then immersed in 1kig of the paint to be tested.

A stop watch is set ready to take readings. The cup was quickly lifted out of the liquid and the timer is set as soon as the top edge of the cup emerges at the surface of the liquid. The paint is seen drifting out through the hole at the bottom of the cup. The timer is stopped at the first break in the liquid stream from the bottom of the cup. The time at the break is recorded as the viscosity number. the cup is cleaned after every test and the process is repeated for all the paints. The viscosity of the paints was calculated using ASTM D4212 [6] and ASTM D1084 [7] and is presented in table 1.The conversion between flow time and viscosity is calculated from the equation below

$$Viscosity = K \ x \ flowtime - \frac{C}{flowtime} \quad [6]$$

2.2 Film Thickness

The film thickness of paint was determined by a film thickness tester according to ASTM D7378-16 [8]. Four unpainted steel samples were wiped with a clean cotton cloth dipped in ethanol and allowed to dry in air. The four paints (alkyd gloss, copper metallic, nickel metallic, chromium metallic paints) were applied on the steel samples with a paint brush to obtain uniform coats. The metallic paints were applied in three layers with a base coat of primer to imitate the already prepared steel samples. The panels were then left to air-dry. Film thickness measurements were taken and recorded in table 2.

The thickness of protective coating is determined using the formula below.

$$\boldsymbol{T_c = \frac{T_1 + T_2 + T_3 + T_4 + T_5}{5}}$$

where,

Tc = Thickness of Protective Coating

T_1 = Thickness of Coating at point A , T_2 = Thickness of Coating at point B

T_3= Thickness of Coating at point C , T_4 = Thickness of Coating at point D

T_5 = Thickness of Coating at point E

III. RESULTS AND DISCUSSION

The results for the viscosity test and coating thickness measurement are presented below.

Table 1: Viscosity Test

Physicochemical Parameter	Analysis Method/ Equipment	Type of Paint			
		Alkyd Gloss	Copper Metallic	Nickel Metallic	Chromium Metallic
Viscosity	ASTM-D-428788 Zahn Cup Viscometer	63.6	79.8	77.9	77.4

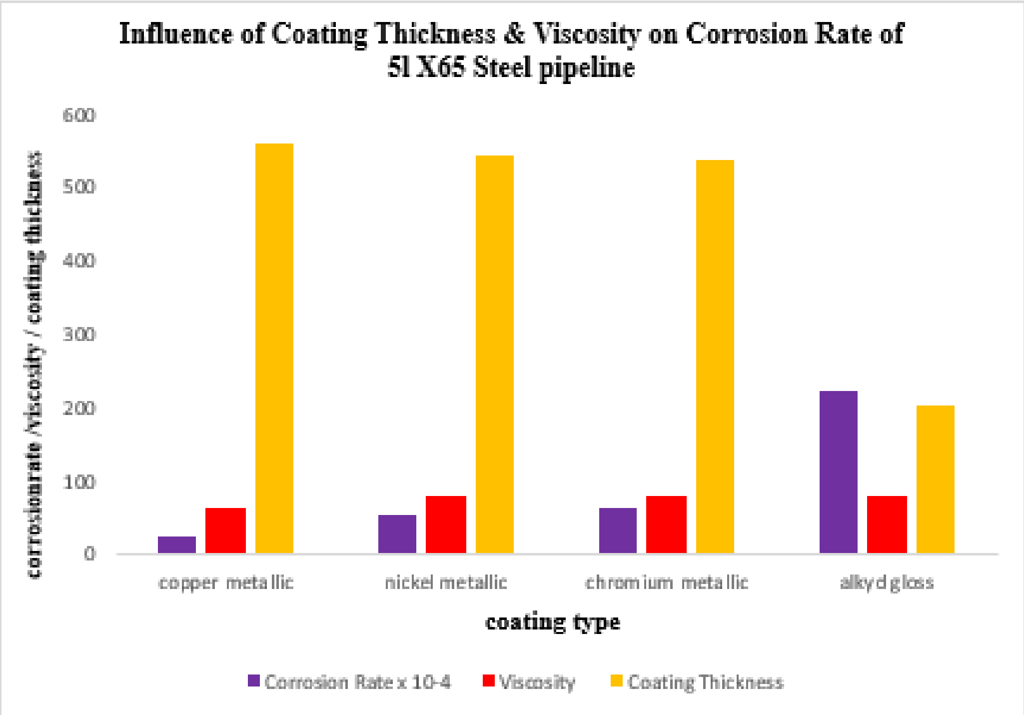
Viscosity is the measure of a paint's thickness and flow and this helps in determining whether the paint can be applied with a brush, a roller, a sprayer, or other methods of application. The viscosities were calculated and the results of all four paints in table 1shows that the alkyd gloss had the lowest viscosity of 63.6 KU. The viscosities of copper, nickel and chromium paints were 79.8KU, 77.9KU and 77.4KU respectively. The viscosity of copper was highest due to the density of the copper metal powder.

The viscosities of the metallic paints were higher due to the addition of metal powders (pigments) to the mixture. Higher viscosity translates to better coverage and coating film thickness. It also leads to resistance in flow and this was noticed during the application of the three metallic paints on the steel substrate. There was no drip effect. In most cases, metallic paints for pipelines are produced in an almost uniform level of viscosity that makes them application friendly. Though the viscosity of the metallic paints were higher than the alkyd gloss paint, they were easily applied by brush as the paints were not too thick.

Table 2: Coating Thickness Measurement

Coating Type	Coating Thickness at different points (µm)					
	Point A	Point B	Point C	Point D	Point E	Average
Copper Metallic Paint	561	560	560	560	559	560
Chromium Metallic Paint	536	535	536	537	536	536
Nickel Metallic Paint	543	542	542	541	542	542
Alkyd Gloss Paint	203	202	201	202	202	202

The result of the average coating thickness (CT) has been calculated and presented in table 2 in appendix. The copper metallic samples had CT of 560µm, nickel with 536µm, chromium 542µm and alkyd gloss had 202µm. The coating film thickness agrees with standard ISO 12944. The alkyd gloss sample has a lower thickness because it is a one-layer coating while the three metallic painted samples are three-layered (this was done to increase film thickness and create better barrier against corrosion). This test also showed slight variations in the thickness of the same sample at different points of the coated surface, this is due to slight variations in the paint coat evenness.



The graph above shows the influence of coating thickness and viscosity of the corrosion rate of 5L X65 steel. The tests results shows that thickness and viscosity of protective coatings greatly affect the extent of corrosion progression. A more viscous coat will most likely provide a thicker coat layer which will in turn serve as a better protection to steel 5L X65.

IV. CONCLUSION

In this research work, three metallic paints were produced, one alkyd gloss paint sourced for comparison of viscosities and film thickness and their effects of corrosion rate of 5L X65 steel pipes. The physicochemical properties of metallic paints produced were compared with that of standard alkyd gloss paints.

The viscosities of the produced metallic paints were calculated to be 79.8KU Cu, 77.9Ni, 77.4KU which are higher than the viscosities of standard alkyd gloss paint with 63.6KU. The viscosity of the paint which directly affects its thickness is an essential factor to consider. The thicknesses were found to be 560µm Cu, 542µm Ni, 536µm Cr and 202µm alkyd gloss. The metallic paints were thicker than the standard alkyd gloss paints. It is concluded that the viscosity and coating thickness has great influence on the corrosion rate of steel 5L X65 in that an increase in the film/coating thickness significantly slows down the corrosion rate of steel.

REFERENCES

[1]. Huang GQ (2001) Corrosion behavior of carbon steels immersed in sea areas of China. Corrosion Sci Protection Technol 13(2):81–84, 88

[2]. Zhu XR, Huang GQ, Lin LY et al (2005) Research progress on the long period corrosion law of metallic materials in seawater. J Chin Soc Corrosion Protection 25(3):142–148

[3]. Wang LX, Wang JJ, Yu JH, Qi HQ (2022) Corrosion performance of arc-sprayed Zn coating in simulated acid rain environment. Welding Joining 06:49–53

[4]. Wang Y, Zhao XN, Wang XD et al (2018) Aluminizing steel surface for providing protection in Marine environment: a technological review. Mater Rep 32(21):3805–3813+3822

[5]. Su X (2015) Study on corrosion behavior of Zn-Al coating in typical simulated environment. Wuhan University of Technology, Wuhan

[6]. ASTM D4212-16 Standard Test Method for Viscosity by Dip-Type Viscosity Cups ASTM International https://www.astm.org/d4212-16.html

[7]. ASTM D1084-16(2021) Standard Test Methods for Viscosity of Adhesives

[8]. ASTM D7378-16 Standard Practice for Measurement of Thickness of Applied Coating Powders to Predict Cured Thickness.