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Comparative Study on Polyvinyl and Epoxy Polyamide (Polymers) Resins as Corrosion Resistance Coating on Low Carbon Steel

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Abstract

Two commonly applied corrosion resistance coatings (Polyvinyl and Epoxy Polyamide resins) in Rivers and Bayelsa areas of Nigeria, have been compared on performance properties. The coatings were applied on low Carbon Steel samples that were cut to specific sizes. These prepared samples were subjected to varying conditions of pH, temperatures and exposure to definite time periods. The corrosion rates in ML per year (MPY) were then analyzed. The results of the corresponding corrosion rate in MPY obtained at PH 2,3,4,5, and 6, for epoxy polyamide resin, were 0.566, 0.553, 0.379, 0.354 and 0.322 respectively, and that for polyvinyl resin were 0.334, 0.326, 0.314, 0.288 and 0.277 respectively. The effect of temperature at 30° C, 4 ° C, 50° C, 60° C and 70°C were compared and corresponding corrosion rate in MP obtained for epoxy polyamide were 0.158, 0.288, 0.477, .655 and 0.810 respectively, while that for polyvinyl resin gave values of 0.122, 0.21,0.411, 0.552 and 0.651 respectively. The time exposure in hours of 692, 1008, 1344, 1680 and 2016 for the test steel samples applied with epoxy polyamide resin coating gave a corresponding corrosion values in MPY of 0.012, 0.016, 0.030, 0.043 and 0.055 respectively, and that for polyvinyl resin coating were 0.002, 0.009, 0.020, 0.034 and 0.044 respectively. The results obtained showed that polyvinyl resin coating have better performance properties over epoxy polyamide resin. Therefore polyvinyl resin coating can be recommended as a good corrosion resistance coating on low carbon steel pipes used in crude oil exploration in Petroleum industries.

Keywords: ***Coatings, Corrosion, Temperature, pH, Exposure time.***

Introduction

As a matter of fact, metals (except gold and platinum) exist in nature in the form of Oxides, Carbonates, Sulphides and Silicate.

These metals are reduced to their metallic state from ores during their extraction and a lot of energy is spenton the extraction process. The pure metals are usuallt at their high energy state as compared to their ores, and this high energy state is not stable, hence pure metal have the tendency to revert back to their natural state. Invariably, when metals are put into use in various forms, they are exposed to the environment containing liquids and gases. For this reason the surface of the metal starts deteriorating or destruction, which is probably due to direct chemical attack or electrochemical attack. The destruction (or deterioration) of a metal by unwanted chemical or electrochemical attack by its environment starting at the surface is called Corrosion.[1]

The annual loss to the whole world through the corrosion of the different materials (metals) has been reported to be about 2 billion dollars (The petroleum corporation (NNPC) reported 162 cases of failure due to Corrosion).[2]

Environmental Conditions are always responsible for corrosion and can be corrected by preventing contact of the surrounding environment with metal. This also resulted to the usage of inhibitors and protective or preventive coatings in the control of corrosion. It has been stated that any substance which when added in small amounts to the corrosive environment of a metallic material and effectively decreases the rate of corrosion is called inhibitor.[3];[4] also stated that a coating is any thin material applied firmly and continuously to the structure which it is designed to protect and prevents contact with the environment. The Peabody (1967)[5] has reported that the use of protective coatings is one of the oldest and most frequent methods of protecting metals from corrosion.

Metal can be protected against corrosion by using a protective coating that is effective and efficient. The coating must possess resistance against impact, chemical resistance to the environment to which it is exposed, resistance to permeation of moisture, stable and the temperature to which it is exposed[5];[6] and[7] confirmed the variations in performances of certain coating in different environments. Asphalt, certain type of adhesives and component binders fillers used in pipeline wrappers to prevent corrosion due to the activities of bacteria and fungi have been reported.[8]

This research paper reports on the corrosive resistance of two commonly used protective coatings (epoxy polyamide and polyvinyl polymer resins) on low carbon steel in Rivers and Bayelsa State of Niger Delta area of Nigeria, when exposed to varying environmental conditions such as pH, temperature and exposure for some time periods.

Methodology

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Material Preparation:

Sample sheets of low carbon steel, containing 0.1-0.2 percent carbon content and density of 7.83g/cm^3, where obtained from a chemical company in Port Harcourt. Each sample sheet (Coupon) was perforated with hole of the same diameter at the side to allow passage of a thread. Thirty pieces of coupons were prepared for the study. The coupon were scrubbed with sand paper to smoothen the surfaces and then sterilized by dipping in absolute ethanol and degreased by washing in acetone. The coupons were then dried in an oven at a temperature of 6000c for 15 minutes. They were then cooled overnight in a dessicor and wrapped with cellophane to prevent any oxidation before usage. The method used for coupon preparation were consistent with international paint protective manual.[9]

Methods of calculating Corrosion Penetration Rate: (CPR)

The prepared coupons were weighed before application of the Polymer coatings with a metller balance model AE 166, to the nearest 0.0001g.

Corrosion penetrating rate is a measure of corrosion reaction.[10],[11]

$$CPR = \frac{KW_1}{DAt} \ldots\ldots Equation\ 1.0$$

Where CPR is

The corrosion Penetrating Rate in milligram per year (MPY); K is a constant which depend on unit used. W$_1$, is weight loss after exposure of coupon to various conditions, at time period t, D and A are Density and exposed coupon area, in g/cm^3 and cm^2 respectively. The surface area used for each coupon is 48.0cm^3.

The parameters that were investigated are: P^H, temperature and exposure time.[12] It has been stated that parameters, such as temperature, pH and exposure time are good environmental indicators in the testing of coating resistance.

pH Analysis

To assess the effect of pH on the corrosion resistance of the selected coatings (epoxy polyamide and polyvinyl resins), the coated coupons were dried, weighed and immersed in identified air-tight plastic containers containing Sulphuric acid of pH 2,3,4,5 and 6 for a period of 12 weeks (2016 hours). At the end of the 2016 hours, the coupons were removed, washed with absolute ethanol, oven dried and weighed. Corrosion rate for each coupon were calculated using equation 1.0

Temperature Analysis

To assess the effect of temperature, the coated were dried, weighed and immersed in identified air-light stainless containers containing sea water of pH 8, previously collected from the salty sea water in Brass, near Brass oil sea terminal (facility of Nigeria Agip Oil Company). The immersed coupons where placed inside an autoclave oven for 2 weeks (336 hrs), at temperatures of 30^{0}c 40^{0}c, 50^{0}c, 60^{0}c and 70^{0}c. At the end of (336 hrs), the coupons were removed, washed in absolute ethanol, oven dried and weighed.

Corrosion rate for each coupon were calculated using equation1:0

Exposure Time Analysis

The effect of exposure time was assessed by immersing the coated coupons in air-light plastic containers containing seawater of pH 8. The test periods were 4 weeks (672 hrs), 6 weeks, (1008 hrs) 8 weeks (1344 hrs), 10 weeks (1680), and 12 weeks (2016 hrs) weeks. The experimental condition of pH 8, was maintained throughout the tests. At the end of the test, the coated coupons were washed in absolute ethanol, dried, weighed and the corrosion rates were calculated for the coupons using equation 1.0.

Results and Discussion

The calculated corrosion rates with pH, temperature and exposure periods (time) for the protective coatings (epoxy polyamide and polyvinyl resins) are persecuted in Tables 1.0-3.0.

The result also shows the effect of P^H, temperature and exposure time on the studied coatings performance.

Table 1.0: Effect of pH of corrodent (Sulpuric acid) on coatings performance

Type of Coating	Wo(g)	W_F (g)	W_i(g)	pH	Exposure Time Hrs	Corrosion Rate (MPY)
Epoxy Polyamide resin	19.850	19.701	0.49	2	2016	0.556
	19.857	19.712	0.145	3	2016	0.553
	19862	19.771	0.091	4	2016	0.379
	19.860	19.781	0.080	5	2016	0.354
	19.859	19.782	0.080	6	2016	0.322
Polyvinyl resin	19.843	19.763	0.080	2	2016	0.334
	19.844	19.766	0.078	3	2016	0.326
	19.795	19.721	0.074	4	2016	0.314
	19.842	19.773	0.069	5	2016	0.288
	19.846	19.783	0.063	6	2016	0.277

W_0 = original weight of coupon before coating: WF =final weight of coupon after coating were applied, W_1 = difference in WF of coupon after testing with the coatings in different pH conditions.

Table 2.0 Effect of Temperature on Coatings performance @ pH=8

Type of Coating	Wo(g)	W_F (g)	W1	T (^{o}C)	Exposure Time Hrs	Corrosion Rate (MPY)
Epoxy Polyamide resin	19.848	19.842	0.006	30	336	0.158
	19.847	19.832	0.014	40	336	0.288
	19.849	19.828	0.027	50	336	0.477

	19.845	19.814	0.031	60	336	0.655
	19846	19.810	0.035	70	336	0.810
Polyvinyl resin	19.848	19.844	0.004	30	336	0.122
	19.848	19.839	0.009	40	336	0.217
	19.846	19.831	0.015	50	336	0.411
	19.847	19.826	0.021	60	336	0.552
	19.845	19.818	0.027	70	336	0.651

W_0 = original weight of coupon before coating: WF =final weight of coupon after coating were applied, W_1 = difference in WF of coupon after testing with the coatings in different temperature conditions.

Table 3.0 Effective of Exposure time on coatings performance @ pH8

Type of coatings	Wo(g)	Wf	Wi	Exposure Time(hrs)	Corrosion Rate (mpr)
ExpoxyPolyanude resin	19.856	19.855	0.001	672	0.012
	19.868	19.857	0.011	1008	0.016
	19.856	19.854	0.002	1344	0.030
	19.856	19.849	0.007	1680	0.043
	19.854	19.844	0.010	2016	0.055
Polycinyl resin	19.856	19.856	0.000	672	0.002
	19.856	19.855	0.001	1008	0.009
	19.854	19.852	0.002	1344	0.020
	19.855	19.848	0.007	1680	0.034
	19.857	19.847	0.010	2016	0.044

W_0 = original weight of coupon before coating: WF =final weight of coupon after coating were applied, W_1 = difference in WF of coupon after testing with the coatings in different exposure time.

The results of the corrosion resistance of epoxy polyamide and polyvinyl resin as protective coatings were measured against sulphuric acid of varying pH values of 2,3,4,5 and 6 are presented in Table 1.0. The result from Table 1.0 reveals that corrosion rates tends to increase with increase in acidity for both coatings, which agrees with previous report for steel coupon,[13] as the pH increases, the corrosion rate increases.

The corrosion rates calculated for epoxy polyamide resin were 0.566, 0.553, 0.379, 0.354 and 0.322 mpy respectively. The calculated corrosion rates for polyvinyl resin at pH 2,3,4,5 and 6 were, 0.334, 0.326. 0.314, 0.288 and 0.277 mpy respectively. From the obtained results, the corrosion resistance of polyvinyl resin is higher than that of epoxy polyamide resins for all mentioned pH values. The higher performance of polyvinyl resin cloud be attributed to the polymerization of the compounds containing the vinyl group and the covalent bond binding the monomeric unit together is stronger than the hydrogen bonds found in the epoxy polyamide resin.[14]

The result of the corrosion performance of epoxy polyamide and polyvinyl resins as protective coatings measured against varying temperature of 30^{o}C, 40^{o}C, 50^{o}C, 60^{o}C and 70^{o}C at pH8 are presented in Table 2.0.

The calculated corrosion rate for epoxy polyamide resin at temperature of 30oC,40^{o}C,50^{o}C, 60^{o}C and 70^{o}C, were 0.158, 0.288, 0.477, 0.655 and 0.810 mpy respectively, while that for polyvinyl resin at temperature of 30^{o}C,40^{o}C,50^{o}C, 60^{o}C and 70^{o}C were 0.122, 0.217, 0.411, 0.552 and 0.651 mpy respectively. The results obtained indicates the general increase in temperature increases the corrosion rate (CR) for the two studied coatings (epoxy polyamide and polyvinyl resins).

This is in accordance with the general rule guiding the rate of chemical reaction, that chemical reaction increases with increasing temperature.[15] the results also shows that polyvinyl resin has better corrosion resistance than epoxy polyamides. The result of the corrosion resistance of epoxy polyamide and polyvinyl resins as protective coatings measured against exposure time in hours of 672, 1008, 1344, 1680 and 2016 is presented in Table 3.0.

The calculated corrosion rates in mpy of epoxy polyamide for exposure time in hours of 672, 1008, 1344, 1680 and 2016 were 0..12, 0.016, 0.030, 0.043 and 0.055 respectively while that for polyvinyl resin at exposure time in hours of 672, 1008, 1344, 1680 and 2016 were 0.002, 0.009, 0.020, 0.034, and 0.044 respectively. The corrosion rate studied for the protective coatings is consistent with the findings that every material structure will deteriorate with time.[16] The rates of deterioration of polyvinyl resin is slower than epoxy polyamide resin and hence polyvinyl resin is a better protective coatings.

Conclusion

It can be concluded that corrosion resistance of the coatings studied depends on certain variables, such as pH, temperature and time of exposure. The results obtained in this study shows that the performance of polyvinyl resin coating is better than that of epoxy polyamide resin. It can therefore be concluded that in an environment where the studied parameters (that is pH, temperature and exposure time) are prevalent, the use of polyvinyl resin as protective coating for pipeline and other structures is strongly recommended.

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