PROTECTIVE EFFICIENCY OF EPOXY RESIN COATING ON MILD STEEL PLATE IN HCL, NAOH AND DISTILLED WATER MEDIA

[1]*Adetunji O. R., [2]Adegbesan O. O., and [3]Okediran I. K.

[1,2] Mechanical Engineering Department, College of Engineering, Federal University of Agriculture, Abeokuta, P.M.B.2240, Abeokuta, Nigeria

[3] Mechanical Engineering Department, Osun State University, Osogbo.

*Corresponding Author; adetunjiolayide@gmail.com

ABSTRACT

Mild steel is one of the major construction materials, which is extensively used in chemical and allied industries for the handling of acid, alkali and salt solutions. It is occasionally coated with epoxy resin to elongate its service life. This study therefore investigated the protective efficiency of epoxy resin coating on mild steel plate in 1M HCl, NaOH, and distilled H_2O media. Coated and uncoated mild steel plates were cut into corrosion coupons, weighed and immersed completely in the media for 5, 10, 15, 20, 25 and 30 days. Weight of each sample was taken after each test period. Weight losses were recorded and corrosion rates were calculated. Temperature and pH of the media were recorded. Protective efficiency of coated mild steel at each duration was also determined. Microstructural images of the corroded coated and uncoated mild steel immersed for 30 days were captured using optical microscope. The result shows that the epoxy resin coated mild steel plate offers better corrosion resistance in distilled H_2O and 1M HCl, but ineffective in 1M NaOH. Conclusively, epoxy resin coating on the mild steel plate improved its anti- corrosion performance in distilled water and hydrochloric acid media.

Keywords; *mild steel, epoxy resin, HCl, NaOH, H_2O, corrosion protection*

INTRODUCTION

Protection is offered by a coating system comprising a combination of a suitable epoxy resin paint, an intermediate coating to offer additional film thickness and protection, it forms a barrier on the surface and a finish that offer appropriate aesthetics and protection against uv rays, rain and other environmental conditions. Coatings are widely used in optical, microelectronic, packaging, biomedical and decorative applications (Adetunji and Aiyedun, 2012). The traditional choice of specific coatings on a cost/performance basis has to a large extent been altered because of safety and health standards, and air pollution. There has been extensive research and development in the area of coatings along certain lines such as water based, continuous solids and powder coatings. A wide variety of modified polymer coatings for specific properties have been reported in literature. Examples of such coatings include: acrylic coatings with copper nanofillers for harder coatings with a combination of high elastic modulus, scratch resistance and wear resistance, hyper branched nanocomposite coatings for scratch resistance, adhesion and flexibility, corrosion resistant polyaniline coatings, polystyrene modified with oligostyrenes coatings for adhesive and anti-corrosive properties, silica/fluoropolymer hydrophobic coatings for rust – resistance, coatings for anti-fog and self-cleaning applications, and self-healing coatings (Ganesh *et al.*, 2009).

Epoxy coatings hold prime position in the coating industry due to their overall good properties: chemical and corrosion resistance, good mechanical properties, excellent adhesion to a variety of substrates, and dielectric properties, high tensile, flexural and compressive strength and thermal stability (Hang *et al.*, 2010). Corrosion is in fact an electrochemical process where the electrical cell is composed of an anode (the corrosion site), an electrolyte (the corrosive medium), and a cathode (Vashi and Naik, 2010). Corrosion can be minimized by employing suitable strategies which in turn stifle, retard or completely stop the anodic or cathodic reaction or both. Among the several methods of corrosion control are cathodic protection, anodic protection coating, alloying, the use of chemical inhibitors and protective coating (Umoren, 2008).

Mild steel is one of the major construction materials, which is extensively used in chemical and allied industries for the handling of acid, alkali and salt solutions (Nurul and Kassim, 2013). For cleaning and descaling; acid solution is also widely used in industry (Witold *et al.,* 2010). Acid cleaning baths are employed to remove undesirable scale from the surface of the metals. Once the scale is removed, the acid is then free for further attack on the metal surface. The use of organic coating is one of the most practical methods for protection against corrosion, especially in acidic media (Touir *et al.*, 2008).Acid solutions, widely used in industrial acid cleaning, acid descaling, acid pickling, require the use of corrosion barrier in order to restrain their corrosion attack on metallic materials.

Corrosion naturally impacts our daily life through chemical reactions that occur between a metal or metal alloys and its environment because metal tends to return to their more stable, oxidized state. Corrosion occurs with both industrial, domestic environment and the corrosion of metal surface increases significantly as the structure ages (Adeloju, 1993). Corrosion should be prevented by the safest and lowest cost method during the earliest stage of corrosion through the use of epoxy resin based paints. Therefore, this research work focused on evaluation of the protective efficiency of epoxy resin coating on mild steel plate in HCl, NaOH and distilled water.

MATERIALS AND METHODS

The materials employed in the research included Samples of Mild Steel Plate (epoxy coated and uncoated plate): Plastic Containers: it contains the coupons and the test solution of HCl, NaOH and H_20.Methylated Spirit: after the removal of the coupon from the solution, it was employed to clean the metal in other to loosen corrosion products. pH Meter (Jenway 3015): it was used to measure the PH value of the test solution prior to, and after each test period had elapsed. Analytical Weighing Balance (Mettler PA214) was employed for measuring the mass of each coupon before immersion and after every test period had elapsed, so as to determine the weight loss arising from the subsequent mass difference. Optical Microscope was employed to study the microstructures of selected samples of fresh and immersed (epoxy coated and uncoated) mild steel sheet respectively.

Methods

The method adopted was the coupon immersion corrosion test. The coupons in this study were made from mild steel plate (which are categorized into the epoxy coated and un-coated respectively). The test solutions were 1M HCl, 1M NaOH and distilled H_2O. Each of the test specimens (coupons) from 1 mm plate was marked with a unique identification code, dimensioned (25 mm × 25 mm), cleaned (using nonmetallic brush) to remove grease and oxidation films, rinse in distilled water (containing detergent) and dried. Two groups of coupons were formed, one group contained fifty four epoxy coated and the other contained uncoated mild steel plate respectively. The epoxy resin coated groups were coated using painting brush and red paint (gloss paint). The samples were then sun dried. The set ups were kept at room temperature undisturbed and were investigated at an interval of five days through 30 days. At every interval, the coupons, (3 epoxy coated and 3 uncoated specimen from each test solution) were removed and rinsed to remove residual test solution and loose corrosion products as the case may be, and then cleaned with spirit and dried. Each coupon was reweighed and the change in weight during immersion was used to determine the corrosion rate. In addition, the pH of each inspected solution was measured and recorded at the required interval. Analyzed comparison was also made from results obtained from the coupon immersion test experiments through calculations, tables, and graphs. Also, continued immersion of the coupons into the retardant solutions was used to monitor the extent of corrosion as a function of time.

Determination of Weight Loss and Corrosion Rate

The weight loss (W_L) is the intended difference in mass of a selected coupon between the final and initial stage of test while the rate of corrosion depicts the amount of corrosion occurring per unit time (for example, mass change per unit area per unit time, penetration per unit time).A simple test for measuring corrosion is the weight loss method. The method involves exposing a clean weighed piece of the metal to the corrosive environment for a specified time followed by cleaning to remove corrosion products and weighing the piece to determine the loss in weight. The rate of corrosion (R) that was used for this study is calculated using the equation;

$$R = \frac{KW}{\rho AT} \quad \textbf{(1)}$$

such that: **R**=corrosion rate (in mm/yr.), **K**= constant (87.6), **W**= weight loss (in mg) of the coupon in time. **t**= time of exposure (in hours), **A**= surface area of each exposed coupon (6.25 cm^2) and **ρ**= density of the coupon (7.85g/cm^3 for the mild steel).

Determination of Corrosion Coating Efficiency

The Protection efficiency of the epoxy resin coating on mild steel is computed by this formula as applied by Adetunji, *et al.*, 2015:

$$I_{eff} = \frac{R0 - R1}{R0} * 100 \quad \textbf{(2)}$$

where I_{eff} = Efficiency of the coating (%), R_0 = Corrosion rate of the mild steel without epoxy coating present, R_1 = Corrosion rate of the mild steel with epoxy coating present.

RESULTS AND DISCUSSION

The outcome of this study comprised values of the weight losses, corrosion rates, coating (epoxy resin) efficiency and resulting pH of solutions which are presented in this section. Tables 1 and Figures 1 and 2 contained data on the above parameters. Both Coated Mild Steel (CMS) and Uncoated Mild Steel (UCM) corrosion rates results are presented in both table and figures.

Table 1: Weight Loss, Corrosion Rate, and Protection Efficiency of Epoxy Resin Coating (in 1M HCl) Against Immersion Time

Immersion Time (Hrs)	Wt.UCS (mg)	Wt.CMS (mg)	CRC(mm/yr)	CRU(mm/yr)	Prot. Ef.(%)
120	222.533	54.733	3.31	0.814	75.4
240	204.2	87.2	1.52	0.649	57.3
360	219.367	141.233	1.09	0.700	35.6
480	419.4	176.633	1.56	0.657	57.9
600	299.567	185.067	0.89	0.551	38.2
720	287.867	191.633	0.71	0.475	33.4

Table 2: Weight Loss, Corrosion Rate, and Coating Efficiency of Epoxy Resin Coating (in 1M NAOH) Against Time

Imm. time(Hrs)	Wt.UCS (mg)	Wt.CMS (mg)	CRC(mm/yr)	CRU(mm/yr)	Prot. Ef.(%)
120	0.533	147.333	0.00794	2.19	-2.75×10^4
240	1.033	136.4	0.00769	1.01	-1.31×10^4
360	1.033	116.6	0.00512	0.578	-1.12×10^4
480	0.433	150.967	0.00161	0.562	-3.47×10^4
600	2.667	147.467	0.00794	0.439	-5.43×10^3
720	16.633	150.667	0.0412	0.374	-8.06×10^2

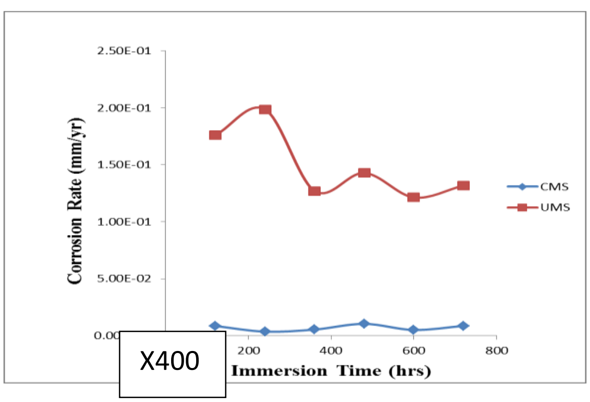

Figure 1: Corrosion rate of CMS and UMS in distilled water against Time

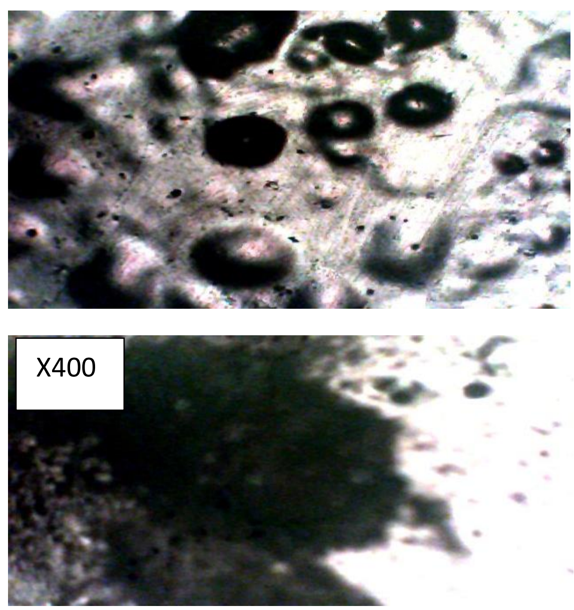

Fig.2a Photomicrographs of CMS (HCl) and UMS (HCl) @ 720H

Microstructures of Coated and Uncoated Mild Steel Samples

The microstructures contained in Figure 3 indicated the extent of corrosion of uncoated mild steel and the resistance of the coated mild steel samples. The dark patches on the photomicrographs of the uncoated mild steel are evidences of corrosion.

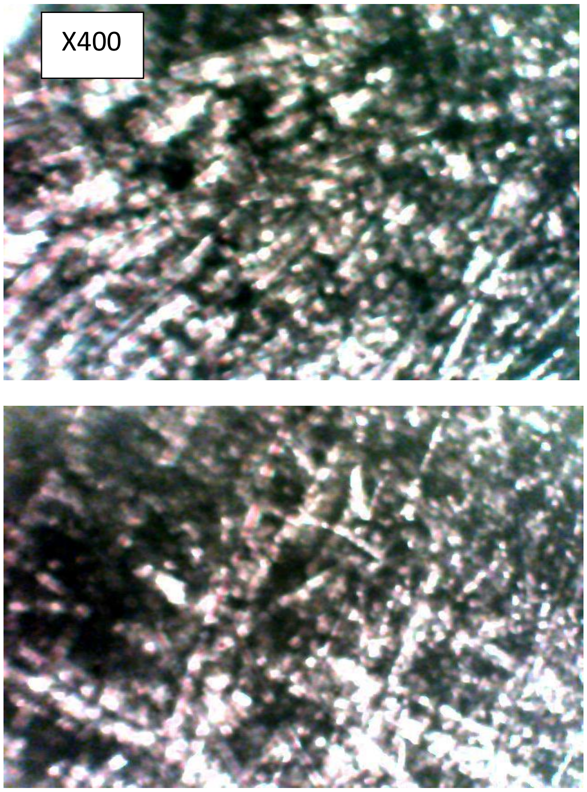

Fig.2b Photomicrographs of CMS(NaOH) and UMS (NaOH) @ 720H

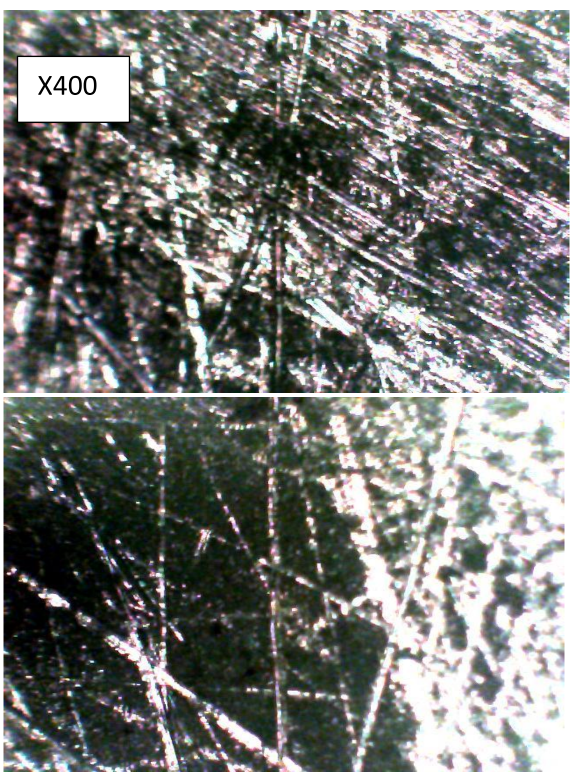

Fig.2c Photomicrographs of CMS (H_2O) and UMS (H_2O) @ 720H

Discussion

Inferences from the coupon immersed in media showed that the coupons produce visible appearance of rust at day 5. It was noticed that the coating on the coupon were totally removed leaving the coupon barely exposed in the solution and the colour of the solutions were changed to red. The NaOH solutions containing the UMS produce no visible form of rust there was a slight increase in the pH value of both NaOH solution. Inferences from the coupon set up for HCl showed that the coupons produce visible appearance of rust at day 5 (relatively minute), the HCl solution containing UMS was found to contain tiny pieces of scale formed in the solution whereas the CMS in HCl produce no visible form of rust there was also an increase in the pH of the HCl solution. Also inferences from the coupon set up for H_2O at day 5 shows that the coupon produces a slight form of rust in the solution containing UMS, the solution was a little bit milky whereas no visible form of rust was observed in the H_2O solution containing CMS.

The trend continued up to day 30 with an increase in the pH value of NaOH solution containing CMS coupon. The colour of the solution remains red. A significant value of weight loss was recorded whereas the NaOH solution containing the UMS coupon produces no visible form of corrosion but an increase in the pH value was recorded. At day 30, corrosion product (Fe^{3+}) on the UMS coupon in HCl solution has accelerated. The UMS coupon gave high cloudy/hazy appearance in HCl solution. There was also a decrease in the pH value of the UMS whereas no visible form of corrosion occurs in the solution containing CMS coupon but a slight increase in the pH value. At day 30, corrosion product (Fe^{3+}) on the UMS coupon in H_2O solution has accelerated. The UMS solution becomes milkier .there was an increase in the pH value towards basicity whereas the solution holding the CMS coupon produces no visible form of rust instead a slight decrease in pH value was recorded.

From the computed average pH index, the highest pH (pH = 14.21) level was found in the NaOH solution containing CMS, second to this was also found in the NaOH retardant solution(CMS), the least pH (pH=0.42) was found in the HCl solution containing CMS. It became evident that dissolved steel ions contributed to the increased alkalinity of the solutions. Comparing this experimental work and the researches of Samad *et al.*, 2014 and Rajasekharam, *et al.* 2013, there is an agreement that the corrosion rate of the three categories of CMS in the selected media decreases with an increase in immersion time which proves that the corrosion resistance of epoxy coated mild steel increases with the immersion time except in NaOH medium

CONCLUSION

The summary of results of study carried out to determine the coating efficiency of epoxy resin coating on mild steel plate showed the followings;

The epoxy resin coating on the mild steel plate was able to protect it up to an average rate of 95.3% in distilled water compared to the 49.6% in the 1M HCl solution and ineffective in the NaOH solution. In the selected media, the uncoated mild steel plate yielded to a higher corrosion rate than the epoxy coated mild steel plate. The margin being more in the 1M HCl solution compared to the distilled water. Overview of pH gave the highest value in NAOH showing the contribution of rapid dissolution rate of mild steel in solution alkalinity. The action of epoxy resin coating on the mild steel sheet had offered it a level of protection which if applied in practice, could be likened to have provided an increased service life.

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