The Corrosion Prevention through Plastic Coating on Steels

Amulya Kumar Sahoo[1] Protyush Kumar Mohanta[2] Soumya Kanta Sahu[3]
[1]Department of Metallurgical and Materials Engineering [2,3]Department of Mechanical Engineering
[1]IGIT Sarang, Dhenkanal, Odisha, India [2]National Institute of Technology, Durgapur, West Bengal, India [3]Adarsha College of Engineering, Angul, Odisha, India

Abstract— Corrosion of pipelines coatings is one of the main problems in oil and gas industries for which a large amount of money is spent each year. Coating is the first defense line in front of a corrosive environment in which pipes have been buried. Good function of a coating depends on its adhesiveness rate to the metal surface. Initial adhesiveness and its durability in the contact conditions are same among those factors that enhance coating efficiency in a long term. The rate of initial adhesiveness has a high relationship with coating movement and surface wetness by this movement in the course of applying the coating and also with the cleanliness and preparedness of pipe surface. The durability and permanence of adhesiveness depends on coating properties including its resistance in front of moisture penetration. Applying coating on the pipelines has high cost so for this reason the selection and application of coating of high importance. Also for underground buried pipe it is not possible to change their coating in short duration unlike other structures. Therefore the coating must ben durable for 20 years. This process to investigate the reason for corrosion in steel pipes with three polythene layers.

Keywords: Beaker, Nacl Salt, Mild Steel, Polythene, Tapes, Epoxy Resin, Hardener, Salt

I. INTRODUCTION

Corrosion is the destructive attack of a material by reaction with its environmental [1] and a natural potential hazard associated with oil and gas production and transportation facilities [2].Almost any aqueous environment can promote corrosion which occurs under numerous complex condition in oil and gas production, processing and pipeline systems [3].This process is composed of three elements an anode, and cathode, and an electrolyte. The anode is the site of the corroding metal, the electrolyte is the corrosive medium that enables the transfer of electron from the anode to the cathode, and the cathode forms the electrical conductor in the cell that is not consumed in the corrosion process [4].Crude oil and natural gas can carry various high-impurity products which are inherently corrosive. In the case of oil and gas wells and pipelines, such highly corrosive media and carbon dioxide (co2), hydrogen sulfide (H2S) free water [5].Continual extraction of Co2, H2S, and free water through oil and gas components can over time make the internal surfaces of these components to suffer from corrosion effects. The line and the component fittings of the lines would undergo material degradations with the varying condition of the well due to changes in the fluid composition, souring of wells over the period, and changes operating conditions of thepressure and temperatures. This material degradation results in the loss of mechanical properties like strength ductility impact strength and so on. This leads to loss of materials, reduction in thickness and at times ultimate failure. A point will be reached where the component may completely brake down and assembly will need to be replaced while production is stopped, the serious consequences of the corrosion process have become a problem of world wide.

This anodic reaction for iron and steel is

$$Fe \rightarrow Fe^{2+} + 2e^{-}$$

After the metal atoms at the anode side release electrons there are four common cathode reactions

$$O_2 + 4H^{+} + 4e^{-} \rightarrow 2H_2O \quad 0.5O_2 + H_2O + 2e^{-} \rightarrow 2OH^{-}$$

$$2H^{+} + 2e^{-} \rightarrow H_2$$

$$2H_2O + 2e^{-} \rightarrow H_2 + 2OH^{-}$$

In the oil and gas industry, carbon dioxide(CO_2) hydrogen sulfide are commonly present and water is there catalyst for corrosion.

II. EXPERIMENTAL ANALYSIS

A. Material selection

BIS 1239 Mild Steel Pipe of diameter 4.4 cm is used as the base metal for this purpose of specific composition.Then it was cut into the length of 3 cm.

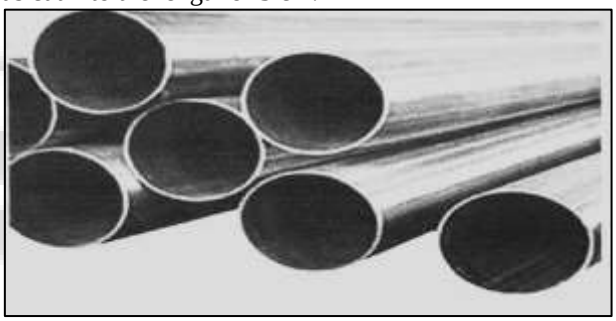


Fig.7 Mild Steel Pipe

Element	Total Iron	C	Mn	P	S
% Composition by Weight	98	0.20	1.30	0.040	0.040

Table 1: Compositions of mild steel

B. For Coatings

1) The first layer is composed of liquid or gum of epoxy resin and hardener.

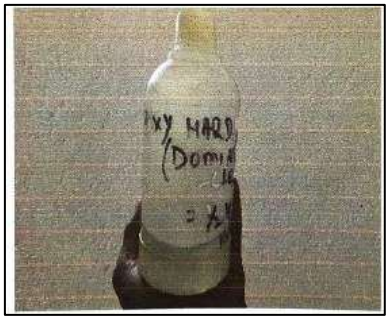


Fig. 8: Epoxy Resin

Epoxy Resins have following properties such as

a) Excellent chemical resistance, particularly to alkaline environments.
b) Outstanding adhesion to a variety of substrates.
c) Very high tensile, compressive and flexural strengths
d) Low shrinkage cure.
e) Excellent electrical insulation properties and retention thereof on aging or exposure to difficult environments.
f) A high degree of Resistance to corrosion.
g) A high Degree of resistance to physical abuse.
h) Ability to cure over a wide range of temperatures
i) Superior fatigue strength

a) Hardener –

The Chemical Substance added to something I order to harden it. It is used especially with paints, resins and varnishes. In some mixtures a hardener is used simply top increase the resilience of the mixture once its sets. In other mixtures a hardener is used as a curing component. A hardener can be either a reactant or a catalyst in a chemical reaction that occurs during the mixing process.

2) Second layer consist of Glue (attached to the tape).

3) Third layer consist of Ultra high Molecular weight Polyethylene (UHMW) Tape.

UHMW Polyethylene is a subset of thermoplastic Polyethylene also known as high modulus Polyethylene. It is a very tough material with the highest impact strength of any thermoplastic presently made. It is an Odourless, tasteless and non-toxic. It is resistance to concentrated Acids and alkalies as well as numerous organic solvents.

It is highly resistance to corrosive chemicals. It has extremely low moisture absorption and a very low coefficient of friction and is highly resistant to abrasion being 15 times more resistant to abrasion than carbon steel.

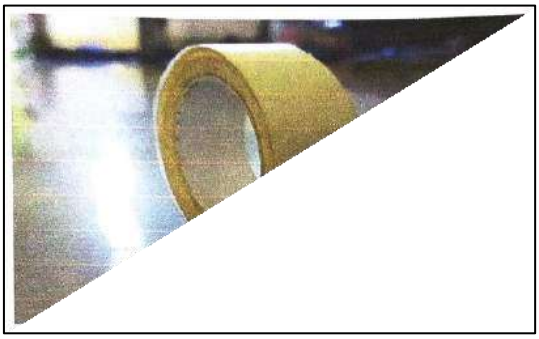


Fig. 3: Ultra-high Molecular weight polyethylene tape

C. For Corrosion testing different Salts such as NaNO3, NaCl, Na2SO4 and various chemical reagents such as HCl, NaOH are also used.

Fig. 6: NaCl Salt

Different Apparatus are also used such as pH meter, 250 ml beakers, measuring cylinder, weighing machine and metal cutting machine.

III. METHODOLOGY

A. Experimental Procedure

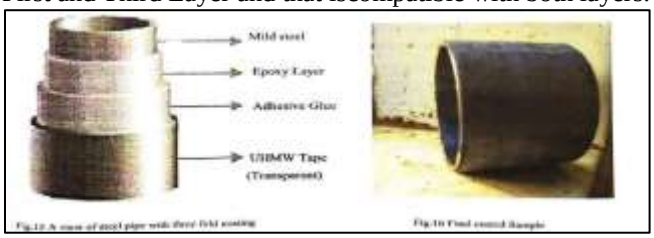
A Mild Steel pipe is taken in which 3 layers of coatings are done

1) First layer

After the pipe surface have been roughly polished, the mild steel pipe is then dipped into the mixture of epoxy resin and hardener, mixed at a ratio of 2:1 and held for some time and after that the material is allowed to dry in room temperature.

2) Second layer

Second layer is the Glue that creates adhesiveness between First and Third Layer and that iscompatible with both layers.



3) Third layer

Ultra-High Molecular Weight Polyethylene (QHMW) Tape coating is used for final coating of the mild steel.

B. Characterization

1) Analysis for Corrosion Testing

Corrosion tests were performed in an open circuit, exposing metal to different aggressive and corrosive conditions (immersion method). Since corrosion is basically an electrochemical process, it can be monitored using electrochemical techniques, too. The immersion test is used extensively to generate uniform corrosion data for alloys used in the process industries under immersion conditions. In this

method, small sections of the candidate material are exposed to the test medium in a 250ml] beaker and the loss of weight of the material is measured for a period of time. The following equation was used for evaluating the corrosion resistance behavior using the immersion method [2-32]

Corrosion Penetration Rate (CPR) = (K x W)/ (A x T x D) (3.1)

Where K is conversion constant (2.40 X 10°), W is the weight loss (g) or weight difference before and after corrosion, T is the time (hour), A is the Area of the Material, and D is density of the metal (g/cm). The corrosion rate is then reported as milligrams per square decimetre per day (MDD).

And following tests were done to understand the corrosion rate on mild steel

1) Effect of different concentration of NaCl : In order to find out the effect of salt concentration on corrosion rates, the coated mild steel pipes are exposed to NaCl solutions with different concentrations (0.5 M, 1.0 M, 1.5 M).Exposure time was 72 hrs at room temperature.
2) Effect of different Corrosive Salts: In this part of our experiment, polyethylene coated mild steel pipes were exposed to corrosive solutions containing constant concentrations (1.0 M) of different salts such as NaCl, NaNO3, Na2SO4, under the same room temperature conditions. Exposure time was 72 hrs at room temperature.
3) Effect of pH : For Performing this experiment, polyethylene plated mild steel pipes were exposed to a Na Solution (1.0 M) for 72 hrs at different pH values, The pH of the solution was adjusted using dilute HCI and NaOH solutions.

2) Effect of Polyethylene thickness on corrosion rates

For performing this experiment, different thicknesses of polyethylene coating were deposited on the steel pipe by controlling the volume of the solutions taken. The coated steel was then exposed to test solutions (1.0 M NaCl) for 72 hrs.

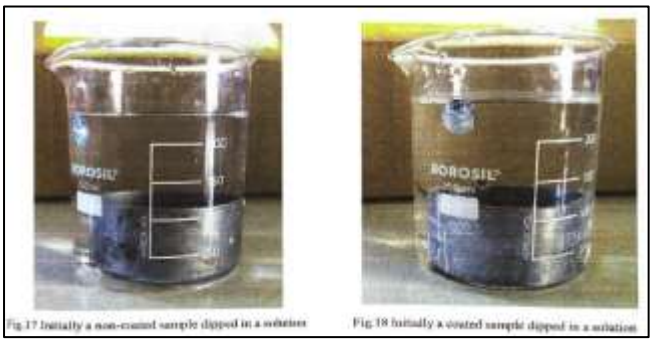


Fig.17 Initially a non-coated sample dipped in a solution Fig.18 Initially a coated sample dipped in a solution

IV. RESULTS AND DISCUSSION

Effect of different concentration of NaCl By performing this experiment, we find that

Diff. conc./wt. of the sample	0.5 M	1.0 M	1.5 M
Initial Weight (gm)	69.6175	69.6175	69.6175
Final Weight (gm)	69.5138	69.5123	69.5129
CPR (MDD)	6.9076	7.0076	6.9676

Table 2: Effect of CPR on different concentration of NaCl for non-coated samples

Diff. conc./wt. of the sample	0.5 M	1.0 M	1.5 M
Initial Weight (gm)	70.7535	70.7985	70.8065
Final Weight (gm)	70.7416	70.7835	70.7935
CPR (MDD)	0.7799	0.9831	0.8520

Table 3: Effect of CPR on different concentration of NaCl for coated samples

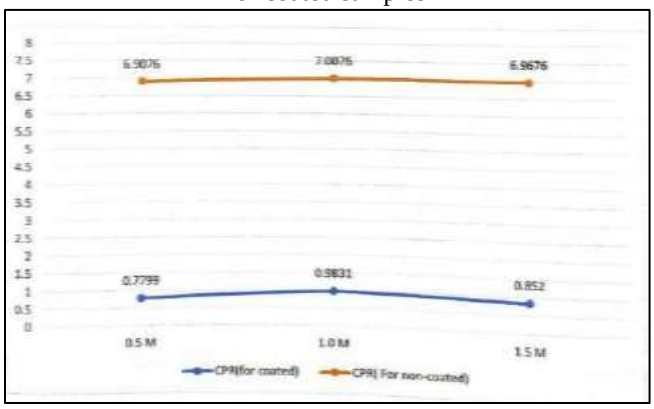


Fig. 19: Variation of CPR with different concentration of NaCl

According to our results show that with increasing concentrations of NaCl, corrosion rates in the case of polyethylene-coated plates decrease. According to the results (Table 2 & 3, Fig 19), the highest corrosion is observed in NaCl 1 Mfor both coated and bare steel samples. In general, the environment has a significant effect on corrosion rates. The important environmental factors are the oxygen concentration in the solution or atmosphere, the pH of the electrolyte,and the temperature, concentration, and nature of various salts in solution in contact with the metal. Chloride is an aggressive anion that normally accelerates corrosion of the metals. The usual role of chloride ions in the accelerationof corrosion rates are their property of dispersing protective film, formation of stable and soluble surface complexes with iron, and catalytic, adsorptive, and field effects. Thus there is a decrease in corrosion after 1.0 M NaCl for both coated and bare steel samples.

A. Effect of different Corrosive Salts: By performing this experiment, we find that

Diff. salts/ wt. of the sample	NaCl	$NaNO_3$	Na_2SO_4
Initial Weight (gm)	69.6175	69.6175	69.6175
Final Weight (gm)	69.5138	69.5123	69.5129
CPR (MDD)	6.9076	7.0076	6.9676

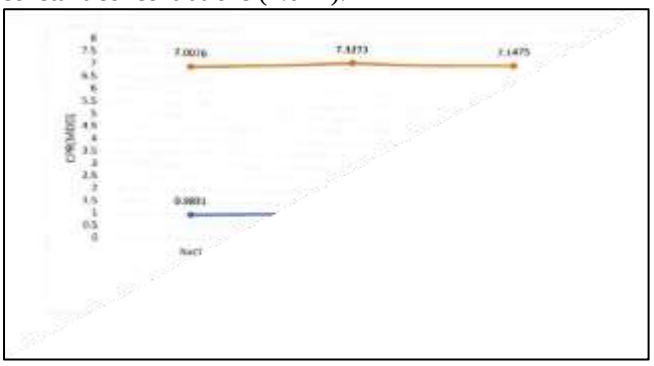
Table 4: Effect of CPR on different corrosive salts for non-coated samples

Diff. salts/ wt. of the sample	NaCl	$NaNO_3$	Na_2SO_4
Initial Weight (gm)	70.7985	70.8798	70.8245
Final Weight (gm)	70.7835	70.8626	70.8085
CPR (MDD)	0.9831	1.1273	1.0486

Table 5: Effect of CPR on different corrosive salts for coated samples

According to our results show that, corrosion rates is highest in case of NaNO; for both polyethylene-Coated as well as bare steel. Followed by Na2SO4 and NaCl according to the results (Table 4 & 5 Graph 2). In general, the environment has a significant effect on corrosion rates. The important environmental factors are the oxygen concentration in the solution or atmosphere, the pH of the electrolyte, and the temperature.

Concentration, and nature of various salts in solution in contact with the metal, It has been found that the order of corrosion ability is NaNO3>Na2SO«>NaCl containing constant concentrations (1.0 M).



B. Effect of pH

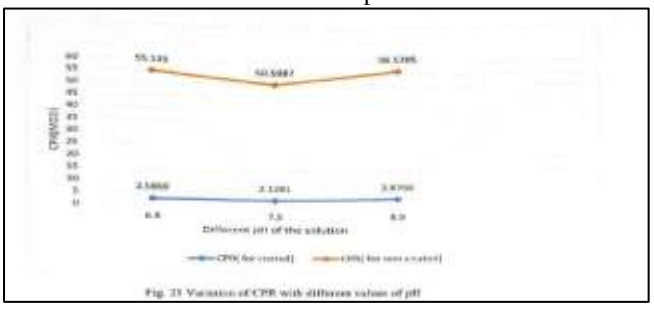
By performing this experiment, we find that

pH of sol./ wt. of the sample	6.8	7.5	8.9
Initial Weight (gm)	69.6175	69.6175	69.6173
Final Weight (gm)	68.7898	68.8579	68.7690
CPR (MDD)	55.1350	50.5987	56.5205

Table. 6: Effect of CPR on different pH of the solution for non-coated samples

pH of sol./ wt. of the sample	6.8	7.5	8.9
Initial Weight (gm)	70.8945	70.8345	70.7646
Final Weight (gm)	70.8550	70.8020	70.7507
CPR (MDD)	2.5869	2.1281	2.8766

Table 7: Effect of CPR on different pH of the solution for coated samples

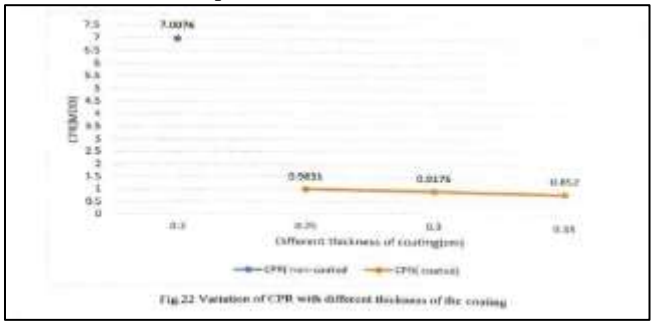


According to our results show that, corrosion rates is highest in case of the solutions having pH 8.9, then decreases with pH 7.5 then increases with pH 6.8 according to the results (Table 6 & 7,Graph 3). In general, the environment has a significant effect on corrosion rates. The important environmental factors are the oxygen concentration in the solution or atmosphere, the pH of the electrolyte, and the temperature, concentration. It is found that the polyethylene-coated steel pipes showed high resistance against the corrosion of bare steel samples in both acidic and basic conditions. Corrosion of bare iron is promoted in both acidic and alkaline conditions, especially in the presence of complexing and oxidizing agents.

C. Effect of Polyethylene thickness on Corrosion Rates

By performing this experiment, we find that

Table.8. Effect of CPR on polyethylene thickness for coated and non-coated samples.



As our data in the (Table 8, Graph 4) clearly shows, to have protection against corrosion, the thickness of the plastic film on the metal surface (mild steel) should be at least 0.25 cm. It was also observed that with increase in the thickness of the coating the corrosion rates decreases.

V. CONCLUSION

Good function of coating depends to a high extent to its adhesiveness rate to metal surface. Initial adhesiveness and its durability in contact condition are of those factors that result in high efficiency of coating in long term. The extent of initial adhesiveness has a very high relationship with coating flow and its wetting when applying coating and also with cleanliness of surface and its readiness. Durability of adhesive depends on coating properties such as its resistance against moisture penetration. It was found that the 3-layer plastic coatings can provide considerable protection, as well as a physical barrier against corrosive environments (e.g., NaCl, HCl, NaOH, Na2SO4, NaNO2) in which the mild steels are exposed. The corrosion rate for the polyethylene coated steel was significantly lower than the bare steel (approx... 10-15 times). Metal passivation (formation of a thin, compact, adherent, and passive layer of Fe2O3 at the interface) may be due to the redox catalytic effect. Ultra-high Molecular weight Polyethylene (UHMWP) and epoxy resin have emerged as one of the most promising candidates for corrosion control applications providing superior corrosion resistance, cheaper protection, and environmentally friendly properties than the present techniques for steel corrosion prevention. Epoxy layer has a very good adhesiveness due to its transverse bonds and has a very high resistance against corrosion and oxygen penetration. But it is vulnerable to the

mechanical hit when storing and line performance. Polyethylene layer is a very good protection to prevent physical damages.

REFERENCES

[1] Roberge PR (2000) Handbook of corrosion engineering. McGraw-Hill, New York
[2] Kermani MB, Smith LM (1997) CO2 corrosion control in oil and gasn production: design considerations. The Institute of Materials, European Federation of Corrosion Publications, London.
[3] Champion Technologies (2012) Corrosion mitigation for complex environments. Champion Technologies, Houston
[4] Corbin D, Willson E (2007) new technology for real-time corrosion detection. Tri-service corrosion conference, USA
[5] Lusk D, Gupta M, Boinapally K, Cao Y (2008) Armoured against corrosion. Hydrocarb Eng 13:115-118
[6] Oyelami BO, Asere AA (2011) Mathematical modelling: An application to corrosion in a petroleum industry. NMC Proceedings Workshop on Environment. National Mathematical Centre, Abuja, Nigeria.
[7] Miller D (1990) Corrosion control on aging aircraft: what is being done.Mater Perform 29:10—11
[8] Hoffman C (1997) 20,000-Hour tuneup. Air and Space 12:39-45
[9] Up Front (1992) The Cost of corrosion in the EEC. Materials performance 31:3
[10] Trethewey KR, Roberge PR (1995) Corrosion management in the twenty-first century. British Corro J 30:192- 197
[11] Uhlig HH (1949) the cost of corrosion in the United States. Chem and Engng News 27:2764
[12] Simons MR (2008), Report of offshore technology conference (OTC) presentation, NACE International oil and gas production
[13] Nimmo B, Hinds G (2003) Beginner's guide to corrosion. NPL, Teddington
[14] Dean F, Powell S (2006) Hydrogen flux and high temperature acid corrosion, 06436th edition. NACExpo 2006 conference
[15] Chilingar GV, Beeson CM (1969) Surface operations in petroleum production. American Elsevier, New York, p 397.
[16] F, Bourg6s-Fricoteoux-GREPAC-ESIEC* O, Savadogo--Ecole Polytechnique de Montral Development of a Recycled Polymer Coating for Steel Corrosion Protection: An Adhesion Study by in Vol. 70, No. 884, September 1998.
[17] Lorand Romanszkia*, Iaryna Datsenkob, Zoltan Mayc, Judit Telegdia, d, Lajos Nyikosa-Polystyrene films as barrier layers for corrosion protection of Copper and copper alloys Wolfgang Sand in Bioelectrochemistry 97 (2014) 7-14.
[18] kishikawa, Takayuki Kamimura, Yoshitaka Soga in The Sumitamo Development of Polypropylene coated steel Pipe for high temperature service by Hirofumi search No.58 Sept.1996.
[19] Rafael Marinho Bandeira, Julia van Drunen, Germano Tremiliosi-Filho, Jose Ribeiro dos Santos Junior, Jose Milton elias de Matos -Polyaniline/Polyvinyl chloride blended coatings for the corrosion protection of carbon steel in progress in organic coatings 106(2017) 50-59.
[20] Application of polyaniline/ylon composites coating for corrosion protection of steel by R. Ansari, Amir H. Alikhani in J. Coat. Technol. Res., 6 (2) 221-227, 2009.

