Journal of Chemical Health Risks

sanad.iau.ir/journal/jchr

ORIGINAL ARTICLE

Effect of Coating on the Corrosion of Carbon Steel in Variable Mediums by Using Coating Multi Walled Carbon Nanotube and Antibacterial Activity

Suadad Noori Ghani

Department of Mechanical Engineering, Faculty of Engineering, University of kufa, Kufa, Iraq

(Received: 10 March 2024 Accepted: 16 November 2024)

KEYWORDS

Metal Steel;

Corrosion rates;

Sulfuric acid;

Acetic acid;

Multi Walled Carbon Nanotubes Material;

Painter coating;

Sea water

ABSTRACT: The corrosion rates of carbon steel in three variable solution mediums (sulfuric acid, acetic acid, and seawater) are estimated by using six samples of mild steel with and without coating after periods (10, 20 and 30 days). The type of coating used is multi-carbon nanotube material with a thickness of 300 nm. In general, for two cases with and without coating the carbon steel, the values of the corrosion rates of the carbon steel in all three mediums decrease with immersion time. Also, it was concluded that the magnitudes of the corrosion rates in sulfuric medium are greater than those of other mediums (acetic acid and seawater). A low value of the corrosion rates of the seawater medium can be selected; this is due to the fact that the ability of acids to corrode metal is greater than that of salt. The effect of metal coating on the corrosion rates is low when the metal samples are submerged in sulfuric acid medium, but a high decrease in corrosion rates due to the metal coating can be noted when the metal samples are immersed in acetic acid medium. Compared to carbon Steel, the carbon steel coated with a multiwalled carbon composite exhibited enhanced antibacterial activity, with a zone of inhibition of 14 mm against Escherichia coli. The carbon steel coated with a multiwalled carbon composite showed good corrosion resistance. The corrosion resistance of the resultant coating was studied by electrochemical analysis.

INTRODUCTION

Structure and composition of corrosion scales, which largely determine the variation of water quality in during water delivery, vary significantly with pipe materials, water qualities and hydraulic conditions; thus, the use of safe metal alloys has a great importance also in health aspects [1-5].

Corrosion is the deterioration of the properties of materials due to interactions with their environments, and corrosion of many materials such as mild steel is inevitable [6]. Most metals, such as steel widely used in various industries (vehicles, pipes, aircraft and other equipment parts) are subject to corrosion due to external conditions and this lead to economic losses, so materials are used to paint these metals that reduce corrosion with time and thus increase the durability of these industries [7]. Also, most metals are exposed to acid attack on a large scale in various factories, such as pickling industries and cleaning. Several methods are used to protect these metals from corrosion and decomposition [8]. In the present study, the carbon steel is coating by painter to prevent or reduce the corrosion rates of these metals. Singh et al. studied the reducing of the corrosion of carbon steel in hydrochloric solution by using some plant extracts. It was founded that the plant extracts have been

*Corresponding author: suadadnoorig@gmail.com (S. Noori Ghani)

DOI: 10.60829/1104896

shown to be highly efficient in preventing corrosion of carbon steel [9].

The effect of coating protection on the corrosion rate of the steel pipeline in saline medium by using cathodic was studied [10]. It was concluded a high resistance to corrosion of the steel pipeline by using cathodic protection, which is severely affected the protective properties of the coating. Song et al. investigated the effects of the soil media on the corrosion of carbon steel and iron. It was established that the iron has a higher resistance to chloride attacks in soil media than carbon steel [11].

Recently, Caldona et al. investigated the effect of acidic medium on the corrosion inhibition of mild steel in Hydrogen chloride solution (1 M) at 40 Co depending upon weight loss method [12]. It is concluded that the efficiency of inhibition to reduce the corrosion increased with increasing concentrations of inhibitor.

A review and analysis of the factors affecting on the rate of corrosion of metal steel in alkaline media, such as (inhibitor source, inhibition efficiency and mechanism of inhibition, was presented by Baitule et al. [13].

Al-Juboori and Alshamaileh studied the possibility of using nano materials as a coating to resist the corrosion in cylindrical pipes made from carbon steel. It was concluded that the nano material used reduced the corrosion of the carbon steel.

In this study, it was concluded that green technology it is one of the preferred methods to prevent or reduce the corrosion in an alkaline medium.

MATERIALS AND METHODS

Corrosion tests

Eighteen samples of carbon steel are used in this study with cylindrical shapes (Diameter of 2 cm and length 2 cm). The chemical composition of samples used are listed in Table 1. The table refer to the carbon steel is as a medium carbon steel. Nine samples are coated by painter and other samples remains as a natural.

The carbon steels are immersion into three different solution mediums (sulfuric acid, acetic acid, and seawater) for three various periods (10, 20 and 30 days). The properties of solution mediums are sulfuric acid, acetic acid, and seawater.

The type of coating used in a project on steel carbon is multi-carbon nanotubes with a thickness of 300 nm. Table 2 shows the properties of the multicarbon nanotubes. The components of multi-wall nanotube material are estimated by using energy dispersive x-ray spectroscopy (Table 3).

At the beginning of the experiment, we weighted the steel carbon, then immersed it in a box-class solution (sulfuric acid, acetic acid, and seawater). The samples remain for 10, 20 and 30 days, then they are taken out, cleaned, dried, and weighed again for the samples corresponding to the immersion times.

To measure the percentage of corrosion, the weight loss method is used to select the corrosion rates from equation (1).

$$CR = \frac{(\Delta W)}{(A * T)} \quad (1)$$

CR: Corrosion rate in (mg cm^{-2-1}. min).

W: Weight loss (mg)

A: Surface area of steel bar (cm^2)

T: Exposure time of corrosion (min)

Antibacterial assay

The antibacterial activity of carbon steel and the carbon steel coated by multiwalled carbon composite towards various pathogenic microorganisms was performed by well diffusion method. The strains of different Gram-positive and Gram-negative microorganisms, such as Bacillus subtilis, Staphylococcus aureus, Shigella flexneri and Escherichia coli were used to test the antibacterial activity of carbon steel and the carbon steel coated by multiwalled carbon composite at room temperature. The bacterial inhibition behavior of carbon steel and the carbon steel coated by multiwalled carbon composite for various microbial strains was determined. During this process, a sterile 6mm well was made on previously prepared and solidified agar plates inoculated with different microorganisms. The zone of inhibition of the carbon steel and the carbon steel coated by multiwalled carbon composite was measured through total diameter of inhibition zone (which appeared as a clear zone) formed around the paper disc. This experiment was repeated at least three time, and the results were expressed in average value along with the standard deviation.

RESULTS AND DISCUSSION

The variations in corrosion rate, CR of the carbon natural steel samples (without coating) with immersed times for three different solution mediums (sulfuric acid, acetic acid, and seawater) are shown in Figures 1–5. The Figure shows that the values of the corrosion rate due to sulfuric acid are greater than those of other mediums (acetic acid, and seawater). A minimum magnitude of the corrosion rate due to seawater can be selected. This is due to the fact that the ability of acids to corrode metal is greater than that of salt. The vertical distance between the three corrosion curves (sulfuric acid, acetic acid, and seawater) is approximately equal.The behavior of corrosion in natural steel samples is similar to that for the carbon coating steel samples, as seen in Figure 7, but the values of the corrosion rate due to acetic acid and seawater are approximately close to each other, and it equals to less than 0.7 mg cm2 min1 at any immersed time.

A maximum value of the corrosion rate due to sulfuric acid can be selected, and it equals to greater than 1.7 mg cm^{-2} min^{-1}. The two corrosion curves for acetic acid and seawater conditions have an approximately horizontal slope (flat curves), and the vertical distance between these two curves, and between the curves of sulfuric acid conditions is very high.

Figure 1 illustrates the effect of the coating of the carbon steel submerged into solution media of the sulfuric acid on the corrosion rate after a period of three different periods 10, 20 and 30 days. From this figure can be noted, the coating of the carbon steel leaded to reduce the values of the corrosion with a low rate. In other words, the values of the corrosion rate of natural and coating carbon steel samples are approximately close to each other.

The influence of the coating of the carbon steel submerged into solution media of the acetic acid on the corrosion rate after a period of three different periods 10, 20 and 30 days can be seen in Figure 2. The Figure shows the coating of the carbon steel is very effective in reducing the value of the corrosion. In other words, the vertical distance between these two corrosion curves is very high.

The comparison between the values of the corrosion rates of the natural and coating carbon samples in seawater is presented in Figure 3. It can be observed from this figure, the coating case leaded to reduce the corrosion with medium rate.

Comparisons between the corrosion rates of natural and coated carbon steel samples in acetic acid solution and Comparison between the corrosion rates of natural and coated carbon steel samples in seawater solution are shown in figures 4 and 5, respectively.

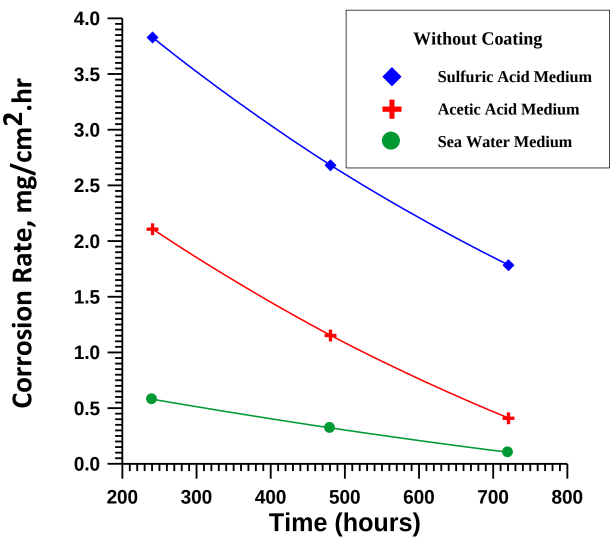

Figure 1. Relationship between corrosion rate and immersed time for natural carbon steel samples (accomplished during current work)

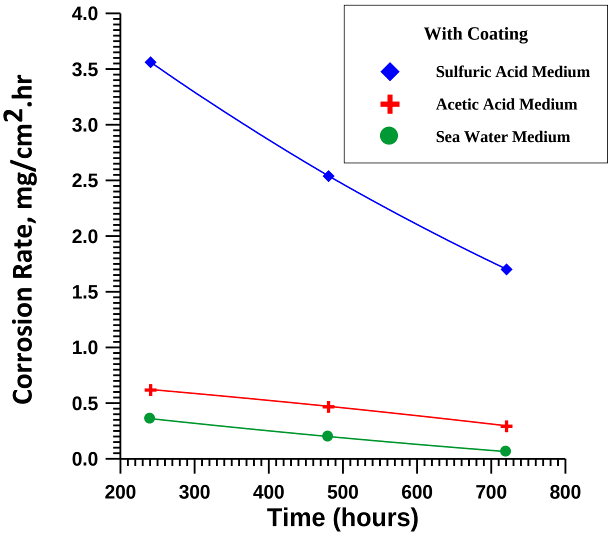

Figure 2. Relationship between corrosion rate and immersed time for coating carbon steel samples (accomplished during current work)

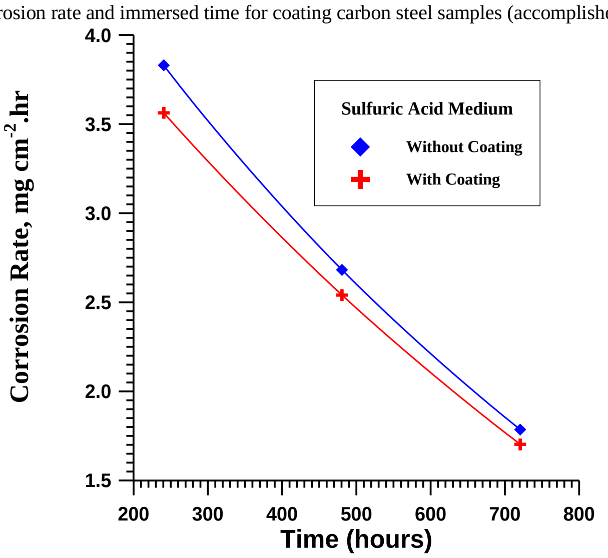

Figure 3. Comparison between the corrosion rate of natural and coating carbon steel sample in sulfuric acid solution (accomplished during current work)

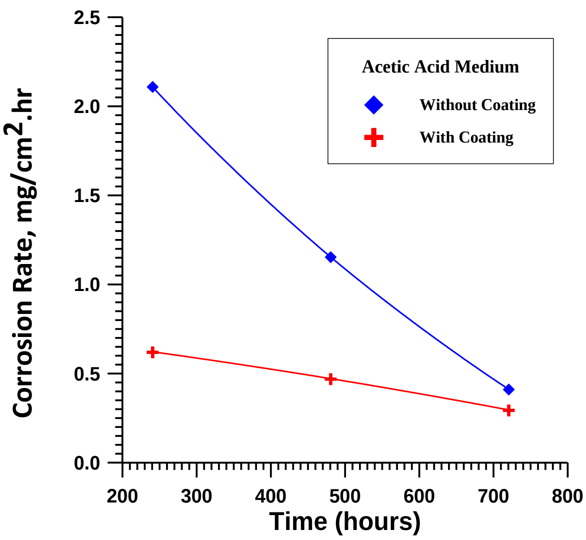

Figure 4 . Comparison between the corrosion rate of natural and coating carbon steel sample in acetic acid solution (accomplished during current work)

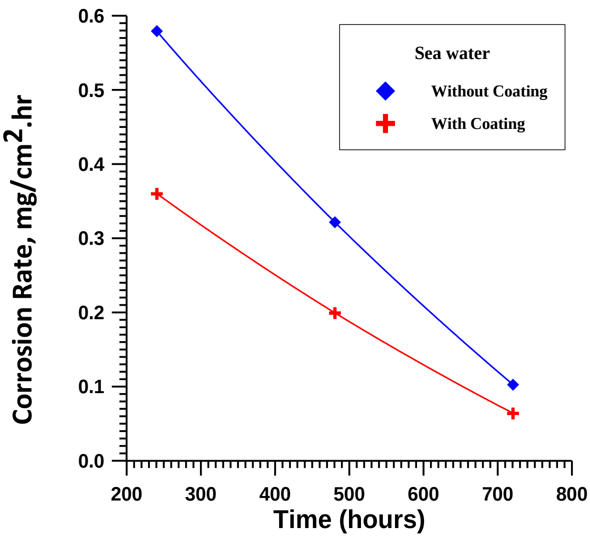

Figure 5. Comparison between the corrosion rate of natural and coating carbon steel sample in sea water solution. (accomplished during current work)

Table 1. Chemical composition of Sample Used (accomplished during current work)

Elements	Contents %
Mo	1.58
P	0.195
C	0.295
Ni	0.165
Fe	0.589
V	0.468
S	0.025
Mn	0.425
Cu	0.078
Cr	4.58

Table 2. Properties of the Multi Walled Carbon Nanotubes (accomplished during current work)

Elements	Values	Unites
Purity (carbon content)	>95 or > 97	%
Outside diameter	20-30	nm
Inside diameter	5-10	nm
Lenght	10-30	Um (TEM)
SSA	> 110	m2 g^{-1} (BET)
Color	black	-
Ash	< 1.5	%(TGA)
Electrical Conductivity	100	s cm^{-1}
Tap density	0.28	g cm^{-3}
True Density	2.1	g cm^{-3}

Table 3. Components of multi-wall nanotube material (accomplished during current work).

Component	Content %
C	97.46
Al	0.19
Cl	1.02
C_0	1.09
S	0.24

MWCNTs played a role in the strength of antimicrobial

Antibacterial activity of carbon steel and the carbon steel coated by multiwalled carbon composite Antibacterial activity of carbon steel and the carbon steel coated by multiwalled carbon composite were tested against the gram-positive and gram-negative microorganisms. The antibacterial results revealed that the carbon steel coated with multiwalled carbon composites exhibits the highest inhibitory effect against the various microorganisms compared to carbon Steel coating. The inhibition zone introduced by carbon steel and the carbon steel coated by multiwalled carbon composite against B. subtilis, S. aureus, S. flexneri and E. coli was higher in the case of gram-negative bacteria than gram-positive bacteria. Nathanael AJ et al. reported that HA did not affect the growth of the gram-positive and gram-negative microorganisms, comparatively [14]. The nanocomposite, the carbon steel coated with a multiwalled carbon composite, showed the highest activity against the various microorganisms compared to carbon Steel. The improvement of the bioactive properties of the carbon steel coated with multiwalled carbon composite may be due to the multiwalled carbon composite attachment effect and spreading effect of osteoblast cells. Moreover, the use of functionalized.

CONCLUSIONS

1. For two cases of carbon steel with and without coating of the carbon steel:

a. The values of the corrosion rates of the carbon steel in all three mediums (sulfuric acid, acetic acid, and seawater) decrease with immersion time.

b. The magnitudes of the corrosion rates in sulfuric medium are greater than those of other mediums (acetic acid and seawater).

c. A low value of the corrosion rates of the seawater medium can be selected.

2. In general, the using of Multi carbon nanotube material with a thickness of 300 nm as a coating for carbon steel is very effective in resisting corrosion with time.

3. The effect of metal coating with nano material on the corrosion rates is low when the metal samples are submerged in sulfuric acid medium.

4. A high decreasing in corrosion rates due to the metal coating can be noted when the metal samples are immersed in acetic acid medium.

5. The vertical distance between the three corrosion curves of the carbon natural steel samples (without coating) for (sulfuric acid, acetic acid, and seawater) is approximately equally.

6. For the coated carbon steel samples, the values of the corrosion rate due to acetic acid and seawater are approximately close to each other, and they equal less than 0.7 mg cm2 at any immersed time. A maximum value of the corrosion rate due to sulfuric acid can be selected, and it equals greater than 1.7 mg cm^{-2}. min^{-1}.

7. For the coating carbon steel samples, the two corrosion curves for acetic acid and seawater conditions have an approximately horizontal slope (flat curves), and the vertical distance between these two curves, and between the curve of sulfuric acid condition is very high.

8. The coating of carbon samples in seawater solution helped reduce the corrosion at a medium rate.

9. The effect of the carbon steel coated with multiwalled carbon composite coating on the antibacterial activity and corrosion resistance of 316L SS was investigated. A multiwalled carbon composite coating greatly enhanced the attachment and differentiation of cells.

ACKNOWLEDGEMENTS

The authors thank the Kufa University that that support

this study.

Conflict of interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

REFERENCES

1. Li M., Liu Z., Chen Y., Hai Y., 2016. Characteristics of iron corrosion scales and water quality variations in drinking water distribution systems of different pipe materials. Water Research. 106, 593-603.

2. Ibe K., Egereonu U., Sowa A., 2002. The impact of handpump corrosion on water quality in rural areas of west African sub-region. Environmental Monitoring and Assessment. 78, 31-43.

3. Dong B., Xu Y., Deng H., Luo F., Jiang S., 2013. Effects of pipeline corrosion on the injection water quality of low permeability in oilfield. Desalination. 326, 141-147.

4. Xu X., Liu S., Liu Y., Smith K., Wang X., Li J., Ma Z., Wang Z., Cui Y., 2020. Water quality induced corrosion of stainless steel valves during long-term service in a reverse osmosis system. Journal of Environmental Sciences. 89, 218-226.

5. Song X., Zhang G., Zhou Y., Li W., 2023. Behaviors and mechanisms of microbially-induced corrosion in metal-based water supply pipelines: a review. Science of the Total Environment. 165034.

6. Khadom A.A., Hassan A.F., Abod B.M., 2015. Evaluation of environmentally friendly inhibitor for galvanic corrosion of steel–copper couple in petroleum waste water. Process Safety and Environmental Protection. 98, 93-101.

7. Qian Y., Li Y., Jungwirth S., Seely N., Fang Y., Shi X., 2015. The application of anti-corrosion coating for preserving the value of equipment asset in chloride-laden environments: a review. International Journal of Electrochemical Science. 10(12), 10756-10780.

8. Firdhouse M.J., Nalini D., 2013. Corrosion Inhibition of Mild Steel in Acidic Media by 5′- Phenyl- 2′, 4′- dihydrospiro [indole- 3, 3′- pyrazol]- 2 (1H)- one. Journal of Chemistry. 2013(1), 835365.

9. Singh A., Ebenso E.E., Quraishi M., 2012. Corrosion inhibition of carbon steel in HCl solution by some plant extracts. International Journal of Corrosion. 2012(1), 897430.

10. Zedin N.K., 2015. Effect of Cathodic Protection on Coating Steel Pipeline in Saline Environment. Diyala Journal of Engineering Sciences. 88-99.

11. Song Y., Jiang G., Chen Y., Zhao P., Tian Y., 2017. Effects of chloride ions on corrosion of ductile iron and carbon steel in soil environments. Scientific Reports. 7(1), 6865.

12. Caldona E.B., Zhang M., Liang G., Hollis T.K., Webster C.E., Smith Jr D.W., Wipf D.O., 2021. Corrosion inhibition of mild steel in acidic medium by simple azole-based aromatic compounds. Journal of Electroanalytical Chemistry. 880, 114858.

13. Baitule P., Victoria S., Manivannan R., Review on assessment of corrosion of mild steel in alkaline environment by using plant extract. 2021.

14. Nathanael A., Mangalaraj D., Hong S., 2011, Biocompatibility and antimicrobial activity of hydroxyapatite/titania bio-nanocomposite, In 18th International Conference on Composite Materials (ICCM 2011) . 21-26.