Open Circuit Potential, Polarization and Thermometric Study of Guar Gum as Corrosion Inhibitor on Mild Steel by in Acidic Media

Rupesh Kushwah¹* and R. K. Pathak²

¹Department of Chemistry, Govt. S.S.A. P.G College, Sihora, Jabalpur, Madhya Pradesh, India.
²Department of Chemistry, Govt. M.L.B. P.G College, Indore, Madhya Pradesh, India.

Authors’ contributions

This work was carried out in collaboration between both authors. Author RK designed the study, performed the statistical analysis, wrote the protocol and managed the literature searches and wrote the first draft of the manuscript. Author RKP managed the analyses of the study. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJOCS/2020/v8i219040
Editor(s): (1) Dr. Srijita Basumallick, University of Calcutta, India.
Reviewers: (1) Idoko, Owoicho, Sheda Science and Technology Complex, Nigeria. (2) Lhaira Souza Barreto, Federal University of Pernambuco, Brazil.
Complete Peer review History: http://www.sdiarticle4.com/review-history/60297

ABSTRACT

The influence of guar gum as inhibitors for mild steel (MS) dissolved in 1.0 M H₂SO₄ had been investigated via various electrochemical tests at 298 K. Open circuit (OC), Tafel plots had been examined. At first OCP shift found to be more negative values which clarify that guar gum having high efficiency as corrosion inhibitors. The inhibition efficiency (IE%) can be improved with improvement of concentration of inhibitor reaching maximum efficiency up to 89.37% at 298 K. The Tafel plots had been illustrated that a maximum difference of $E_{corr}$ 68 mV, that shows that the guar gum worked as mixed type inhibitor. Thermometry investigation shows maximum IE is found to be 86.99.

Keywords: Guar gum; 1.0 M H₂SO₄; corrosion; mild steel; Tafel plots; thermometry.
1. INTRODUCTION

Mild steel (MS) has been utilized in industrial purpose, building and more in petroleum manufacturing, Army equipment, fertilizers and extra industries. So the mild steel protection in aqueous as well as in acidic solutions is worldwide requested, environmental, cost effective and aesthetical important [1]. The use of inhibitor has been very essential way to reduce the mild steel corrosion.

The organic compounds are commonly utilized as corrosion inhibitors as it includes heteroatom for example O and N atoms. But the organic compounds are hazards and unfriendly environment inhibitors [2]. So the search for alternative friendly environment inhibitors are more important. Mild steel is an iron alloy, which undertake dissolution smoothly in acid intermediate. Acid, intermediate is commonly applied in synthetically laboratories in addition to various industries like acid cleaning, acid descaling, acid pickling and oil wet cleaning, etc. In other hand CS has been utilized via dissimilar states in chemical and associated industries for acid treating, basic and salt solutions [3]. The organic inhibitors adsorb on metallic surface and then the lower rate of corrosion [4]. It has been noticed that adsorption be controlled largely on definite physicochemical attributes of the inhibitor groups, as electron density, function groups t donor to s, π-orbital manner and molecular electronic structure [5-10]. Generally, organic inhibitors having oxygen and/or nitrogen as conjugated double bonds and polar groups in their structures which have been noticed as good corrosion inhibitors for a lot of metallic elements and alloys in different media [11-27].

The organic inhibitors inhibiting job are commonly referred towards their contacts with metallic surfaces via their adsorption. The polarity of functional groups has been considered as the reaction center that settle down adsorption process. On the other hand, the inhibitor adsorption on a metal surface be controlled via scant reasons, for example the nature and surface charge of metal, adsorption manner, the chemical composition of inhibitors and electrolyte solution [28].

2. EXPERIMENTAL

2.1 Carbon Steel Sample

Tests were done on carbon steel of the composition having (wt. %): 0.09% C, 0.23% Mn, 0.07% Si, 0.016% S, 0.022% P and the rest iron. Samples of 1x1 cm² were used.

2.2 Chemicals

The solution of 1 M H₂SO₄ was prepared by 98% H₂SO₄. Stock solutions of guar gum were prepared in 0.5 M H₂SO₄ and the required concentrations were made by appropriate dilution.

2.2.1 Inhibitor

Guar gum were used as a inhibitor in various concentration.

2.3 Electrochemical Tests

Electrochemical experiment had been done by utilizing a three electrode cell (a) Working electrode, The electrode dimensions are 1x1 cm² and had been fixed from one side of a copper wire by a paste of acetone and AgNO₃ and swelled in epoxy resin,(b) Saturated calomel electrode (SCE) taken as reference electrode,(c) Graphite rod (1.0 cm²) used as auxiliary electrode. All electrochemical tests had been achieved in 1.0 M H₂SO₄ solution in the absence and presence of different concentrations of guar gum at 298 K under aerated and unstirred conditions.

For electrochemical test an assembly made by a power supply model number YX-1502 DD, calomal electrode having model number Korrsas calomal K13 and a multimeter UNI-T UT-33d.

2.3.1 Open circuit potential (OCP)

In this step in electrochemical experiment. Working electrode (sample) had been tested with time during the 15 minutes. This time required to achieve steady state and gain (OCP) value.

2.3.2 Polarization method

This method involve DC potentiodynamic polarization techniques that had been used to investigate current density of corrosion process under steady state conditions by applying the potential from-1300 to +1300 mV to plot the Tafel polarization curve and the resultant current had been plotted in logarithm scale vs. potential with respect to SCE, Extrapolating of two Tafel regions of plot gives (Ecorr) and (icorr) corrosion potential. By (icorr) we able to calculate the rate of corrosion.
The inundation potential (OCP at t=0) indicates the steady state potential of mild steel in aerated conditions. The variation in OCP can be calculated using the following equations:

\[ \text{CR} = \left[ 0.13 (i_{corr}) \text{ (Equivalent weight)} \right] / D \]  
(1)

where, \( D \) is the density in g/cm³.

\[ I\% = \theta \times 100 = \left[ 1 - \left( \frac{i_{corr}}{i_{corr}} \right) \right] \times 100 \]  
(2)

### 2.3.3 Thermometric method

Eddy and Ebenso [29] describe a temperature-based method for corrosion rate. By the increase in temperature per unit of time, the reaction number (RN) and inhibition efficiency were calculated using equations 4 and 5.

\[ \text{RN} \left( ^\circ\text{C/min} \right) = \frac{[T_f - T_i]}{T} \]  
(3)

\[ \% \text{IE} = \left[ \frac{(RN_{ab} - RN_{pr})}{RN_{ab}} \right] \times 100 \]  
(4)

Where,

- RNab is the reaction number in the absence of inhibitors.
- RNpr is the reaction number in the presence of inhibitors.

### 3. RESULTS AND DISCUSSION

#### 3.1 Electrochemical Tests

##### 3.1.1 Open circuit potential (OCP)

Fig. 1 shows evidence for the influence of various concentrations of guar gum as inhibitors on the variation of OCP of mild steel with time in aerated, non-stirred 1.0 M H₂SO₄ solution at 298 K. The steady-state value of OCP is much negative than the inundation potential (OCP at t=0), indicating that before the steady state the pre-inundation, air oxide local film formed has to break up [30]. The value of steady state potential (Ecorr) which achieved quickly (after about 15 min of inundation), is in contact to the bare metal free corrosion [31]. It has been noteworthy that (Ecorr) shifts to much negative value without the alteration general feature of E/t plot, while upon raising the concentration of guar gum as inhibitors.

Firstly, the OCP has been proceeding with lower negative potential values, then attend a maximum one. After assuring time relying on guar gum inhibitor concentrations, the value of potential decrease and obtain a reasonably constant value. The data obtained have been suggested that two counter-acting processes taken place, the first one being a formation of the sample electrode surface protective adsorbed layer, and as a result delayed-action corrosion process takes place moving the OCP to more noble data. Corrosion of metal has been occurring on the second one, that has been made value of potential back towards among these two counter-acting operations can possibly elucidate semblance of a peak in the OCP vs. time plot as shown in Fig. 1. The value of steady-state potential proceed towards more negative values with raising guar gum inhibitor concentrations. At first OCP shift to more negative values (as a result of corrosion inhibition process) accomplishing higher one [32,33]. These potential data clarify that guar gum having high efficiency as corrosion inhibitors.

![Fig. 1. Variation in open circuit potential (OCP) with time record for mild steel in 1.0 M H₂SO₄ in the absence and presence of various concentrations of guar gum inhibitors at 298 K](image-url)
3.1.2 Potentiodynamic polarization (PP)

The addition of guar gum in the solution taken for investigation makes a change in polarization curves at 298 K, that have been illustrated in Fig. 2. The value of corrosion current densities \( i_{corr} \) and the value of corrosion potentials \( E_{corr} \) has been obtained at the intersection point from the extrapolation of cathodic and anodic curves. Polarization curves tells that the addition of guar gum inhibitors to the solution used for test causes no change in the identity of polarization curves, but become more wider and extrapolated at a lower current density, indicating that the molecules of inhibitor interfere with reactive sites on working electrode surface. The polarisation parameters had been listed in Table 1 suggest that on increasing the inhibitor concentrations decrease in \( i_{corr} \) reported since the ability of molecules of inhibitor has been enhanced to block more and more reactive sites which is necessary for corrosion process. In genral, if the absolute difference in \( E_{corr} \) doesn’t exceed with ± 85 mV, the inhibitors have been categorized as a mixed type inhibitor as found in this research work. From the polarization data, a little change in \( E_{corr} \) values in the presence of inhibitors, with a maximum difference of 68 mV, relative to the obtained value of \( E_{corr} \) from free acid solution. The value of IE% has been obtained from polarization studies via the subsequent equation (5):

\[
\text{IE}\% = 1 - \left( \frac{i_{corr}^{0}}{i_{corr}} \right) \times 100
\]

3.2 Thermometric Analysis

In thermometric analysis we pour the sample in 1 M \( \text{H}_2\text{SO}_4 \). Temperature of system increases due to exothermic reaction between acid and metal surface we allow to stand system till it reaches steady state. Initial and final temperature of system noted carefully by digital thermometer.

Inhibitor efficiency obtained by thermometric analysis shows good agreement with potentiodynamic analysis shown in Table 2.

It is clear with above table that on increasing concentration of inhibitor value of reaction number decreases and value of inhibitor efficiency increases.

![Fig. 2. Potentiodynamic cathodic and anodic plots of mild steel in 1.0 M \( \text{H}_2\text{SO}_4 \) in the presence and absence of various concentrations of guar gum inhibitors at 298 K](image)

Table 1. Electrochemical parameters (\( i_{corr} \), \( E_{corr} \), surface coverage and IE%) associated with polarization tests of mild steel in 1.0 M \( \text{H}_2\text{SO}_4 \) solution in the absence and presence of different concentrations of guar gum at 298 K

| Concentration of inhibitor (ppm) | \(-E_{corr}\) mV | \( i_{corr} \times 10^4 \) mA/cm² | CR | \( \theta \) | %IE |
|---------------------------------|-----------------|---------------------------------|----|------|------|
| blank                           | 455             | 11.236                          | 10.32 | nil | nil |
| 200                             | 492             | 5.0312                          | 4.62 | 0.55 | 55.22 |
| 400                             | 513             | 2.956                           | 2.71 | 0.73 | 73.69 |
| 600                             | 519             | 1.563                           | 1.43 | 0.86 | 86.32 |
| 800                             | 523             | 1.194                           | 1.09 | 0.89 | 89.37 |
Table 2. Reaction number and inhibitor efficiency of corrosion system in 1 M H2SO4 in absence and presence of various concentration of inhibitor

| Concentration of inhibitor (ppm) | Reaction number | % IE |
|--------------------------------|----------------|------|
| blank                          | 0.062          | nil  |
| 200                            | 0.03           | 51.29|
| 400                            | 0.019          | 69.23|
| 600                            | 0.011          | 81.96|
| 800                            | 0.008          | 86.99|

4. CONCLUSION

Open circuit potential, Polarization and thermometry have been utilized in order to study the corrosion inhibition process of mild steel in 1.0 M H2SO4 via corrosion inhibitors "guar gum". The major conclusion is:

1. The corrosion process reduces strongly with guar gum and inhibitor efficiency raised with rising concentrations of guar gum.
2. The value of open circuit potential has been reported more positive with raising inhibitor concentrations.
3. The corrosion current reduces on raising concentrations of guar gum.
4. The inhibition efficiency data resulted from the polarization and thermometry methods are compatible with each other.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Marko Chigondo, Fidelis Chigondo. Recent natural corrosion inhibitors for mild steel: An overview. Journal of Chemistry; 2016.
2. Hazazi OA, Fawzy A, Awad M. Int synergistic effect of halides on the corrosion inhibition of mild steel in H2SO4 by a triazole derivative: Kinetics and thermodynamic studies. J. Electrochem. Sci. 2014;9:4086.
3. Farag AA, Ibrahim IM. Modazar as promising corrosion inhibitor of carbon steel in hydrochloric acid solution. IJSR. 2014;3:1087.
4. Kshama Shetty S, Nityananda A, Shetty. Ionic liquid as an effective corrosion inhibitor on 6061 Al-15 vol. Pct. SiC(p) composite in 0.1 M H2SO4 medium - an ecofriendly approach. Canadian Journal of Chemical Transactions. 2015;3:41.
5. Arab ST, Noor EA. Inhibition of acid corrosion of steel by some S-alkylisothiouronium iodides. Corrosion. 1993;49:122.
6. Rasini IA. Influence of sodium salts of organic acids as additives on localized corrosion of aluminum and its alloys. Corrosion. 1993;49:821-828.
7. Hajjai N, Ricco I, Srhiri A, Lattès A, Souafiaoui M, Benbachir A. Effect of N-alkylbetaines on the corrosion of iron in 1 M HCl solution. Corrosion. 1993;49:326-334.
8. Elachouri M, Hajji MS, Salem M, Kettir S, Coudert R, Essassi EM. Some surfactants in the series of 2-(alkyldimethylammonio) alkanol bromides as inhibitors of the corrosion of iron in acid chloride solution. Corros. Sci. 1995;37:381-389.
9. Luo H, Guan YC, Han KN. Inhibition of mild steel corrosion by sodium dodecyl benzene sulfonate and sodium oleate in acidic solutions. Corrosion. 1998;54:619-627.
10. Migahed MA, Azzam EMS, Al-Sabagh AM. Corrosion inhibition of mild steel in 1 M sulfuric acid solution using anionic surfactant. Mater. Chem. Phys. 2004;85:273-279.
11. Osman MM, Omar AM, Al-Sabagh AM. Corrosion inhibition of benzyl triethanol ammonium chloride and its ethoxylate on steel in sulphuric acid solution. Mater. Chem. Phys. 1997;50:271-274.
12. Zucchi F, Trabanelli G, Brunoro G. The influence of the chromium content on the inhibitive efficiency of some organic compounds. Corros. Sci. 1992;33:1135-1139.
13. Villamil RFV, Corio P, Rubim JC, Agostinho MLS. Effect of sodium dodecysulfate on copper corrosion in sulfuric acid media in the absence and presence of benzotriazole. J. Electroanal. Chem. 1992;472:112-119.
14. Zhao TP, Mu GN. The adsorption and corrosion inhibition of anion surfactants on aluminium surface in hydrochloric acid. Corros. Sci. 1999;41:1937-1944.
15. Abd El Rehim SS, Hassan H, Amin MA. Corrosion inhibition of aluminum by 1,1 (lauryl amido) propyl ammonium chloride in HCl solution. Mater. Chem. Phys. 2001;70:64-72.
16. Abd El Rehim SS, Hassan H, Amin MA. The corrosion inhibition study of sodium dodecyl benzene sulphonate to aluminum and its alloys in 1.0 M HCl solution. Mater. Chem. Phys. 2003;78:337-348.

17. Guo R, Liu T, Wei X. Effects of SDS and some alcohols on the inhibition efficiency of corrosion for nickel. Colloids Surf. A. 2002;209:37-45.

18. Branzoi V, Golgovici F, Branzoi F. Aluminium corrosion in hydrochloric acid solutions and the effect of some organic inhibitors. Mater. Chem. Phys. 2002;78:122-131.

19. Oukhrib R, El Ibrahim B, Bourzi H, El Mouaden K, Jmiai A, El Issami S, Bammou L, Bazzi L. Quantum chemical calculations and corrosion inhibition efficiency of biopolymer “chitosan” on copper surface in 3%NaCl. JMES. 2017;8:195.

20. Al-Azzawi AM, Hammud KK. Effect of contact time, initial cobalt ion concentration, pH and biosorbent dosage of surface orange peel and maize agro-waste adsorbents to remove cobalt from water. IJRPC. 2016;6:391.

21. Fadoua El-hajjaji, Merimi I, Latifa El Ouasif, Mostafa el ghoul. Portugaliae electrochimica acta 1-Octyl-2-(octythio)-1H-benzimidazole as a new and effective corrosion inhibitor for carbon steel in 1 M HCl. Portugaliae Electrochimica Acta. 2019;37(3):131-145.

22. Sani UM, Sman UU. Electrochemical corrosion inhibition of mild steel in hydrochloric acid medium using the antidiabetic drug janumet as drug. International Journal of Novel Research in Physics Chemistry & Mathematics. 2016;3(3):30-37.

23. Kolo AM, Sani UM, Kutama U, Usman U. Adsorption and inhibitive properties of januvia for the corrosion of Zn in 0.1 M HCl. The Pharmaceutical and Chemical Journal. 2016;3:109.

24. Ameh PO, Sani UM. Cefuroxime axetil: A commercially available pro-drug as corrosion inhibitor for aluminum in hydrochloric acid solution. Journal of Heterocyclics. 2015;1:2.

25. Al-Shafey HI, Abdel Hameed RS, Ali FA, Aboul-Magd AS, Salah M. Effect of expired drugs as corrosion inhibitors for carbon steel in 1M HCL solution; 2020.

26. Kolo AM, Sani UM, Kutama U, Usman U. Adsorption and inhibitive properties of januvia for the corrosion of Zn in 0.1 M HCl. The Pharmaceutical and Chemical Journal. 2016;3(1):109-119.

27. Kushwah R, Pathak RK. Inhibition of mild steel corrosion in 0.5 M sulphuric acid solution by aspirin drug. International Journal of Emerging Technology and Advanced Engineering. 2014;4:880-884.

28. Fouda AS, EL-Haddad MN, Abdallah YM. Septazole: Antibacterial drug as a green corrosion inhibitor for copper in hydrochloric acid solutions. IJIRSET. 2013;2:7073.

29. Ofoegbu SU, Ofoegbu PU. ARPN Journal of Engineering and Applied Sciences. 2012;7:272.

30. Ebenso EE. Adsorption, synergistic inhibitive effect and quantum chemical studies of ampicillin (AMP) and halides for the corrosion of mild steel in H2SO4. Bull. Electrochem. 2003;19:209.

31. Shalabi K, Abdallah YM, Hala M. Hassan, Fouda AS. Adsorption and corrosion inhibition of atropa belladonna extract on carbon steel in 1 M HCl solution. Int. J. Electrochem. Sci. 2014;9: 1468.

32. Abdallah YM, Hala M. Hassan, Shalabi K, Fouda AS. Effects of Arctostaphylos uva-ursi extract as green corrosion inhibitor for Cu10Ni Alloy in 1 M HNO3. Int. J. Electrochem. Sci. 2014;9:5073.

33. Fouda AS, Elewady GY, Shalabi K, Abd El-Aziz HK. Alamines as corrosion inhibitors for reinforced steel and their effect on cement based materials and mortar performance. RSC Adv. 2015;5:36957.