Corrosion Inhibition of Monel in 0.2N HCl Solution by Tris (hydroxymethyl) aminomethane

Rana Afif Majed Anaee[1]

Abstract— This study deals with the inhibition of monel in 0.2N HCl solution by Tris (hydroxymethyl) aminomethane by five concentrations 200, 400, 600, 800 and 1000 ppm using electrochemical measurements using Potentiostat. Generally, the results of corrosion test showed that Tris acted as cathodic inhibitor because it was shifted corrosion potentials to more active values. Good efficiencies have been obtained especially in the presence of 600 ppm of Tris. Langmuir adsorption model was achieved, and gave good fitting. Cyclic polarization test indicated the decreasing in hysteresis loop of monel in the presence of Tris especially in the presence of 600 ppm. The small values of equilibrium constant of adsorption process and Gibbs free energy showed the physically adsorption of Tris.

Index Terms—Monel; Tris; Inhibition; Electrochemical methods.

1 INTRODUCTION

Nickel–copper alloy is a solid solution binary alloy, combining high strength (comparable to structural steel) and toughness over a wide range with excellent resistance to many corrosive environments. The alloy can be used at temperatures up 4278°C and as high as 5388°C in sulfur-free oxidizing atmospheres. It has excellent mechanical properties at subzero temperatures. The alloy is readily fabricated and is virtually immune to chloride ion stress corrosion cracking in typical environments. Generally, its corrosion resistance is very good in reducing environments, but poor in oxidizing conditions. The general corrosion resistance of alloy in the nonoxidizing acids, such as sulfuric, hydrochloric, and phosphoric is improved over that of pure nickel. The influence of oxidizers is the same as for nickel. The alloy is not resistant to oxidizing media such as nitric acid, ferric chloride, chromic acid, wet chlorine, sulfur dioxide, or ammonia. Monel exhibits excellent resistance to hydrofluoric acid solutions at all concentrations and temperatures. Again, aeration or the presence of oxidizing salts increases the corrosion rate. This alloy is widely used in HF alkylation, is comparatively insensitive to velocity effects, and is widely used for critical parts such as bubble caps or valves that are in contact with flowing acid. Monel is subject to stress corrosion cracking in moist, aerated hydrofluoric or hydrofluorosilicic acid vapor. However, cracking is unlikely if the metal is completely immersed in the acid. The corrosion behavior of nickel, Inconel 600 and Inconel 690 was studied in different concentrations of HCl solution and its inhibition by natural rosemary oil using galvanostatic polarization techniques. It was found that, HCl accelerate the corrosion of nickel and its alloys [1]. The inhibition of copper corrosion by Benzotriazole (BTA) in 5% HCl has been investigated by weight loss technique at different temperatures. Maximum value of surface converge was 0.998 for BTA at 35°C and 15 g/l inhibitor concentration, while the lower value was 0.868 at 55 °C and 1 g/l inhibitor concentration [2].

The corrosion inhibition of copper-nickel alloy by Ethylenediamine (EDA) and Diethylenetriamine (DETA) in 1.5M HCl has been investigated by weight loss technique at different temperatures. Maximum value of inhibitor efficiency was 75% at 35 °C and 0.2 M inhibitor concentration EDA, while the lower value was 4% at 35 °C and 0.01 M inhibitor concentration DETA [3].

The corrosion of copper – nickel alloy in hydrochloric acid was investigated at different temperatures, inhibitor concentrations and corrosive solution velocities. Weight loss technique was used to evaluate the corrosion rate data [4]. Some indole derivatives are investigated as corrosion inhibitors for nickel in 0.5 M HCl solution using potentiodynamic polarization and electrochemical impedance spectroscopy (EIS) techniques. A significant decrease in the corrosion rate of nickel was observed in the presence of investigated indole derivatives [5]. The corrosion behavior of the nickel electrode was investigated using open circuit potential measurements, galvanostatic, and potentiostatic polarization techniques. The effect of open circuit potential, current densities, NaOH concentration, Cl^- anions, and some natural oils e.g. sesame oil, water cress oil, wheat germ oil and almond oil as an inhibitors for corrosion of the nickel in $1x10^{-2}$ M NaOH solution was studied [6].

The aim of present work is attempt to inhibit corrosion of Monel in 0.2N HCl solution at room temperature using Tris. Tris is an organic compound with the formula $(HOCH_2)_3CNH_2$. Tris is extensively used in biochemistry and molecular biology. In biochemistry, Tris is widely used as a component of buffer solutions, such as in TAE and TBE buffer, especially for solutions of nucleic acids. It contains a primary amine and thus undergoes the reactions associated with typical amines, e.g. condensations with aldehydes.

2 MATERIALS AND METHODS

Ni- alloy was cut into square shape with (1 cm^2) area, and made into electrode by pressing a copper wire into a hole on one side and then insulating all but one side with an epoxy resin. The exposed area was grinding on emery papers 500, 800, and 1000 mesh grit. The electrochemical cell was of the usual type with provision for working electrode (Monel), aux-

- [1]*Rana Afif Majed Anaee: Assistant Prof. Dr. at Materials Eng. Dep.- University of Technology/ Iraq-Baghdad, E-mail: dr.rana_afif@yahoo.com , dr.rana.a.anaee@uotechnology.edu.iq*

ISSN 2229-5518

iliary electrode (Pt electrode), and a Luggin capillary for connection with an SCE reference electrode.

The basic solution was 0.2N HCl solution, HCl obtained by GCC with purity 35.4% and density 1.19g.cm^{-3}, which prepare in distilled water.

Electrochemical measurements were performed with a potentiostat WINKING M Lab200 at scan rate 5mV/sec. The main results obtained were expressed in terms of the corrosion potentials (E_{corr}) and corrosion current density (i_{corr}) in addition to calculate the cathodic and anodic Tafel slopes by using extrapolation method.

3 Results and Discussion

3.1 Electrochemical Behavior

Figure (1) shows the polarization curves of monel in 0.2N HCl solution in the absence and presence of Tris, these curves show the cathodic and anodic regions. At cathodic sites, evolution of hydrogen molecules takes place as follows:

$$2H^{+} + 2e \rightarrow H_2 \uparrow \qquad (1)$$

While at anodic sites, dissolution of nickel occurs according to the following reaction:

$$Ni \rightarrow Ni^{2+} + 2e \qquad (2)$$

From Tafel plots can be seen that the presence of 600 ppm Tris shifts the anodic curve to less current density values. Corrosion parameters of monel in corrosive medium are listed in Table (1). These data show that the presence of Tris shifts corrosion potential, in general, toward active direction except in the presence of 200 ppm. All concentrations of Tris shifted the corrosion current density to less value. Cathodic Tafel slopes were increased; also anodic Tafel slopes were increased except for 200 ppm of Tris.

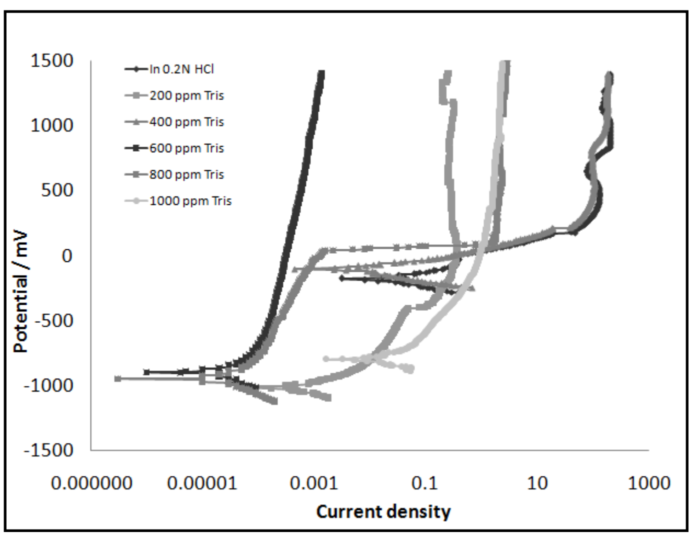


Figure (1) Polarization curves of monel in 0.2N HCl solution in the absence and presence of five concentrations of Tris.

Table (1): Corrosion parameters of Monel in 0.2N HCl solution in absence and presence five concentrations of Tris as inhibitor.

Conc. of Tris ppm	$-E_{corr}$ mV	i_{corr} µA.cm^{-2}	$-b_c$ mV.dec^{-1}	$+b_a$ mV.dec^{-1}	IE%
0	177.20	13.330	74.3	59.1	-
200	98.80	5.4300	92.3	53.8	59.265
400	1012.7	0.2554	87.6	68.2	98.084
600	897.6	0.0169	208.9	193.9	99.873
800	942.4	0.0173	165.6	170.7	99.870
1000	799.2	6.760	76.1	95.0	49.287

From polarization curves can be concluded that Tris acted as cathodic inhibitor.

The inhibition efficiency IE (%) can be calculated using the equation given below [7]:

$$IE\% = \frac{(i_{corr})_a - (i_{corr})_p}{(i_{corr})_a} \times 100 \qquad (3)$$

Where (icorr)a and (icorr)p are the corrosion current density (µA.cm-2) in the absence and the presence of the inhibitor, respectively. The data of IE% showed that 600 ppm of Tris had the highest efficiency. Tris has one amine group and three hydroxyl groups, these functionality groups have the ability to adsorb on monel surface.

The active (—:NH2) group contains a pair of unshared electrons which it donates to the metal surface. The polar amine group displaces water molecules from the surface. On adsorption, most of the metal surface is covered by the adsorbed water molecules. The inhibitors react by replacing water molecules by organic inhibitor molecules as follow [8]:

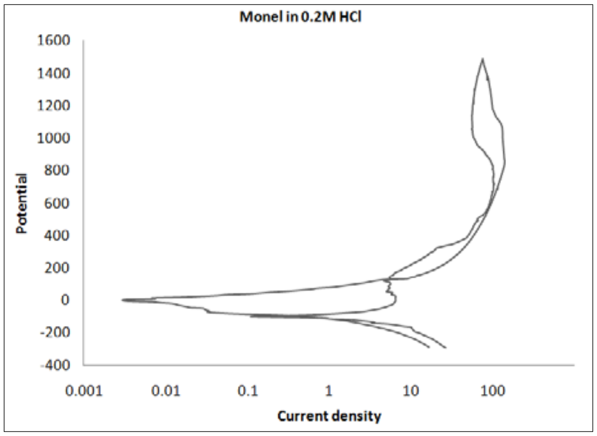
$$Org.molecule_{(aq)} + nH_2O_{(ads)} \rightarrow Org.molecule_{(ads)} + nH_2O_{(soln)} \qquad (4)$$

Here n represents the number of molecules which are replaced to accommodate the organic molecule.

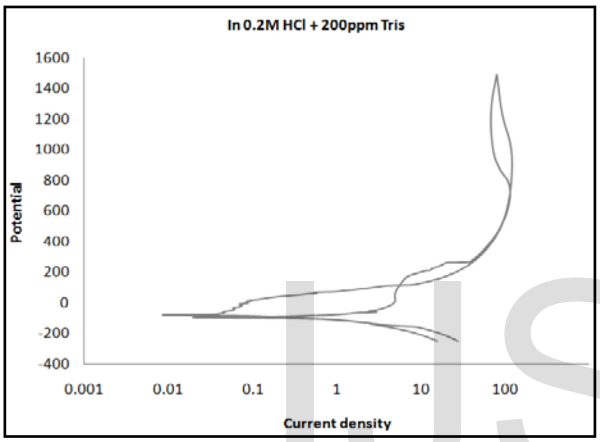
3.2 Cyclic Polarization

Cyclic polarization test was performed to estimate the resistance to pitting corrosion, where the hysteresis loop increases as the susceptibility of material to corrosion increases. Cyclic polarization curves for monel in 0.2N HCl solution in the absence and presence of Tris indicate that the hysteresis loop became smaller in the presence of inhibitors. This result confirms the inhibitive action for Tris. The best curve can be observed in the presence of 600ppm as shown in Figure (2).

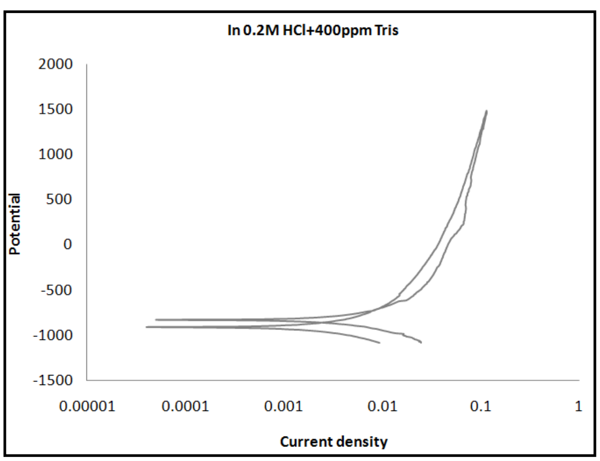
ISSN 2229-5518



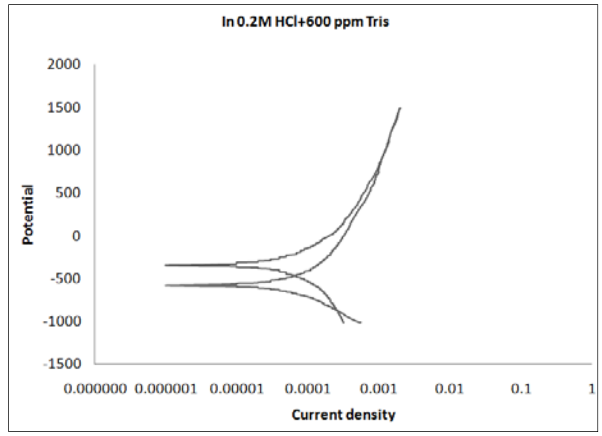
(a)



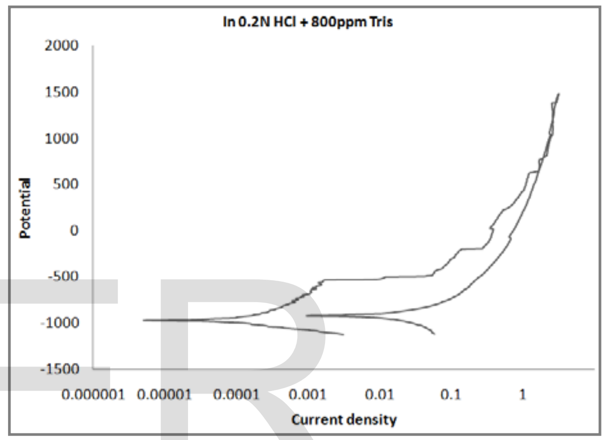
(b)



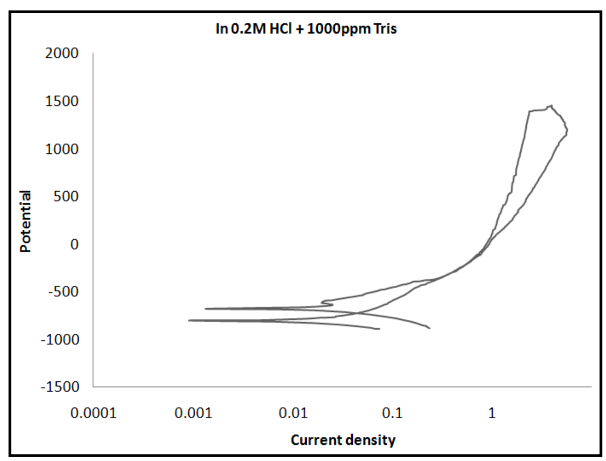
(c)



(d)



(e)



(f)

Figure (2 a-f): Cyclic polarization of monel in 0.2N HCl solution in the absence and presence of Tris with five concentrations.

ISSN 2229-5518

3.3 Adsorption Isotherm and Thermodynamic Calculations

In order to get more information about the mode of adsorption of the respective Tris on monel electrode surface, the data obtained from electrochemical technique have been tested with Langmuir isotherm. The testes indicated that the adsorption of the studied Tris on monel surface is best described by Langmuir. Langmuir adsorption isotherm relationship is represented by equation [9]:

$$log\ (C/\theta) = log\ C - log\ K \qquad (5)$$

where C is the concentration of the inhibitor in the bulk electrolyte, θ, is the surface coverage by inhibitor molecules and K is the equilibrium constant of adsorption. Plot of log (C/θ) vs. log C is shown in Fig. (3). Values of adsorption parameters deduced from the isotherms are presented in Table (2). From the results obtained, the R^2 values for the plot is closer to unity (0.849), indicating that the adsorption of the studied Tris is consistent with the Langmuir adsorption model.

The Langmuir isotherm is based on the assumption that each site of metal surface holds one adsorbed species. Therefore, one adsorbed H_2O molecule is replaced by one molecule of the inhibitor adsorbate on the monel surface.

The equilibrium constant of adsorption deduced from the Langmuir adsorption model is related to free energy of adsorption (ΔG^o_{ads}) of the inhibitor as follows [9]:

$$\Delta G^o_{ads} = -2.303RT\ log 55.5K \qquad (6)$$

The value of ΔG^o_{ads} is shown in Table (2).

The negative values of ΔG^o_{ads} indicated the spontaneous adsorption. Therefore, the adsorption of the studied Tris on monel surface is spontaneous and is consistent with the mechanism of electrostatic transfer of charge from the charged inhibitor's molecules to charged metal surface which supports physicsorption.

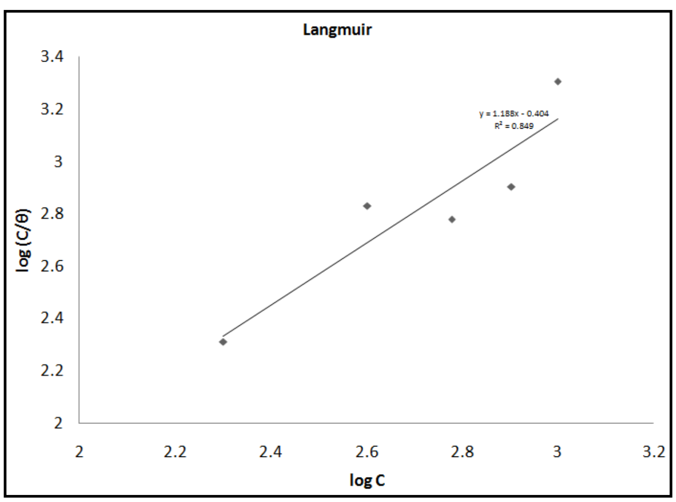


Figure (3): Adsorption isotherm of Tris on monel surface in 0.2N HCl solution.

Table (2): Adsorption parameters for Tris on monel surface.

Model	*R^2*	*$\Delta G_{ads}{}^o$/kJ.mol^{-1}*	*Log K*	*K*
Langmuir	0.849	-12.258	0.404	0.3945

4 Conclusion

Tris (hydroxymethyl) aminomethane was used to inhibit the corrosion of Monel in 0.2N HCl solution with five concentrations include 200, 400, 600, 800 and 1000 ppm, and gave good efficiencies by electrochemical measurements involve polarization test and cyclic polarization. Tris was obeying Langmuir isotherm with small values of equilibrium constant and the change in free energy of adsorption, i.e., the adsorption of Tris is physically adsorption.

References

[1] M. Abdallah, S.O. Al Karanee, and A.A. Abdel Fattah, "Corrosion behavior of nickel and its alloys in HCl and its inhibition by natural rosemary oil", ZAŠTITA MATERIJALA, Vol.50 (2009), broj 4. p.205-212.

[2] A. Anees Khadom, S. Aprael Yaro, and H. Abdul Amir, "Adsorption mechanism of benzotriazole for corrosion inhibition of copper-nickel alloy in hydrochloric acid", J. Chil. Chem. Soc., Vol.55, No.1 (2010), p.150-152.

[3] A. Anees Khadom, A. S. Yaro, A. Y. Musa, A. Mohamad, and A. H. Kadhum, "Corrosion Inhibition of Copper-nickel Alloy: Experimental and Theoretical Studies", Journal of the Korean Chemical Society, Vol. 56, No. 4 (2012).

[4] A. A. Khadom, "Effect of Corrosive Solution Motion on Copper – Nickel Alloy Pipe in Presence of Naphthylamine as a Corrosion Inhibitor", J. Mater. Environ. Sci., Vol.4, No. 4 (2013), p.510-519.

[5] A.S.Fouda, H.Tawfik, N.M.Abdallah and A.M.Ahmd, "Corrosion Inhibition of Nickel in HCl Solution by Some Indole Derivatives", Int. J. Electrochem. Sci., Vol.8 (2013) p. 3390-3405.

[6] M. Abdallah, I. A. Zaafarany, S. Abd El Wanees, and R. Assi, "Corrosion Behavior of Nickel Electrode in NaOH Solution and Its Inhibition by Some Natural Oils", Int. J. Electrochem. Sci., Vol.9 (2014), p. 1071-1086.

[7] K.F. Khaled, and E. Ebenso, "Cerium salt as green corrosion inhibitor for steel in acid medium", Research on Chemical Intermediates, DOI: 10.1007s 11164-013-1167-3, April 2013.

[8] Zaki Ahmad, " Principle of corrosion engineering and corrosion control", ISBN: 0750659246, Pub. Date: September 2006, Publisher: Elsevier Science & Technology Books.

[9] Da-Quan Zhang, Qi-Rui Cai, Xian-Ming He, Li- Xin Gao and Guo-Ding Zhou, "Inhibition effect of some amino acids on copper corrosion in HCl solution", Materials Chemistry and Physics, Vol.112 (2008), p.353-358.