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Corrosion inhibition of Sodium tungstate on carbon steel in 3.5 % NaCl

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Abstract

Sodium tungstate was examined as corrosion inhibitors for carbon steel in 3.5 % NaCl solution using potentiodynamic polarization and electrochemical impedance spectroscopy methods. The inhibition efficiencies obtained from all methods employed are in good agreement with each other. The results obtained revealed that Sodium tungstate inhibits the corrosion of carbon steel in the investigated corrosive medium and the inhibition efficiency reached to81.9 %. Polarization curves reveal that Sodium tungstate can be classified as mixed inhibitor type.

Keywords: Sodium tungstate, corrosion inhibition, C-steel.
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1. Introduction

Carbon steel is one of the most widely used engineering materials in pipelines for the transmission of water, petroleum products and chemicals, as well as for vessels used in oil and gas production systems. This is because carbon steel has excellent mechanical properties and low cost [1-5], therefore it is extensively used under different conditions in petroleum industries [6]. Carbon steel can be defined as steel that contains only residual amounts of elements other than carbon. The carbon steel often contains carbon content equals to or less than 0.35 wt.% to facilitate welding and is usually classified according to its carbon content into three categories. Steels of less than 0.25 wt.% carbon are often referred to as mild steel and have high strength. Low carbon steels contain too little carbon (below 0.15 wt.% carbon) to acquire hardening, while medium carbon steels contain about 0.25–0.35 wt.% carbon to achieve higher strength [7]. Corrosion is described as the deterioration of metallic materials by an electrochemical process or the steady eating away of metals by the effect of an aggressive environment.

Among the numerous procedures for metal protection against corrosion, the use of corrosion inhibitors is the most practical method owing to its advantages of economy, high efficiency, and wide applicability in various fields [8, 9]. Corrosion inhibitor is any chemical substance which reduces the deterioration of metal by the effect of its surroundings when added to the medium (usually in small amounts) [10]. An inhibitor to be effective, it must displace water from the vicinity of the metal surface then interact with the anodic and/or cathodic sites therein, modify electrochemical reactions by their action from the solution side of the metal/solution interface and increases corrosion resistance. An efficient corrosion inhibitor should have high free energy of adsorption on a metal surface to form adsorbed film which impede ongoing electrochemical dissolution reactions by reducing or preventing contact with the solution. Inhibitors can be divided according to their chemical nature into three types: (i) inorganic inhibitors, (ii) organic inhibitors, and (iii) mixed-substance inhibitors [11, 12]. Inorganic compounds such as chromate, phosphate, molybdate [13-14], nitrite and nitrate [15] compounds are widely used as corrosion inhibitors in several media and for various types of metals and alloys.

In this work, the inhibition performance of Sodium tungstate for carbon steel in 3.5 % NaCl was investigated using potentiodynamic polarization and electrochemical impedance spectroscopy (EIS).

2. Experimental

2.1. Materials

Sodium tungstate hydrated (96%) from Nice India and Sodium Chloride Alpha chemika India

2.2. Chemical composition of carbon steel sample (C-steel 316).

AISI 316 Stainless Steel vs. ASTM A36 Carbon Steel: Both AISI 316 stainless steel and ASTM A36 carbon steel are iron alloys. They have 67% of their average alloy composition in common. There are 28 material properties with values for both materials. Properties with values for just one material (4, in this case) are not shown.

Type 316 is an austenitic chromium-nickel stainless steel containing molybdenum. This addition increases general corrosion resistance, improves resistance to pitting from chloride ion solutions, and provides increased strength at elevated temperatures. Properties are similar to those of Type 304 except that this alloy is somewhat stronger at elevated temperatures.

2.3. Potentiodynamic polarization.

Potentiodynamic polarization method was used to determine the anodic and cathodic polarization curves of carbon steel in 3.5 % NaCl in absence and presence of different concentrations of inhibitors. E vs. log I curves recorded. The corrosion kinetic parameters such as corrosion current (Icorr), corrosion potential (Ecorr), cathodic Tafel slope (βc), and anodic Tafel slope (βa) were derived from the Tafel curves.

2.4. Electrochemical impedance spectroscopy (EIS).

The same electrode of C-steel used in potentiodynamic polarization was also used. Each experiment was performed on new polished electrode using a new prepared electrolyte.

3. Result and discussion

3.1. Potentiodynamic polarization technique

The representative potentiodynamic polarization curve of carbon steel in carbon steel in 3.5 % NaCl solution in the absence and presence of various concentrations of the inhibitor is shown in Fig.1.

Some corrosion kinetics parameters, such as corrosion potential (E_{corr}), cathodic and anodic Tafel slopes (β_c & β_a), corrosion current density (I_{corr}) achieved from the extrapolation of the anodic and cathodic polarization curves, corrosion rate (C_r) and inhibition efficiency (*IE* %) were computed and presented in Table 1.

The inhibition efficiency (*IE* %) and the degree of surface coverage (θ) were calculated as follow:

$$IE\ \% = [(I_{corr"free"} - I_{corr"inh"}) / I_{corr"free"}] \text{ x } 100$$

$$(\theta) = IE\ \% / 100$$

Where, $I_{corr"free}$ and $I_{corr"inh"}$ are the corrosion current densities for carbon steel electrode in absence and presence of the inhibitor [16, 17].

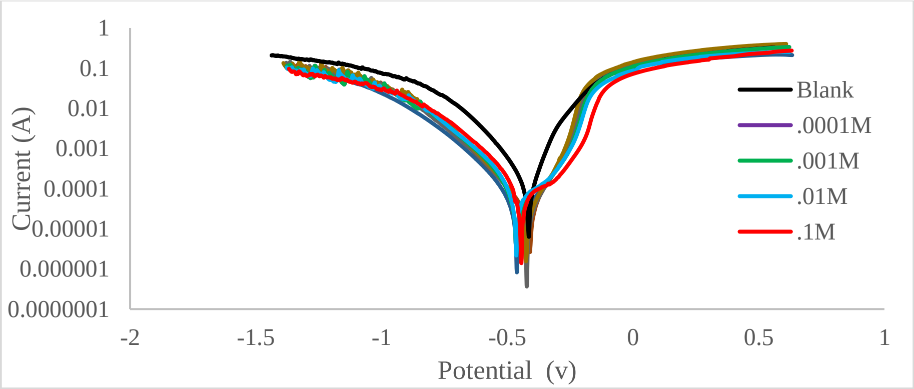

Fig (1): Potentiodynamic polarization curves of carbon steel in 3.5% NaCl solution in absence and presence of different concentrations of Sodium tungstate

Table (1): Corrosion parameters of carbon steel in 3.5% NaCl solution in absence and presence of different concentrations of Sodium tungstate.

Conc. (M)	β_a (V/decade)	β_c (V/decade)	Ecorr, (V)	I corr (A)	Cr (mm/year)	IE%	θ
free	0.1219	0.14722	-0.43809	0.000227	7.1833		
0.1	0.1677	0.14903	-0.42	4.50E-05	1.2796	80.18	0.801
0.01	0.16126	0.16376	-0.41205	4.91E-05	1.4477	78.37	0.783
0.001	0.13845	0.13918	-0.43857	5.00E-05	1.856	77.9	0.779
0.0001	0.13125	0.12346	-0.45215	5.12E-05	1.8877	77.4	0.774

Data in Table. 1. Reveals that, when the concentration of this inhibitor was increased, the inhibition efficiencies increased while the corrosion current densities decreased. This increase in inhibition efficiency with increasing inhibitor concentration indicated that this compound was acting as an adsorption inhibitor. The inhibitive action of this compound was discussed in terms of blocking the electrode surface by adsorption of the molecules through the active centers contained in its structure.

This inhibitor cause change in the anodic and cathodic Tafel slopes and no definite trend was observed in the shift of Ecorr values in the presence of different concentrations of this inhibitor, suggesting that this compound behaves as mixed-type inhibitors. The values of the cathodic Tafel slope (β_c) and the anodic Tafel slope (β_a) for the inhibitor were shifted slightly. The slight variations in the Tafel slope suggested that the synthesized inhibitor is blocking the cathodic and anodic sites without changing the corrosion mechanism [18, 19].

3.2. Electrochemical impedance spectroscopy (EIS) technique.

Figs (2.) Nyquist diagrams of carbon steel in carbon steel in 3.5 % NaCl solution in absence and presence of different concentrations of the inhibitor at 25 °C. The impedance diagram shows the same trend (one capacitive loop), however, the diameter of this capacitive loop increases with increasing concentration of inhibitors while the straight line in the impedance of blank

The inhibition efficiency (*IE* %) and the degree of surface coverage (θ) were calculated using charge transfer resistance as follow [20]:

$$IE\ \% = [(R_{ct''inh''} - R_{ct''free''}) / R_{ct''inh''}] \times 100$$

$$(\theta) = IE\ \% / 100$$

Where, $R_{ct''free''}$ and $R_{ct''inh''}$ are the charge transfer resistance values in the absence and presence of inhibitors for C steel in carbon steel in 3.5 % NaCl. The impedance parameters obtained by fitting the EIS data to the equivalent circuit. The degree of surface coverage (ϴ) and the inhibition efficiency percentage (*IE* %) were listed in Table 2. It was found that, the concentration of inhibitors increased, the R_{ct} values increased. The increase in R_{ct} value is due to the adsorption of inhibitor on the metal surface [21].

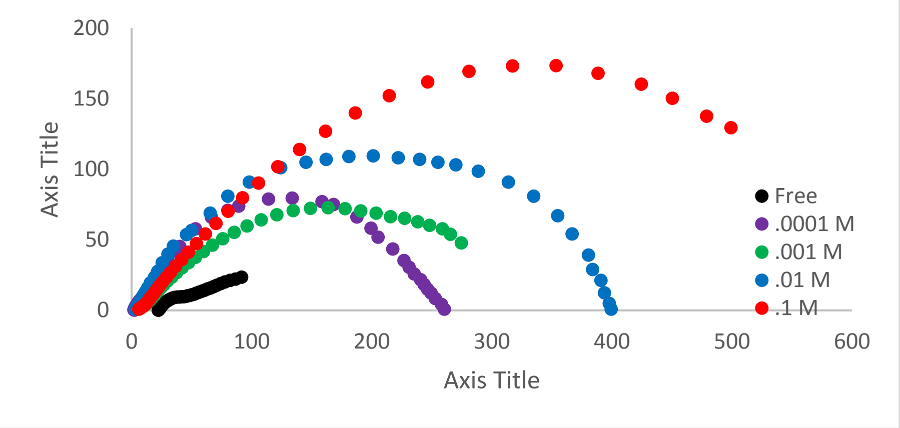

Fig (2): Nyquist diagrams of carbon stee1 in 3.5% NaC1 so1ution in absence and presence of different concentrations of Sodium tungstate.

Tab1e (2): Impedance of carbon stee1 in 3.5% NaC1 so1ution in absence and presence of different concentrations of Sodium tungstate.

Sodium tungstate	R_S. (Ω)	R_{CT}. (Ω)	θ	IE%
Blank	7.1	99.29		
.0001 M	0.738	453.17	0.78	78
.001 M	0.77	470.3	0.7888	78.88
.01 M	0.796	500.21	0.8015	80.15
.1 M	1.5	550.2	0.8195	81.9

4. Conclusions

1. The inhibitor acted as good corrosion inhibitors for carbon steel in carbon steel in 3.5 % NaCl
2. Polarization curves indicated that the inhibitor acted as mixed-type inhibitor for carbon steel in carbon steel in 3.5 % NaCl
3. The corrosion inhibition increased with increasing the inhibitors concentration.
4. E1ectrochemica1 impedance spectroscopy (EIS) and potentiodynamic polarization measurements gave similar results.
5. The concentration of inhibitors increased, the Rct values increased due to the adsorption of inhibitor on the metal surface

References

[1] P. Kalaiselvi, S. Chellammal, S. Palanichamy, G. Subramanian, Artemisia pallens as corrosion inhibitor for mild steel in HCl medium, Mater. Chem. Phys., 120 (2010) 643- 648.

[2] K. Usher, A. Kaksonen, I. Cole, D. Marney, Critical review: Microbially influenced corrosion of buried carbon steel pipes, Int. Biodeterior. Biodegrad, 93 (2014) 84-106.

[3] X. Li, S. Deng, H. Fu, T. Li, Adsorption and inhibition effect of 6-benzyl aminopurine on cold rolled steel in 1 M HCl, Electrochim. Acta, 54 (2009) 4089-4098.

[4] M.A. Migahed, M.M. Attya, S.M. Rashwan, M. Abd El-Raouf, A.M. Al-Sabagh, Synthesis of some novel nonionic surfactants based on tolyltriazole and evaluation their performance as corrosion inhibitors for carbon steel, Egypt. J. Pet., 22 (2013) 149-160.

[5] M.A. Hegazy, A.Y. El-Etre, M. El-Shafaie, K.M. Berry, Novel cationic surfactants for corrosion inhibition of carbon steel pipelines in oil and gas wells applications, J. Mol. Liq., 214 (2016) 347-356.

[6] M. Deyab, Effect of cationic surfactant and inorganic anions on the electrochemical behavior of carbon steel in formation water, Corros. Sci., 49 (2007) 2315-2328.

[7] P. Flenner, Carbon Steel Handbook, Electric Power Research Institute, 2007.

[8] N. El Hamdani, R. Fdil, M. Tourabi, C. Jama, F. Bentiss, Alkaloids extract of Retama monosperma (L.) Boiss. Seeds used as novel eco-friendly inhibitor for carbon steel corrosion in 1 M HCl solution: Electrochemical and surface studies, Appl. Surf. Sci., 357 (2015) 1294-1305.

[9] M. Faustin, A. Maciuk, P. Salvin, C. Roos, M. Lebrini, Corrosion inhibition of C38steel by alkaloids extract of Geissospermum laeve in 1 M hydrochloric acid: Electrochemical and phytochemical studies, Corros. Sci., 92 (2015) 287-300.

[10] Q. Hu, Y. Qiu, G. Zhang, X. Guo, Capsella bursa-pastoris extract as an ecofriendly inhibitor on the corrosion of Q235 carbon steels in 1 mol L− 1 hydrochloric acid, Chin. J. Chem. Eng., 23 (2015) 1408-1415.

33] M. Hegazy, M. Abdallah, H. Ahmed, Novel cationic gemini surfactants as corrosion inhibitors for carbon steel pipelines, Corros. Sci., 52 (2010) 2897-2904.

[11] A.M. Al-Sabagh, N.G. Kandile, N.M. Nasser, M.R. Mishrif, A.E. El-Tabey, Novel surfactants incorporated with 1,3,5-triethanolhexahydro-1,3,5-triazine moiety as corrosion inhibitors for carbon steel in hydrochloric acid: Electrochemical and quantum chemical investigations, Egypt. J. Pet., 22 (2013) 351-365.

[12] S. Garai, S. Garai, P. Jaisankar, J. Singh, A. Elango, A comprehensive study on crude methanolic extract of Artemisia pallens (Asteraceae) and its active component as effective corrosion inhibitors of mild steel in acid solution, Corros. Sci., 60 (2012) 193-204.

[13] K. Boumhara, M. Tabyaoui, C. Jama, F. Bentiss, Artemisia Mesatlantica essential oil as green inhibitor for carbon steel corrosion in 1 M HCl solution: Electrochemical and XPS investigations, J. Ind. Eng. Chem., 29 (2015) 146-155.

[14] Z. Dong, X. Guo, J. Zheng, L. Xu, Investigation on inhibition of CrO4 2− and MoO4 2− ions on carbon steel pitting corrosion by electrochemical noise analysis, J. Appl. Electrochem., 32 (2002) 395-400.

[15] M. Deyab, K. Eddahaoui, R. Essehli, T. Rhadfi, S. Benmokhtar, G. Mele, Experimental evaluation of new inorganic phosphites as corrosion inhibitors for carbon steel in saline water from oil source wells, Desalination, 383 (2016) 38-45.

[16] M. Abdallah, Hatem M. Eltass, M. A. Hegazy, H. Ahmed, Adsorption and inhibition effect of novel cationic surfactant for pipelines carbon steel in acidic solution, Protection of Metals and Physical Chemistry of Surfaces, 52 (2016), 721–730.

[17] M. Sahin, G. Gece, F. Karc, S.Bilgic, Experimental and theoretical study of the effect of some heterocyclic compounds on the corrosion of low carbon steel in 3.5% NaCl medium. Journal of Applied Electrochemistry, 38, (2008). 809–815.

[18] X. Li, S. Deng, G. Mu, H. Fu, F.Yang, Inhibition effect of nonionic surfactant on the corrosion of cold rolled steel in hydrochloric acid. Corrosion Science, 50, (2008), 420–430

[19] M. N. El-Haddad, K. M. Elattar, Role of novel oxazocine derivative as corrosion inhibitor for 304 stainless steel in acidic chloride pickling solutions, Research on Chemical Intermediates, 39, (2012), 3135–3149

[20] M. Benabdellah, A. Aouniti, A. Dafali, B .Hammouti, M. Benkaddour, A.Yahyi, A. Ettouhami, Investigation of the inhibitive effect of triphenyltin 2-thiophene carboxylate on corrosion of steel in 2 M H3PO4solutions, Applied Surface Science, 252, (2006), 8341-8347

[21] R. Chami , F. Bensajjaya, S. Alehyena, M. El Achouri, A. Bellaouchou, A. Guenbour, Inhibitive effect of ester-quats surfactants in the series of (alcanoyloxy)propyl n-alkyl dimethyl ammonium bromide on the corrosion of iron in acid medium, Colloids and Surfaces A: Physicochem. Eng, 480, (2015), 468–476