Available online at www.joac.info

ISSN: 2278-1862

Journal of Applicable Chemistry

2014, 3 (3): 1144-1148

(International Peer Reviewed Journal)

Inhibition Efficiency of Ranolazine On 304 Stainless Steel in Marine Environment

M. D. Medhi

Chemistry Research Laboratory, Dept. of Chemistry, R. J. College (University of Mumbai), Ghatkopar (W), Mumbai-400 086, **INDIA**

Email: mandarmedhi@yahoo.com

Accepted on 13th May 2014

ABSTRACT

Certain piperazine derivatives like Ranolazine an antianginal drug is used as corrosion inhibitor for protection of 304 Stainless Steel in Marine environment. The inhibition effect of the compound was investigated by using electrochemical polarization techniques i.e. potentiodynamic and open circuit potential in the concentration ranges 5 to 30ppm. Results obtained reveals that such a heterocyclic organic compound is a very good corrosion inhibitor and exhibits the best performance at a very low concentration of 15ppm. Potentiodynamic curve indicates that compound is a mixed type of inhibitor having heteroatoms present in the side chain as well as in the ring of the compound.

Keywords: Corrosion, 304 Stainless Steel, Inhibitors, and Electrochemical techniques.

INTRODUCTION

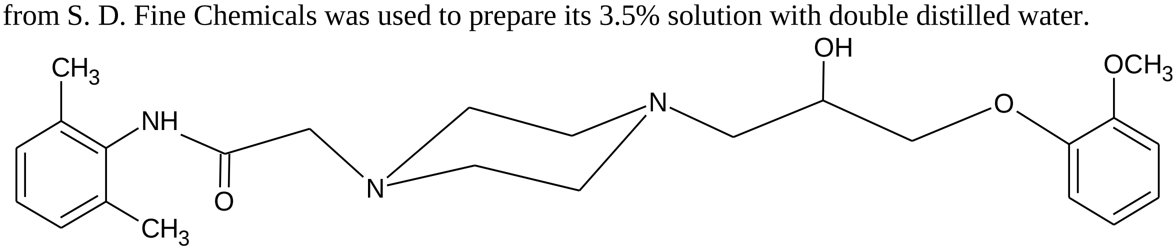
Ranolazine, a piperazine derivative is a well-known antianginal drug used in the field of medicine and pharmaceutics. Being heterocyclic in nature, having N and O atoms, their ability to inhibit the corrosion of 304 stainless steel in 3.5% NaCl solution needs to be verified. Organic compounds especially belonging to the class of heterocycles containing heteroatoms like O, N, S, Se etc. with loosely bound loan pair of electrons and π electrons, if available undergo adsorption on the surface of a metal and helps to protect the material from aggressive environment. Corrosion inhibition of metals like Cu, iron, mild steel, stainless steel, Al etc. have been studied by various workers with the help of organic compounds at different concentrations in acidic, basic and salt solutions [1-7] Stainless steel, due to its high strength, workability and high corrosion resistance property are used in various engineering applications like chemical and pharmaceutical industry [8], food and beverage industry [9], petrochemical industry [10-11], oil and water pipe lines [12], ship and Naval structures [13]; architectural applications, water supply and desalination plants [14].

Protection of the structural parts of the various industries will save leakage of the pipeline, on line and off line structures and also life and economy. The corrosion inhibition actions of the organic compounds containing heteroatoms such as undecanoic acid hydrazide, 2-mercaptobenzothiazole and 2-hydrazinobenzothiazole on carbon steel in HCl solution [15], morpholinium caprylate, morpholinium sebacate and laurate [16-17]**,** morpholinium oleate [18] and morpholinium stearate [19] have been investigated for steel. Al-Suhybani *et al* [20] investigated the corrosion inhibition efficiency of azoles: 2-mercaptobenzoazole (CBA), and its derivatives (2-mercaptobenzoimidazole, 2-mercaptobenzoxazole, 2-mercapto benzothiazole); 2-methyl benzoazole and its derivatives (2-methyl benzimidazole, 2-methyl benzoxazole, 2-methyl benzothiazole and 2-methyl benzoselenazole) for 304 stainless steel in acidic solution where some provides inhibition efficiency up to 90% at a concentration of $5x10^{-4}$ M and stated efficiency of the heteroatoms in the decreasing order as Se> S > N > O. Excellent corrosion inhibitors like Rhodanine azosulpha drug [21], triazole and oxadiazole derivatives [22], pyridazine derivatives [23], organic acid hydrazides [24](salicylic acid hydrazide, anthranalic acid hydrazide, benzoic acid hydrazide, cinnamic acid hydrazide), and alkyl (methyl, butyl, hexyl, octyl) esters of 4- and 5- carboxybenzotriazole [25] for steel have been study. The aim of the present investigation was to find out the suitable inhibitor for control of corrosion of 304 stainless steel in marine environment.

MATERIALS AND METHODS

304 Stainless Steel of commercial grade in sheet form having composition as follows: C -0.06%, Si - 0.52%, Mn- 0.11%, P- 0.032%, S-0.018%, Ni- 8.26%, Cr- 19.17%; and Iron- balance, were used in the present investigation. For electrochemical polarization, samples of 1cm x 3 cm were sheared from the commercial grade sheets. The surface of these samples was successively polished by using the Emery papers of grades 1 / 0, 2 / 0, 3 / 0, and 4 / 0 obtained from Sianor, Switzerland to obtain a scratch free mirror finish surface. The polished samples were washed with detergent solution, rinsed with distilled water and finally degreased with acetone. The specimens were dried and stored in a desiccators containing silica gel as a dehydrating agent.

Ranolazine an antianginal compound was procured and its inhibition efficiency was determined with electrochemical techniques. Molecular structure of this compound is shown in **Fig.1**. Pure NaCl obtained from S. D. Fine Chemicals was used to prepare its 3.5% solution with double distilled water.



N-(2,6-dimethylphenyl)-2-{4-[2-hydroxy-3-(2-methoxyphenoxy)propyl]piperazin-1-yl}acetamide

Fig.1. Molecular Structure & IUPAC Name of Ranolazine

Electrochemical Measurement System, DC 105, containing software of DC corrosion techniques from M / S Gamry Instruments Inc., (No. 23-25) 734, Louis Drive, Warminster, PA-18974, USA has been used for performing corrosion potential and polarization experiments.

For electrochemical polarization studies (corrosion potential, and potentiodynamic polarization) flag shaped specimens with sufficiently long tail were cut from the stainless steel sheet. These samples were polished as described earlier leaving a working area of $1cm^2$ on both sides of the flag and a small portion at the tip for providing electrical contact. Rest of the surface was isolated from the corroding solution by coating with enamel lacquer including side edges. The test specimen was connected to the working electrode holder with the help of a screw. About 50mL of the corrosive medium was taken in a mini corrosion testing electrochemical cell. This volume was appropriate to permit desired immersion of electrodes. The electrochemical investigation was carried out using microprocessor based corrosion measurement system (CMS-105, Gamry Instruments Inc., USA.). The three-electrode i.e. working electrode, reference electrode (calomel), and counter electrode (graphite rod), system cell was used throughout the electrochemical measurements. Open circuit potential measurement and potentiodynamic polarization of the samples were investigated in the concentration ranges 5,10,15,20, and 30 ppm of the inhibitor. The value of inhibition efficiency in terms of corrosion current density:

$$E = 100 \times (i_o - i) / i_o \qquad \text{......................... 1}$$

Where i_o and i are the corrosion current density of the uninhibited and inhibited samples.

RESULTS AND DISCUSSION

Open Circuit Potential Measurement (OCP): The influence of the corrosive and inhibitive species present in the electrolyte may be predicted by analyzing the nature of the OCP curve. The variation of open circuit potential of 304 Stainless Steel exposed to 3.5% NaCl solution containing inhibitor i.e., Ranolazine is shown in **fig. 2**. The steady state potential is obtained after few minutes of the exposure period. In the presence of different concentration of inhibitor, OCP is shifted towards the positive potential direction and gets stabilized thus indicating the adsorption of the inhibitor on the metal surface. Maximum shift of the corrosion potential in the positive direction is obtained in the presence of 10ppm of Ranolazine, which indicates its optimum concentration.

Potentiodynamic Polarization: The anodic and cathodic polarization curves of 304 Stainless Steel exposed to 3.5% NaCl solution containing, Ranolazine in concentrations ranges from 5-30 ppm is shown in the **Fig. 3**, which was carried out at a scan rate of 10 mV/S. The effect of different concentration of this compound on various electrochemical parameters like corrosion potential (E_{corr}), corrosion current density (I_{corr}), anodic Tafel constant (β_a), cathodic Tafel constant (β_c), corrosion rate and % inhibition efficiency etc. of 304 Stainless steel is shown in **Table-1**. Maximum inhibition efficiency of Ranolazine at 15 ppm is 87.77%. This inhibition function is probable due to adsorption of the inhibitors on the metal surface.

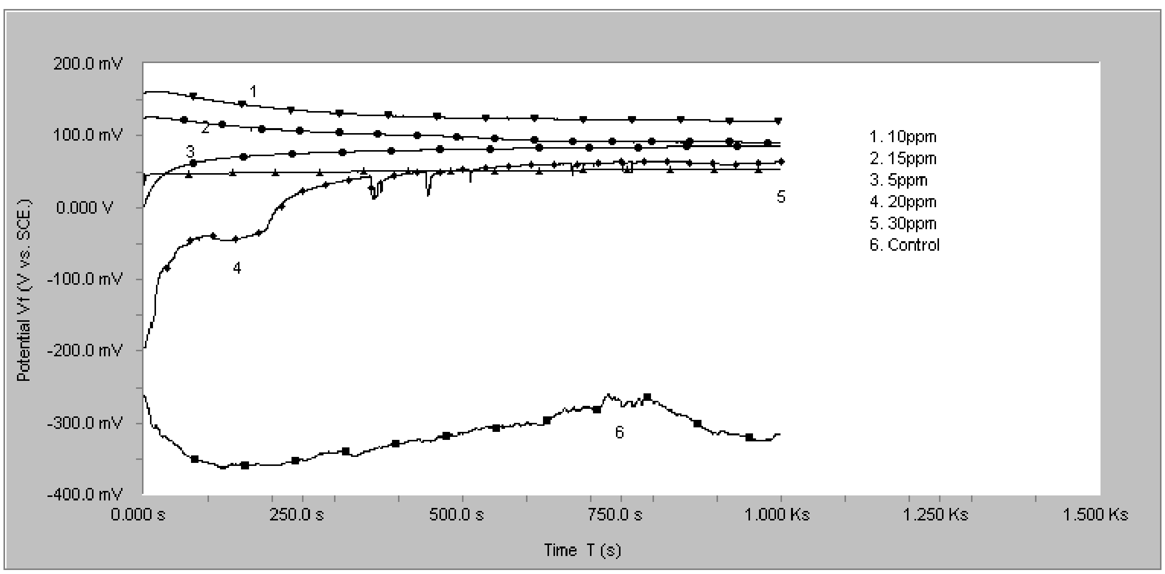


Fig.2. Corrosion potential of 304 Stainless steel exposed to 3.5% NaCl solution with different concentrations of Ranolazine.

Table-1. Electrochemical Parameters for Inhibition of Corrosion of 304 Stainless Steel Exposed to 3.5% Sodium Chloride with Different Concentrations of Ranolazine

Concentration (PPM)	βa (V/dec.)	βc (V/dec.)	Icorr (μA.cm^{-2})	Ecorr (mV)	Corr. Rate (mpy)	Inhibition Efficiency
Control	568.4e-3	259.8e-3	608.1	-290.9	277.9e-3	-----
			Ranolazine			
30	492.5e-3	160.9e-3	200.0	-284.0	91.55e-3	65.11
20	585.8e-3	268.1e-3	153.0	-82.30	69.38e-3	74.00
15	454.7e-3	266.3e-3	68.20	-61.80	31.29e-3	87.77
10	556.5e-3	219.4e-3	112.0	–61.90	50.72e-3	81.73
5	706.2e-3	247.3e-3	113.0	–136.0	52.29e-3	81.35

Corrosion inhibitors with heteroatoms having loosely bound lone pair of electrons and π electrons undergo adsorption (chemisorptions/physisorption), or complexation on the metal / metal oxide surface preventing the access of cathodic reactant (O_2, H^+ etc.), and inhibits the dissolution of metal, whereas the inhibition efficiency (E) depends on the parameters of the system (pH, temperature, exposure period, metal composition etc), aggressive electrolyte as well as on the structure of the inhibitor molecules, it's dipole moment and solubility [26-28]. Ranolazine contains 4 oxygen atoms and 3 nitrogen atoms with homo- and heterocyclic rings with conjugated and isolated double bonds may get effectively adsorbed on the surfaces of stainless steel and protects the surface from aggressive ions.

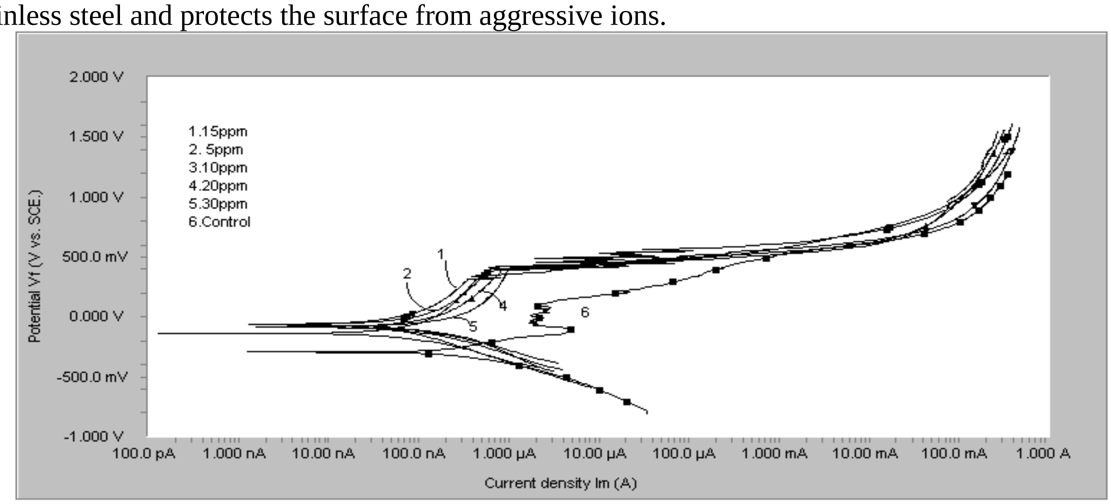


Fig.3. Potentiodynamic polarization of 304 Stainless steel exposed to 3.5% NaCl solution with different concentrations of Ranolazine.

Here the organic compound having heteroatoms with lone pair of electrons act as a Lewis base and the Fe with vacant d-orbital acts as a Lewis acid. The affinity of the compounds towards adsorption on the Fe surface is more than that of the H_2O and aggressive chloride ions. This stability of inhibitor-Fe adsorption bond is based on the Pearson's Hard and Soft Acid and Base principle [29]

$$Fe \longrightarrow Fe^{+2} + 2e^- \quad \text{(Anodic reaction)}$$

$$Fe^{+2} + O_2 + 2e^- + H_2O \longrightarrow [Fe(H_2O)_x]^{2+} \; / \; Fe(OH)_2 \quad \text{(Cathodic reaction)}$$

Adsorption

$$\text{Inhibitor}_{(solution)} + [Fe(H_2O)_x]^{2+} \longrightarrow [Fe(\text{Inhibitor})_y]^{2+} + x\,H_2O \text{ solution}$$

Complexation / Stabilized

Where, x is the number of water molecules replaced by y number of inhibitor molecules and x >>> y.

The complex formed is stabilized on the surface assumed nonporous and insoluble in the medium where the inhibitor is chemically inert doesn't decompose during service condition. It is inferred since both compounds inhibit corrosion. The adsorbed layer effectively protects the steel surface from the aggressive nature of the chloride ions.

APPLICATIONS

Ranolazine, an antianginal drug is useful as corrosion inhibitor for protection of 304 Stainless Steel in Marine environment.

CONCLUSIONS

1. Ranolazine is a good corrosion inhibitor for 304 Stainless steel in sodium chloride solution.
2. It acts as a mixed type of inhibitor.

REFERENCES

[1] M. Zaky, F. H. Assaf, *Br. Corros. J.* **2002,** 37(1), 48-55.
[2] R. D. Armstrong, J. A. Harrison, H.R. Thirsk, *Corros. Sci.* **1970,** 108, 679.
[3] R. D.K. Misra, *Electrochem. Acta* , **1986,** 31 , 51.
[4] D. Chebabe, Z. A. Chikh, N. Hajjaji, A. Srhiri, F. Zucchi, *Corros. Sci.* **2003,** 45 , 309-320
[5] H. Luo, Y. G. Guan, K. N. Han, *Corrosion*, **1998,** 54, 721.
[6] J. Vosta, N. Hackerman, *Corros. Sci.* **1990,** 30, 949.
[7] G. Quartarone, T. Bellomi, A. Zingales, *Corros. Sci.* **2003,** 45, 715-733.
[8] R. J. Valentine, ASM Handbook Corrosion, 6th Ed, **1998,** Vol. 13, 1225.
[9] B. B. Morton, *J. Inst. Petrol.* **1948**, 34 (239), 1-68.
[10] E. L. Hildebrand, *Mater. Prot. Perfor*. **1972,** 11(7), 19-22.
[11] The Role of Stainless Steel in Petroleum Refining, American Iron and Steel Institutes, **1977**.
[12] A.J. Sedriks, P. Dudts, *Corrosion*, **2001,** 57(1), 84-91.
[13] M. von Bour, *Naval Forces,* **1997,** 18(6), 98.
[14] E. W. Dreyman, ASM Handbook Corrosion, 6th Ed., **1998,** Vol. 13, 1221.
[15] M. Athar, H. Ali, M. A. Quraishi, *Br. Corros. J.* **2002,** 37**,** 155.
[16] E. Vuorinen, P. Ngobeni, G. H. Van Der Klashorst, W. Skinner, E. De Wet, W. S. Ernst, *Br. Corros. J*. **1994,** 29**,** 120-121.
[17] W. Skinner, F. Du Preez, E. Vuorinen, *Br. Corros. J.* **1999,** 34, 151-152.
[18] D. G. Duncan: *Patent De 2101388*, German Patent Office, Bonn, Germany, **1971.**
[19] K. J. Balakrishna, S. D. Sharma: *Patent IN 103539*, Indian Patent Office, New Delhi, India, 1968
[20] A. M. Al-Mayouf, A. K. Al-Amery, A.A. Al-Suhybani, *Br. Corros. J.* **2001,** 36**,** 127.
[21] M. Abdallah, *Corros. Sci.* **2002,** 44, 717-728.
[22] F. Bentiss, M. Triesnel, H. Vezin, M. Lagrenee, *Corros. Sci.* **2003,** 45, 371-380.
[23] A. Chetouani, A. Aouniti, B. Hammouti, N. Benchat, T. Benhadda, S. Kertit, *Prog. Org. Coating.* **2002**, 45, 373-378.
[24] M. A. Quraishi, R. Sardar, D. Jamal, *Mat. Chem. Phy*. **2001,** 71, 309-313.
[25] J. Bartley, N. Huynh, S.E. Bottle, H. Flitt, T. Natoya, D.P. Schweinsberg, *Corros. Sci*. **2003,** 45, 81-96.
[26] I. Lukovits, E. Kalman, F. Zucchi, *Corrosion*, **2001,** 57, 3.
[27] V. S. Sastri, J. R. Perumareddi, *Corrosion,* **1997,** 53, 617.
[28] V. S. Sastri, J. R. Perumareddi, *Corrosion*, **1994,** 50,432.
[29] R. G. Pearson, *Inorg. Chem*. **1988**, 27**,**734.