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Evaluation of Corrosion Inhibition of Mild Steel in sea water by 2-Furaldehyde

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The inhibition efficiency of 2-furaldehyde in controlling corrosion of mild steel in sea water has been studied by electrochemical polarization, quantum chemical, SEM and thermal analysis methods. The inhibition efficiency at 298K with 10^{-1}M inhibitor concentration is found to be 67.6%. The inhibition can be attributed to p¶-d¶ bonding and through ion pair formation.

Key words: 2-furaldehyde, corrosion inhibition, adsorption,

Introduction

Furan and its derivatives have been used as corrosion inhibitors for mild steel in acidic medium.[1-4] . Sea water has been increasingly used as cooling fluid in various industries. Sea water is a complex natural electrolyte. The corrosion is severe due to the presence of chloride ions and dissolved oxygen. So, it is imperative to study the corrosion aspect and find out suitable corrosion inhibitors to be used in sea water. The present study aim to (i) find out the corrosion inhibition effects of 2-furaldehyde in sea water, (ii) propose a mechanism of the corrosion inhibition for the inhibitor in sea water.

Experimental

Specimen: Mild steel (c =0.15%, Mn = 1.02%, Si = 0.085%, S = 0.025% and P = 0.025%) of 2mm thickness were used. The specimen was cut in to 1cm x 1cm for galvanostatic studies. Each mild steel specimen was carefully coated with epoxy resin leaving one flat surface uncoated. The exposed surface was polished with emery papers of 150,320,400 and 600 grades and finally with 4/0 polishing paper. The surface cleaning

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was done in ultrasonic cleaner Ralsonic model R-30/40 using de-ionised water. For galvanostatic studies, potentials were measured with the help of DPM (Digital Potentiometer) against saturated calomel electrode with platinum wire electrode as counter electrode. The mild steel specimens were dipped in sea water and in sea water=2-Furaldehyde for 6 hours. The open circuit potential was achieved in 6 hours. The quantum chemical parameters were calculated using pm3. SEM studies was done with JEOL840 SEM operated at 10KV in the secondary electron mode

Chemicals: 2-Furaldehyde AR grade was used. Sea water with salinity 35.6ppt was used. The solutions were prepared using few drops of ethanol for homogeneity

Results and discussion

Galvanostatic polarisation:

Figure1 gives the polarization curves for 2-furaldehyde at different concentrations in sea water at 298K.The corrosion current densities (Icorr), Ecorr and tafel slope values are presented in Table.1. The values in sea water point to oxygen reduction reaction as predicted by Deslouis et.al.[5]. The tafel slope values vary slightly with inhibitor concentrations for 2-furaldehyde. The slight variation of anodic tafel slope values indicate that the inhibitor exert influence on iron dissolution by posing a barrier. 2-furaldehyde has produced a shift in the open circuit potential indicating retardation of cathodic partial process. Donging.[6] has proposed the following mechanism for inhibition of corrosion of steel in chloride medium,

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$M + Cl^- \rightarrow [M\text{-}Cl^-]_{ad}$

$[M\text{-}Cl^-]_{ad} + H_2O + \rightarrow [M\text{-}OH]_{ad} + Cl^- + H^+$

$[M\text{-}Cl^-]_{ad} + H_2O \rightarrow [M\text{-}OH\text{-}Cl^-]_{ad}$

Marcus and Herbelin [7] have proposed that an exchange takes place between Cl^- and OH^- ions in the passive layer in chloride environment. Maitra et.al.[4] has found that inhibitive action is directly proportional to the charge density on the hetero atom. The inhibitive action can be attributed to p¶-d¶ interaction between mild steel and 2-furaldehyde. There may be a transfer of charge from 2-furladehude to the mild steel surface forming a coordinate type of bond through the oxygen atom. The presence of aldehyde group at 2- position may lead to ion pair formation. The lower efficiency can attributed to stronger Cl^- ion adsorption and exchange reaction between Cl- and OH^- ions in the passive layer. The inhibition efficiency increases with inhibitor concentration and decreases with increase in temperature (Fig.2). The decrease in efficiency with increase in temperature may be attributed to desorption process at high temperature.

Thermal Analysis studies:

Assuming monolayer adsorption over mild steel by the inhibitor, Langmuir's adsorption may be written as $(\Theta/1\text{-}\Theta) = Ace^{-Q/RT}$ where A =constant, C = concentration of the inhibitor, Q= heat of adsorption, T= temperature, $\Theta = 1\text{-}(i_c/i_0)$, i_0 & i_c = corrosion current in uninhibited and inhibited solutions respectively. Fig. 3. gives the plot of log ($\Theta/1\text{-}\Theta$) and 1/T and from the slope Q value was calculated. Effective activation energy (Ea) was calculated by Ea = - 2.303x1.987x [d log i/d(1/T)]. The values are presented in table2.

2- Furaldehyde retards corrosion at ordinary temperature but inhibition is reduced at higher temperature. The amount of decrease in inhibition efficiency depends on the

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difference of effective activation energy. The values indicate that 2-furaldehyde molecules are bound to the surface of mild steel by specific adsorption processes which lead to formation of surface film over mild steel surface. Changes in activation energies suggest that the inhibitor changes the potential differences of metal –solution interface by adsorption.

Quantum chemical studies:

HOMO and LUMO were calculated using pm3 method. E_{HOMO} and E_{LUMO} are found to be -9.712eV and -0.451eV respectively. These values point to adsorption of the inhibitor molecule on mild steel surface. The low inhibition efficiency of 2-furaldehyde is attributed to larger difference between the two values as smaller gap in energy values lead to decrease in corrosion rate.[8].

Scanning Electron Microscope Studies.

The scanning electron micrographs of mild steel in sea water with and without inhibitor are shown in figure4. Severe corrosion can be seen in mild steel treated with sea water only (a). Severely corroded surface is quite clearly visible in fig.2 (a). There is presence of corrosion products on the metal surface. Addition of 2-furaldehyde lessens the corrosion of mild steel to some extent as evident from the micrograph (b).The corroded parts are somewhat seems to be covered. The corroded parts as seen in fig.4 (a) are not seen in fig.4 (b). 2-furaldehyde molecules are not able to provide complete protection to mild steel. The corrosion products are also seen in the micrograph but to lesser extent as compared to sea water.

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The following mechanism may be proposed in the light of above results:

$Fe \rightarrow Fe^{+2} + 2e^-$

$Fe^{+2} + [O] \rightarrow Fe^{+3} + e^-$

$Fe^{+3} + 2\text{-FD} \rightarrow [Fe^{+3} - 2\text{-FD}]$

The cathodic reaction: $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$

Conclusions:-

1. 2-furaldehyde inhibits corrosion of mild steel in sea water to some extent. The low inhibition can be attributed to preferential adsorption of chloride ions on the mild steel surface.

2. Inhibition efficiency increases with inhibitor concentration and decreases with increase of temperature.

3. It acts as cathodic type inhibitor.

4. The results of SEM are in correlation with the results of electrochemical , thermal analysis and quantum chemical studies.

References

1. L.Jha,A.B.Varkey & G.Singh, Trans SAEST,25(1), (1990) 29-32.
2. G.Singh,R.R.Singh, & P.K.Kar, proc. Of 5th National Convention of Electrochemist, Chennai, (1993) C-18.
3. E.machnikova, K.H.Whitmire & N.Hackerman, Electrochimica acta, Vol.53, No.20, (2008) 6024-6032.

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4. A.N.Maitra,A.Hecht,H.G.Feller & B.Droste,Metalloberflache,33,3(1979)

5. C. Deslouis, M.C. Lafont, N. Pébère and D. You, Corros. Sci. 34, (1993) 1567.

6. Wang Donging., proc. 11th ICC., Italy,vol.4, (1990), 597.

7. P. Marcus and J.M. Herbelin, Corros. Sci., 34, (1993), 1123.

8. V.S.Sastri & J.R.Perumareddi,Corrosion,50(1994),432.

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Fig.1. Galvanostatic polarization curves for mild steel in presence of different concentrations of 2-furaldehyde in sea water

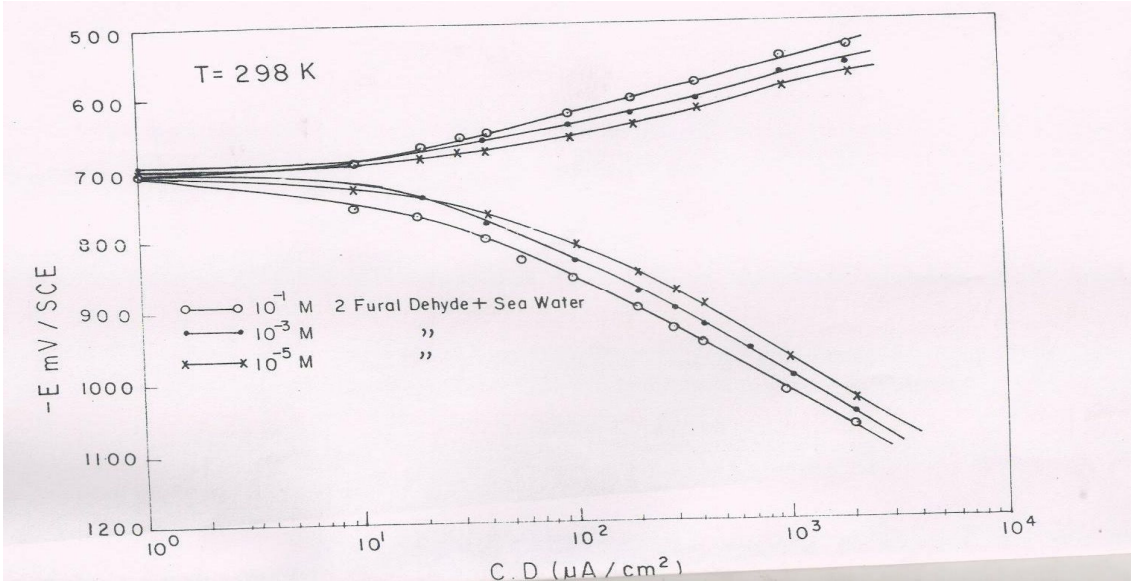
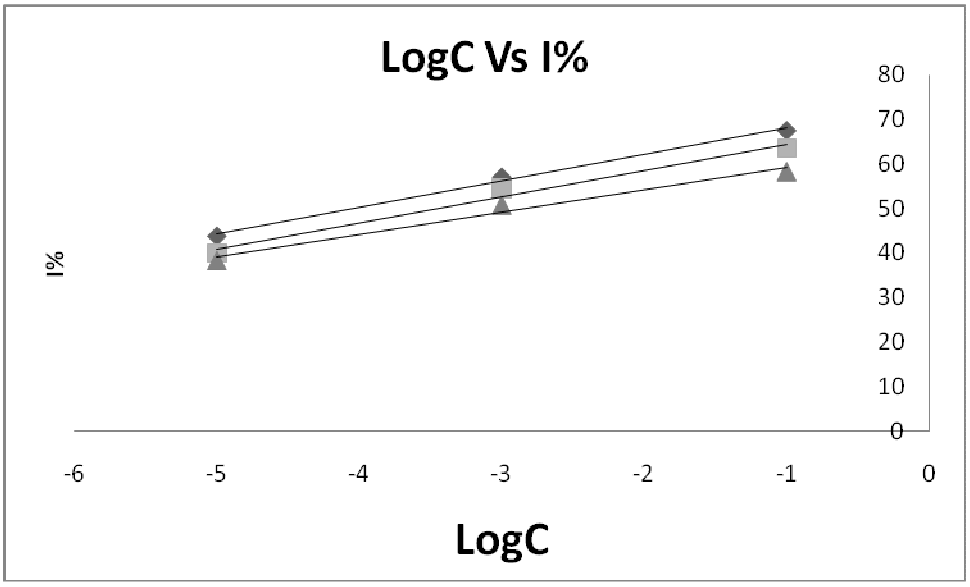


Fig.2. LogC vs I% at different temperature



◊=298K □ =308K Δ=318K

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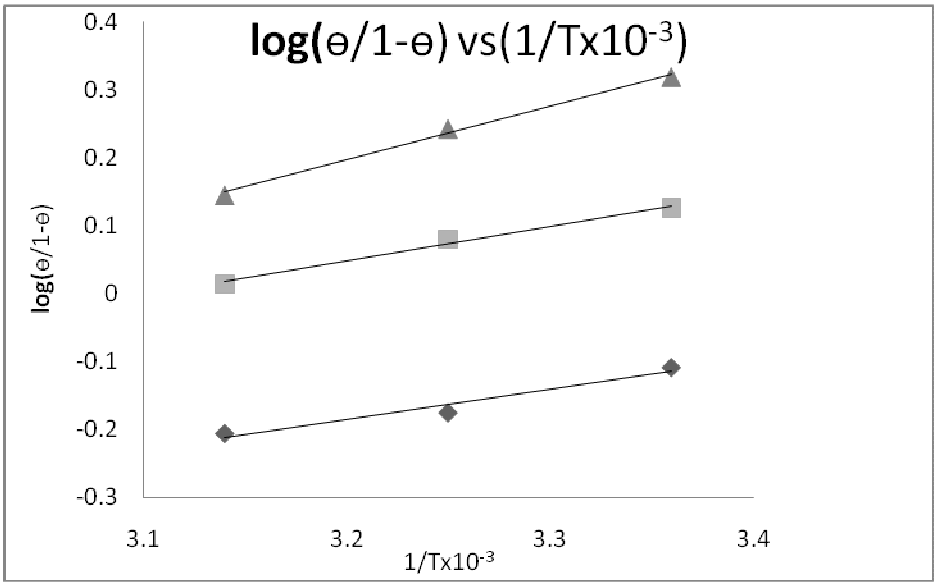
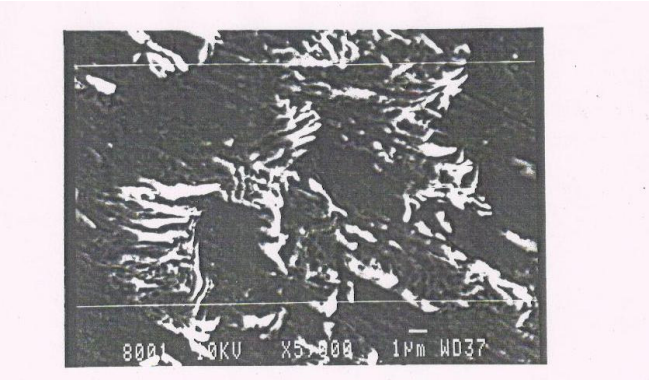
Fig.3. Log (ɵ/1- ɵ) Vs $1/Tx10^{-3}$

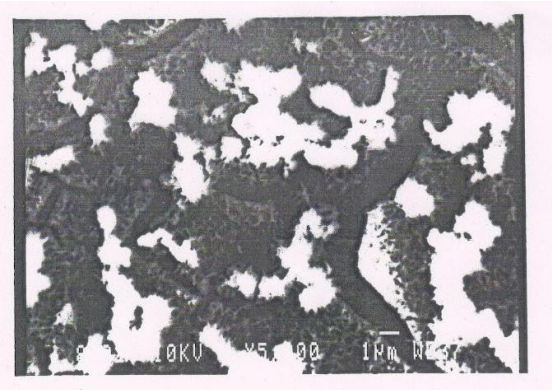


◊=10^{-5}M □ =10^{-3}M Δ=10^{-1}M

Fig.4.(a) SEM of mild steel in (a) sea water and (b) in presence of 10^{-1}M 2-furaldehyde in sea water



(a)



(b)

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Table1. Corrosion parameters of mild steel in presence and absence of 2-furaldehyde in sea water

Concentration	Temperature (K)	Corrosion potential (mV)vsSCE	Corrosion current (mA/cm^2)	bc (mV/dec)	ba (mV/dec)	Inhibition efficiency (I%)
0 (sea water)	298	710	0.525	150	60	--
10^{-1}M 2-FD	298	730	0.170	175	75	67.6
10^{-3}M 2-FD	298	710	0.225	175	75	57.1
10^{-5}M 2-FD	298	735	0.295	170	70	43.8
0 (sea water)	308	720	0.550	165	65	--
10^{-1}M 2-FD	308	740	0.200	185	85	63.6
10^{-3}M 2-FD	308	715	0.250	180	85	54.5
10^{-5}M 2-FD	308	745	0.315	175	80	40.0
0 (sea water)	318	750	0.600	170	69	--
10^{-1}M 2-FD	318	765	0.250	180	85	58.3
10^{-3}M 2-FD	318	745	0.295	175	80	50.8
10^{-5}M 2-FD	318	770	0.370	175	80	38.3

Table 2.Heat of adsorption and Effective activation energy values of mild steel in presence of 2-furaldehyde in sea water.

concentration	Q (Kcal)	Ea (Kcal)
10^{-1}M 2-FD	18.824	2.768
10^{-3}M 2-FD	8.75	2.031
10^{-5}M 2-FD	5.381	1.769
0 (sea water)	--	1.523

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