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Full Length Research Paper

Inhibiting effect of cetyl pyridinium chloride (CPC) on the corrosion of mild steel in acidic medium

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The inhibiting effect of Cetyl Pyridinium Chloride (CPC) on mild steel in 1M Hydrochloric acid has been studied by using three techniques namely: weight loss, electrochemical polarization and metallurgical research microscopic techniques. Results obtained reveal that CPC is good inhibitor and shows very good corrosion inhibition efficiency (IE). The IE was found to vary with concentration of inhibitor and temperature. The electrochemical polarization result revealed that CPC is anodic in nature.

Key words: Corrosion inhibition, mild steel, electrochemical polarization.

INTRODUCTION

Mild steel is widely used as an inexpensive structural metal for fabrication of large number of products. Corrosion of metals generally occurs in the presence of oxygen and moisture and involves two electrochemical reactions. Oxidation occurs at anodic site and reduction occurs at cathodic site. In acidic medium hydrogen evolution reaction predominates. Corrosion inhibitors reduce or prevent these reactions, they are adsorbed onto the metal surface and act by forming barrier to oxygen and moisture and some of the inhibitors facilitate formation of passive film on the metal surface. Most of the well-known acid inhibitors used in industry are organic compounds having multiple bonds in their molecules that mainly contain nitrogen, sulphur, oxygen atoms through which they get adsorbed on the metal surface (Swift et al., 1993; Skryler et al., 1991; Moretti et al, 2004; Frignani et al., 1991; Granese et al., 1992; Raicheva et al., 1993). The effect of temperature on the inhibiting process is of great importance in industry. Effective inhibitors are expected to perform under a wide range of conditions (Prakash et al., 2006) reported the use of four inhibitors namely 2-mercaptobenzoxazol, 2-mercaptobenzimidazol, N-cetyl-pyridiniumbromide and propargylbenzene sulphonate was studied in the presence of 20% HCl solution. The use of surfactants has been studied and it was shown that the inhibition efficiency increases with the no. of carbon atoms in the molecule. These compounds show very good inhibition efficiency near their critical micelle concentration (Achouri et al., 2001; Chababe et al., 2003; Boxayad et al., 1998; Bastidas et al., 2000). Appa rao and coworkers, 2006, studied the effect of ternary inhibitor system containing phosphonate, molybdate and Zn^{2+} in corrosion control of carbon steel. Some researchers also studied inhibition effect of selected quaternary ammonium compounds (Bereket and Yurt, 2002; Monika et al., 2005; Chaudhary et al., 2007). In the present paper, study of the inhibiting effect of CPC on mild steel surface in aggressive 1M HCl solutions is presented.

EXPERIMENTAL

Electrolyte

For the preparation of aggressive HCl solution AR grade(Aldrich) HCl was used. Approximate concentrations of acid were prepared using double distilled water. Inhibitor concentrations ranging from 50 to 250 ppm in 1 M HCl solution were prepared.

Specimens

Mild Steel specimens of chemical composition C-0.14, Si-0.03, Mn-0.32, S-0.05, P-0.2, Ni-0.01, Cu-0.01, Cr-0.01 and Fe-Balance (wt %) were used. The specimens were mechanically polished with emery papers of 150, 320 and 600 grade, degreased with acetone, washed in double distilled water and finally dried. The cleaned specimens were weighed before and after immersion in 1 M HCl for 24 h in the absence and presence of various concentrations of CPC at different temperatures in the range of (25°, 35°&45°C).

Table 1. Inhibition efficiencies (IE) obtained from weight loss data in 1 M HCl solution in presence and absence of Cetyl Pyridinium chloride (CPC) at different temperatures.

Temperature (^oC)	Concentration of CPC (ppm)	Corrosion rate (mpy)	IE (%)
25	ZERO	206.65	Blank
25	50	25.10	87.85
25	100	21.05	89.81
25	150	17.00	91.77
25	200	13.36	93.53
25	250	12.55	93.92
35	ZERO	606.80	Blank
35	50	31.16	94.86
35	100	25.10	95.86
35	150	23.48	96.61
35	200	18.21	97.30
35	250	6.88	98.86
45	ZERO	1755.82	Blank
45	50	27.12	98.45
45	100	25.50	98.54
45	150	22.26	98.73
45	200	21.45	98.77
45	250	25.50	98.86

Weight loss measurements

The mild steel strips of size (3.0 x 1.5 x 0.0025) cm were used for weight loss measurements. Weight loss measurements were carried out at different temperatures (25^o, 35 and 45^{o}C) for 24 h in 1M HCl solutions. The specimens were weighed before and after immersion and the percentage inhibition efficiency (1E) was calculated using the following equation.

$$IE = \frac{(w_o - w)}{w} \times 100$$

where w_o and w are the weight loss in absence and presence of the inhibitor respectively.

Electrochemical polarization measurements

For electrochemical polarization studies mild steel strips of same composition and coated with commercially available lacquer with exposed area of 1.0 cm^2 were used and experiments were carried out at temperature 35 $\pm$ 1^{o}C. The electrochemical measurements were carried out in a conventional three-electrode cell. The working electrode was a mild steel specimen of 1 cm^2 area. A saturated calomel electrode (SCE) and a platinum foil were used as the reference and auxiliary electrodes respectively. The temperature was controlled thermostatically at 35 $\pm$ 1^{o}C. Equilibrium time leading to steady state of the specimens was 30 min. Electro chemical polarization studies were carried out using a potentiostat/galvanostat PGS 20IT (Radiometer Analytical SA).
Corrosion rate (CR) was calculated using the following formula.

$$CR = \frac{0.13 \times I_{corr} \times EW}{D}$$

where I_{corr} = Corrosion current density in mA/cm^2.

EW = Equivalent weight of the metal in g/eq.
D = Density of metal in g/cm^3.

Metallurgical research microscopy technique

To study the morphology of corroded surface of the specimen after exposing it to 1 M HCl in the absence and presence of various concentrations of both the inhibitors at various temperatures range (25^o to 45^{o}C) micrographs were taken through Metallurgical research microscope (JSM– 840 JEOL). All micrographs were taken at magnification of x 400.

RESULTS AND DISCUSSSIONS

Weight loss studies

The corrosion inhibition efficiencies (IE) of CPC obtained from weight loss data are given in Table 1. It is seen that CPC inhibit corrosion of mild steel in 1M HCl acid at all concentrations under study. It has been observed that IE of CPC increases with the increase in Concentration as shown in Figure 1. The influence of temperature on IE of CPC at various concentrating is shown in Figure 2. The IE increases with temperature up to 45^{o}C and after that it decreases, IE decreases at higher temperature due to desorption of inhibitor.

Electrochemical polarization measurements

Figure 3 shows the polarization curves in 1M HCl solutions with and without addition of CPC at different concentrations. The corrosion current density decreases with

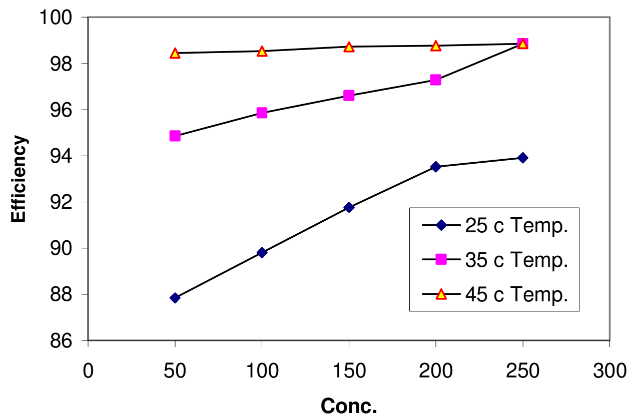

Figure1. Variation of percentage inhibition efficiency with CPC concentration.

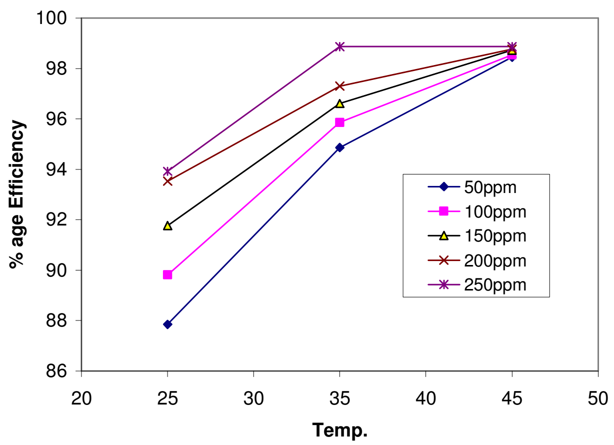

Figure 2. Variation of percentage inhibition efficiency of CPC with solution temperature.

increasing inhibitor concentrations and the corrosion potential shifts depending on the inhibitor concentration. The values of the electrochemical parameters obtained from the polarization curves, namely: corrosion potential (E_{corr}), cathodic Tafel slope (β_c), anodic Tafel slope (β_a),corrosion current density (I_{corr}), resistance polarization (Rp) and %age inhibition efficiency (%I.E.) for the different concentrations of CPC is given in Table 2. The inhibition efficiency in each case was calculated according to the following equation.

$$IE\ (\%) = (1 - I_{corr} / I'_{corr}) \times 100$$

where I_{corr} and I'_{Corr} are the corrosion current density in the absence and in the presence of inhibitor respectively.

The results depicted in Table 2 shows a decrease of the corrosion current density with the increasing CPC concentrations. The addition of CPC also leads to change in cathodic and anodic Tafel slopes. The corrosion potential is found to shift to more positive potential with in-

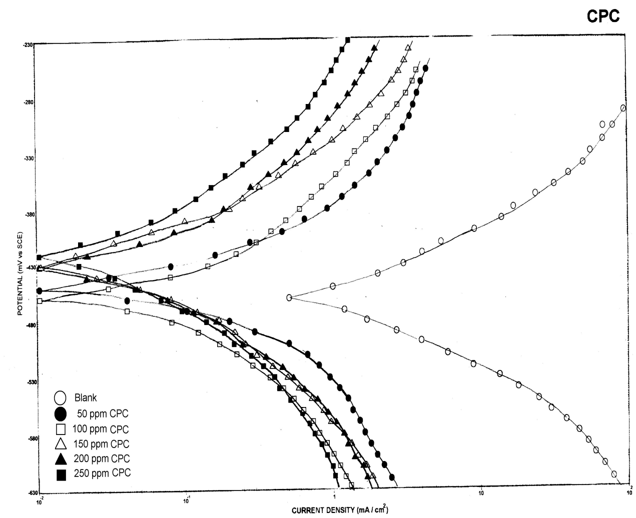

Figure 3. Polarization curves of mild steel in 1M HCl in absence and presence of various concentrations of CPC.

crease in inhibitor concentration in presence of CPC. Thus the corrosion inhibition of mild steel in 1M HCl solutions is predominantly under anodic control. The inhibition efficiency is found to reach to a maximum valueat 250 ppm inhibitor concentrations. The maximum values attained is 98% in 1M HCl solutions in presence of 250 ppm concentrations of CPC at 35°C.

Metallurgical research microscopy

In order to evaluate the conditions of the mild steel surfaces in contact with 1M HCl solutions, a superficial analysis was carried out. The micrographs of the specimens in presence of 1 M HCl solutions are shown in Figure 4 (a). The influence of the CPC addition (250 ppm) on the mild steel in Figure 4(b). It can be calculated from the figures that pitting corrosion does not occur and solid particles do not appear on the surface. The surface roughness of the mild steel appears lower with addition of the inhibitor than that without addition. The roughness is found to be more uniform after treatment with acidic solution which contains CPC.

Corrosion inhibition of mild steel in acidic solution by CPC can be explained on the basis of adsorption. CPC inhibit the corrosion by controlling the anodic reaction.

Conclusions

Cetyl pyridinium chloride (CPC) inhibited mild steel corrosion in 1M HCl solutions. Corrosion inhibition of mild steel in 1M HCl solutions by CPC is under anodic control. Inhibition efficiency of CPC increases with concentration. The weight loss measurements are in good agreement with electrochemical method. The micrograph show that inhibition of corrosion by CPC is due to formation of pro-

Table 2. Electrochemical parameters of mild steel corrosion in 1 M HCl solution containing various concentration of Cetyl Pyridinium Chloride (CPC) at 35^{0}C.

Concentration	E corr (mV)	βa mv/ decades	βc mv/ decades	I.corr. µA/cm^2	Corrosion Rate (mpy)	IE (%)
Blank	-464	1.95	2.48	1300	600.51	Blank
50	-450	47.62	65.21	70	32.33	94.62
100	-456	79.89	110.11	56	25.87	95.69
150	-430	75.00	120.00	49	22.64	96.23
200	-430	111.11	103.45	41	18.94	96.85
250	-425	105.24	110.00	19	9.23	98.46

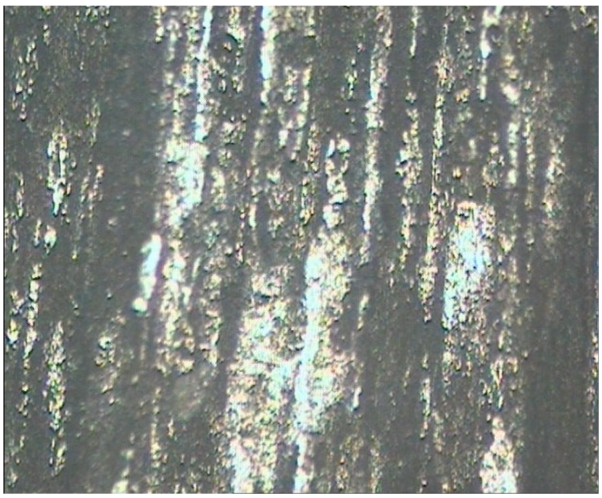

Figure 4a. -Mild steel sample blank kept in 1 M HCl for 24 h at 35^{o}C.

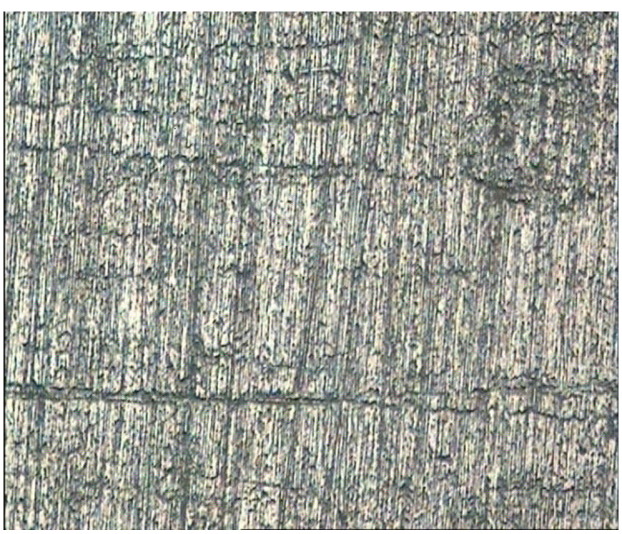

Figure 4 (b). Mild steel sample kept in 1 M HCl for 24h with 250 ppm CPC at 35^{o}C.

tective film on the mild steel surface.

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