THE INHIBITIVE EFFECT OF HYDROXYETHYLCELLULOSE ON MILD STEEL CORROSION IN HYDROCHLORIC ACID SOLUTION

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ABSTRACT

The inhibitive effects of Hydroxyethylcellulose (HEC) as inhibitor for mild steel corrosion in 1.0M HCl and 1.5M HCl under atmospheric exposure have been investigated using weight loss technique. The study revealed that mild steel corrodes in HCl solution, but is inhibited in the presence of HEC. The corrosion rate decreased with increase in HEC concentration. The inhibition efficiencies increased with inhibitor concentration. The maximum inhibition efficiency of 69.617% and 58.145% were observed with mild steel corrosion in 1.0M HCl and 1.5M HCl respectively. This inhibition could be attributed to the molecules of the HEC adsorbed on the mild steel surface forming elastic film which reduces the surface area available for corrosion attack. The corrosion current was also determined. It was observed that corrosion current was higher in 1.5M HCl than 1.0M HCl. Also, the corrosion current decreased with increasing inhibitor concentration.

Keywords: Hydroxyethylcellulose; Mild steel; Inhibition efficieny; Corrosion current; Hydrochloric acid.

INTRODUCTION

Some metals such as mild steel, copper, zinc, aluminium and their alloys lend themselves to many engineering applications because of their outstanding inherent and synergistic properties. However, during service these metals come in contact with aggressive environments which negatively affect their stability in service leading to a phenomenon often called corrosion. Corrosion, therefore, is the destruction of materials resulting from an exposure and interaction with the environment (Sharma, et al. 2010). It is a major problem that must be confronted for safety, environment and economic reasons in various chemical, mechanical, metallurgical, biochemical and medical engineering applications, and more specifically in the design of a much more varied number of mechanical parts which equally vary in size, functionality and useful lifespan. To reduce these corrosion problems in aggressive environments, inhibitive effects of various chemical compounds and naturally occurring substances have been evaluated as effective corrosion inhibitors (Sanghari et al., 1995). The naturally occurring substances containing polar functions with nitrogen, sulphur and/or oxygen in the conjugated system have been reported to exhibit good inhibitive properties (Ameer, et al., 2000; Popova, et al., 2003; Oguzie et al., 2004; and Quraishi and Sharma, 2005). A number of organic compounds (Mathiyamsu, et al., 2001; Ochao, et al., 2004; Oguzie et al., 2004, Oguzie, 2004) are known to be applicable as corrosion inhibitors for steel in acidic environments. In view of this, the use of polymers as corrosion inhibitors has attracted considerable attention recently (Rajendran, et al. 2005). Polymers are used as corrosion inhibitors because, through their functional groups they form complexes with metal ions and on the metal surface these complexes occupy a large surface area, thereby blanketing the surfaces and protecting the metal from corrosive agents present in the solution (Rajendran, et al. 2005). The corrosion inhibition of mild steel in 1M H_2SO_4 by Polyvinyl pyrrolidone (PVP), (Umoren et al. 2008) and the synergistic effect of iodide ions were investigated using weight loss and hydrogen evolution methods in the temperature range of 30-60^oC. The corrosion rates of mild steel decreased with the increasing concentration of PVP, while the inhibition efficiency (%I) increased. Corrosion inhibition of mild steel in 2M HCl and 1M H_2SO_4 by leaf extracts of Occimum viridis (OV) has been reported (Oguzie, 2006). (Umoren, et al., 2006) has reported that inhibition (%I) increased with increase in temperature and concentration of PVA, on the corrosion inhibition of mild steel using polyvinyl alcohol (PVA) in H_2SO_4 at 30 – 60^oC. Umoren et al (2006), has also reported good inhibitive capability of polyethylene glycol (PEG) using weight loss and hydrogen techniques. The inhibition effect of some polyethylene glycols (PEGs) on carbon steel corrosion at 25^0C in 0.5N HCl as corrosive medium was evaluated by weight loss polarization and electrochemical impedance spectroscopy techniques (Ashassi – Sorkhabi et al. 2006). In this paper, weight loss technique was employed to study the inhibitive capability of Hydroxyethylcellulose (HEC) on the corrosion of mild steel in Hydrochloric acid. The effects of inhibitor concentration and corrodent concentration are reported.

MATERIALS AND METHODS

Mild steel sheet of composition (wt.%) C = 0.18, Mn = 0.5, P = 0.35, Si = 0.03, and the remainder Fe, was obtained from delta steel company, Delta state. The Mild steel sheets of thickness, 0.2cm were mechanically press cut into 4cm x 2cm coupons. A small hole was drilled at one side of the coupons to support the hook. The coupons were polished mechanically using silicon carbide papers of grade no. 166, washed thoroughly with distilled water and degreased with ethanol and acetone and air dried. Stock solutions of 5.0 x 10^{-4}M, 1.0 x 10^{-3}M, 1.5 x 10^{-3}M, 2.0 x 10^{-3}M and 2.5 x 10^{-3}M of HEC (Hydroxyethylcellulose) were prepared. Similarly, Stock solutions of 1.0M HCl and 1.5M HCl were prepared using serial dilution principle.

Gravimetric (Weight loss) measurements

250ml beakers containing different concentrations of HCl solution and HEC solution were used. The weighed mild steel coupons were suspended in the beaker with the aid of glass rods and hooks. The coupons were retrieved at 24-hour interval, progressively for 7 days (168hours); washed by immersion in distilled water and ethanol. At the end of the test, the coupons were carefully washed in absolute ethanol and nitric acid to quench further corrosion. The weight losses of coupons were evaluated in grammes as the difference between the initial weight before immersion and weight after immersion. From the results obtained the following corrosion parameters were evaluated.

Corrosion Rate: This is expressed in millimeter per year (mm/yr).

$$\text{Corrosion rate (mm/yr)} = \frac{87600W}{\rho A t}$$

Where W = weight loss in grammes (g)

ρ = density of the coupon (g/cm^3)

A = area of coupon in cm^2

t = time of exposure (hours)

Inhibition Efficiency (IE%): This is percentage by which corrosion rate is reached in the presence of inhibitor compared with the rate in which corrosion occurs without inhibitor ie

$$IE\% = [1- (W_1/W_0)] \times 100$$

Where W_1 = weight loss in the presence of inhibitor

W_o = weight loss in the absence of inhibitor

Surface coverage (θ):- This is the area covered by the inhibitor.

$$\theta = [1- (W_1/W_0)]$$

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RESULTS AND DISCUSSIONS

The corrosion rates of mild steel coupons in 1.0M HCl and 1.5M HCl with and without various concentrations of inhibitor (HEC) were determined. The results obtained are presented in Tables 1.0 and 2.0 respectively. It was observed that corrosion rates decreased with increase in concentration of the inhibitor (HEC). This showed that HEC in solution inhibited the corrosion of mild steel in HCl.

Presented in the Tables 1.0 and 2.0 also are the inhibition efficiency and degree of surface coverage of HEC. It was observed that inhibition efficiency and degree of surface coverage increased with increasing concentration of inhibitor (HEC).

Table 1.0
Calculated values of corrosion rate (mm/yr), inhibition efficiency (IE %) and degree of surface coverage (θ) for hydroxyethylcellulose (HEC) in 1.0M HCl corrosion of Mild Steel from weight loss data.

Inhibitor Concentration	Corrosion Rate (mm/yr)	Inhibitor Efficiency (I.E. %)	Degree of Surface Coverage (θ)
Blank	2.476	-	-
$5.0x10^{-4}$M	1.061	54.720	0.547
$1.0x10^{-3}$M	0.964	56.342	0.563
$1.5x10^{-3}$M	0.751	64.454	0.645
$2.0x10^{-3}$M	0.740	69.322	0.693
$2.5x10^{-3}$M	0.621	69.617	0.696

Table 2.0
Calculated values of corrosion rate (mm/yr), inhibition efficiency (IE %) and degree of surface coverage (θ) for hydroxyethylcellulose (HEC) in 1.5M HCl corrosion of Mild Steel from weight loss data.

Inhibitor Concentration	Corrosion Rate (mm/yr)	Inhibitor Efficiency (I.E. %)	Degree of Surface Coverage (θ)
Blank	3.075	-	-
$5.0x10^{-4}$M	1.784	34.364	0.344
$1.0x10^{-3}$M	1.672	46.136	0.461
$1.5x10^{-3}$M	1.287	53.032	0.530
$2.0x10^{-3}$M	1.281	57.551	0.576
$2.5x10^{-3}$M	1.073	58.145	0.581

From the results, it was obvious that mild steel corroded in HCl solution. This is expressed in terms of weight loss of mild steel. The rate of corrosion is dependent upon the concentration of the corrodent (HCl). Upon addition of inhibitor, (HEC), it was observed that the weight loss decreased. However, the weight loss decreased more as the concentration of inhibitor increased. This is evident in Fig. 1 and Fig. 2.

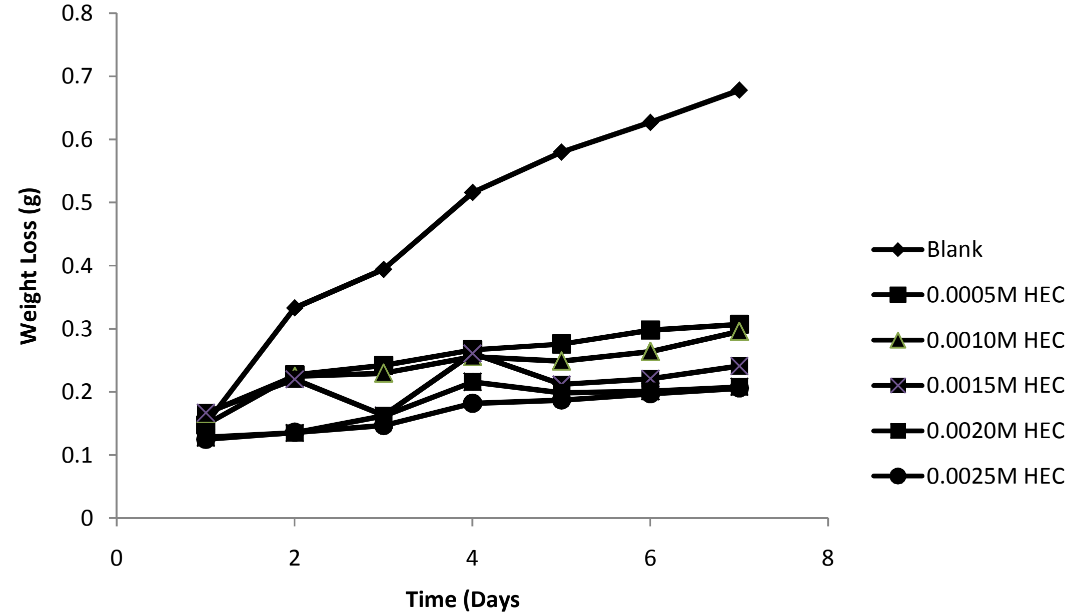

Fig. 1: Plot of Weight loss for Mild Steel corrosion in 1.0M HCl in the presence and absence of different concentration of HEC

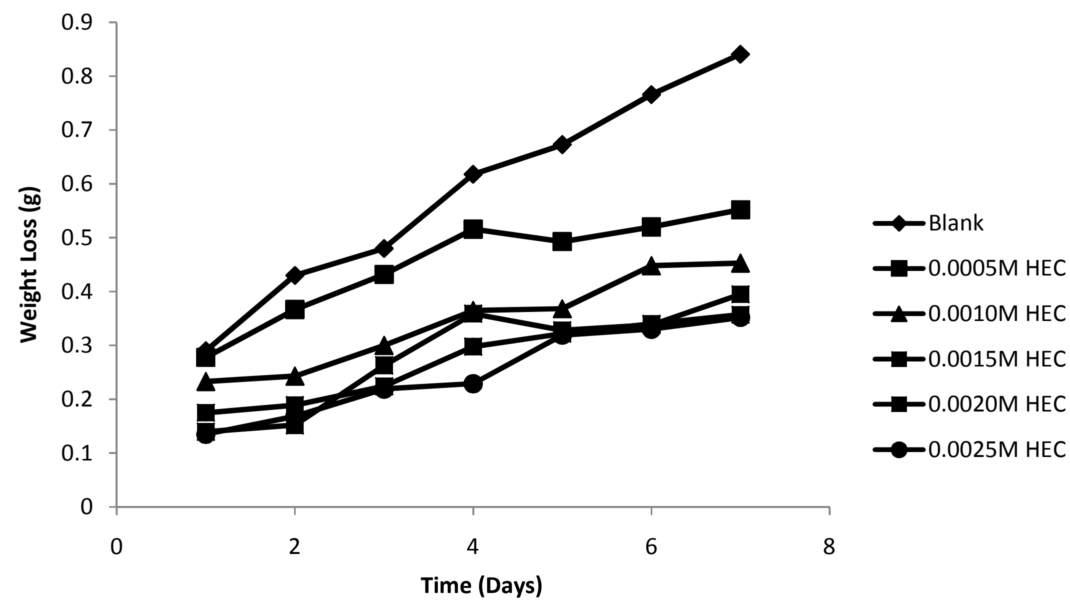

Fig. 2: Plot of Weight loss for Mild Steel corrosion in 1.5M HCl in the presence and absence of different concentration of HEC

In Fig. 3, the corrosion rate was shown to be higher in 1.5M HCl than in 1.0M HCl. This was because the acidic strength in the former was more than in the latter and therefore should have more attack on substrates. In addition, the corrosion rates decrease with increase in inhibitor concentration. The decrease could be due to adsorption of molecules of HEC on the surface of the mild steel, hence forming elastic films which may retard the diffusion of HCl to the mild steel as well as reduce the exposed surface for corrosion.

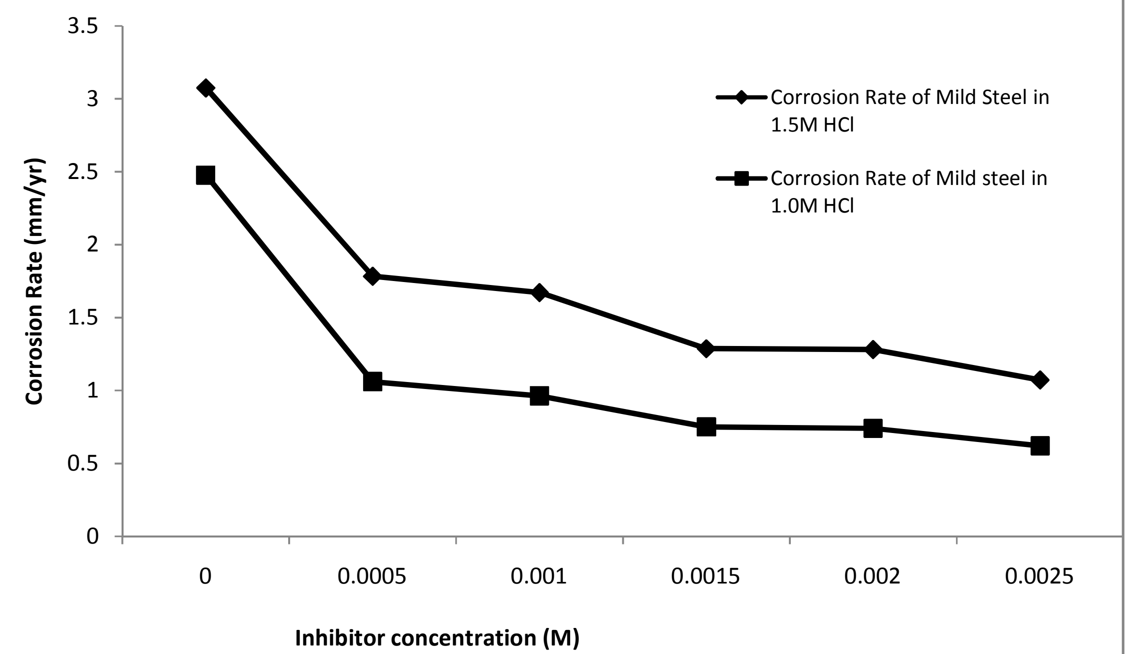

Fig.3: Corrosion Rate of Mild Steel in the Presence and absence of of HEC in 1.5M HCl and 1.0M HCl

The inhibition efficiency and degree of surface coverage of HEC are shown in Fig. 4 and Fig. 5. As shown, inhibition efficiency increases with inhibitor concentration. The maximum percentage inhibition of 69.147% and 58.145% were recorded for 1.0M HCl and 1.5M HCl respectively. Similar results were revealed by degree of surface coverage determination, where higher concentration of inhibitor covered more surface both in 1.0M HCl and 1.5M HCl, thereby reducing the mild steel surface area available for corrosion.

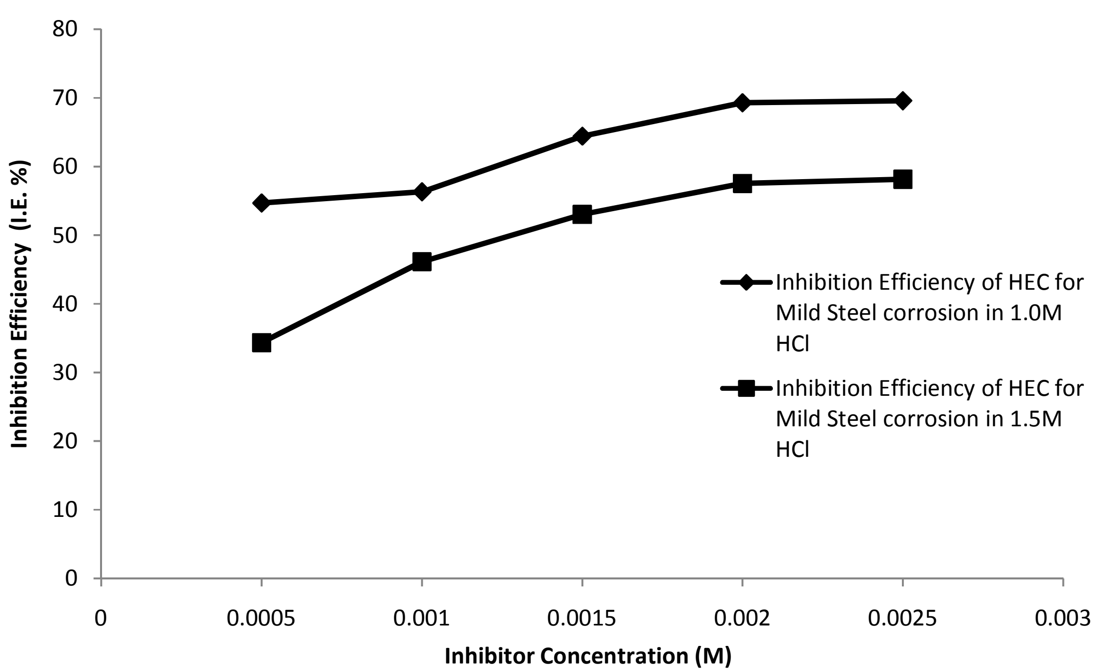

Fig 4: Inhibition Efficiency of Mild Steel in the Presence and Absence of HEC in 1.0M HCl and 1.5M HCl

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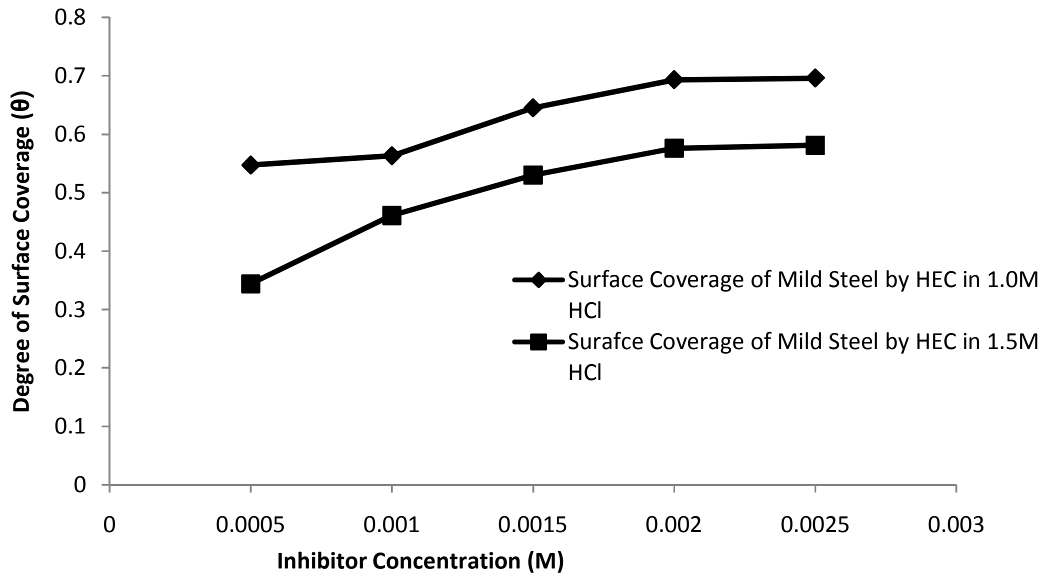

Fig.5: Degree of surface Coverage of Mild Steel by HEC in 1.0M HCl and 1.5M HCl

Corrosion Current

Corrosion current is determined from the expression (Jonnes, 1996):

$$I_{corr} = \frac{CR \times \rho \times A}{K \times Ew}$$

Where I_{corr} = corrosion current in Amps.

CR = corrosion rate in mm/yr

ρ = density of metal coupon in g/cm^3

A = Area of coupon in cm^2

K = Constant that defines the units for the corrosion rate

Ew = Equivalent weight of corrodent in grams/equivalent

Table 3. Calculated values of corrosion current (Amps) for Mild steel corrosion in 1.0M HCl and 1.5M HCl.

Inhibitor Concentration	1.0M HCl	1.5M HCl
Blank	1.106×10^{-4}	$1.37\ 1x\ 10^{-4}$
0.0005M	5.008×10^{-5}	9.001×10^{-5}
0.0010M	4.807×10^{-5}	7.393×10^{-5}
0.0015M	3.927×10^{-5}	6.445×10^{-5}
0.0020M	3.395×10^{-5}	5.826×10^{-5}
0.0025M	3.361×10^{-5}	5.716×10^{-5}

Form the results obtained, corrosion current was observed to decrease with increasing inhibitor concentration. Again, corrosion current was observed to be higher in 1.5M HCl than in 1.0M HCl.

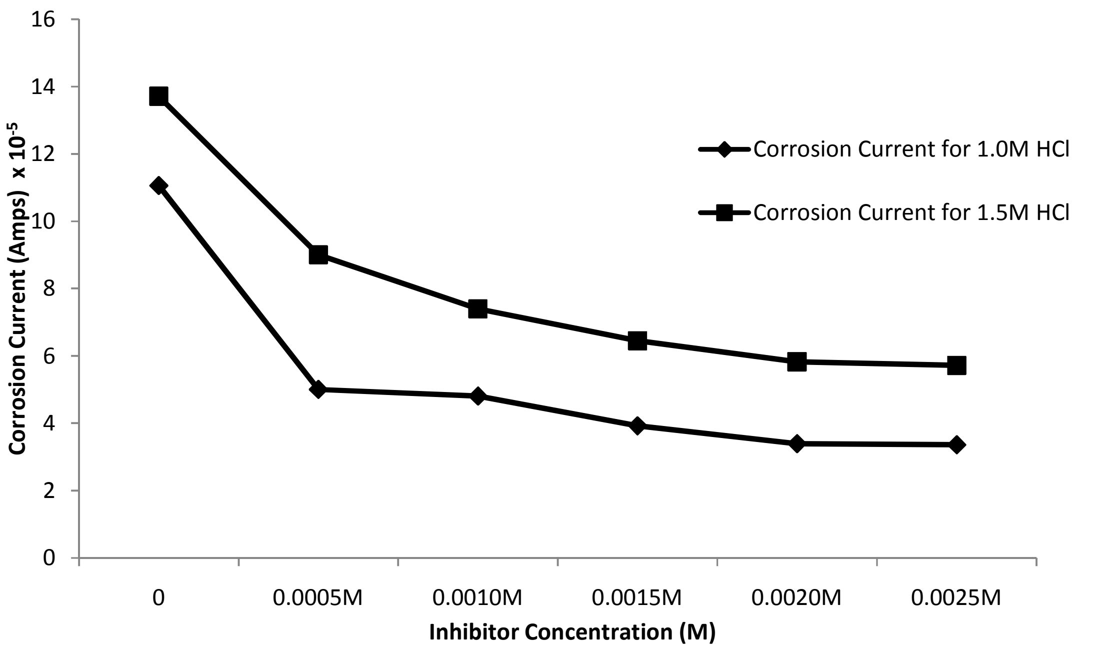

Fig.6 : Plot of Corrosion Current for Mild Steel Corrosion in 1.0M HCl and 1.5M HCl

CONCLUSION

1. Hydroxyethylcellulose (HEC) worked effectively as an inhibitor for corrosion of mild steel in 1.0M HCl and 1.5M HCl solutions.
2. Corrosion rate increased with increase in corrodent concentration but decreased as inhibitor concentration increased.
3. The inhibition efficiency and surface coverage increase with increase in inhibitor concentration.
4. The inhibition is attributed to the molecules of HEC which is adsorbed on the surface of the mild steel.
5. The higher the concentration of HCl, the higher the rate of corrosion.
6. The corrosion current was observed to decrease with increasing inhibitor concentration. Again, corrosion current was higher in 1.5M HCl than in 1.0M HCl

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