A Study of Mild Steel Corrosion Using *Adhatoda Vasica* (AV) Extract as Inhibitor in Different Acid Medium

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Abstract: Corrosion behavior of mild steel in acidic medium using *Adhatoda vasica* (AV) extract was investigated. The inhibitive effective of *Adhatoda vasica* on the corrosion of mild steel in different acidic medium has been studied by weight loss and polarization methods. The E_{corr} values are shifted slightly towards negative side in presence of inhibitors which indicate the inhibitors inhibit the corrosion of mild steel in acids solution by controlling both anodic and cathodic reactions due to the blocking of active sites on the metal surface. It is evident that inhibitors bring about considerable polarization of the cathode as well as anode. It was, therefore, inferred that the inhibitive action is of mixed type.

Keywords: Corrosion, Inhibition, Mild Steel, *Adhatoda vasica* (AV).

Introduction

Mild steel is widely used in most of the chemical industries due to its low cost and easy availability for fabrication of various reaction vessels, tanks, pipes, *etc.* Since it suffers from severe corrosion in aggressive environments, it has to be protected. Acids have been used for drilling operations, pickling baths and in de-scaling processes. To reduce the corrosion problems in these environments inhibitive effects of various organic compounds have been tried so far. Organic compounds having hetero atoms are found to have higher basicity and electron density and thus assist in corrosion inhibition[1]. There are numerous naturally occurring substances like *Embellica officianalis, Terminalia chebula, Terminalia bellirica*[2], a mixture of latter three, *Sapindus trifolianus*, *Capparis decidua*[3], *Prosopis juliflora*[4] and

Quinoline based Cinchona alkaloids[5] have been evaluated as effective corrosion inhibitors. Due to the bio-degradability, eco-friendliness, cost-effectiveness, less toxicity and easy availability of this material, the trend of using them have become increasingly important in the recent years. To evaluate the extract of *Adhatoda vasica* (AV) probable acid corrosion inhibitor in mineral acid for mild steel.

Experimental

According to ASTM method as reported already, all the test specimens having the size of 5 cm × 1 cm (Fe = 99.687, Ni = 0.012, Mo = 0.015, Cr = 0.043, S = 0.014, P = 0.009, Si = 0.007, Mn = 0.196 and C = 0.017) were used for the weight loss measurements. Mild steel specimen was polished using 1/0, 2/0, 3/0 and 4/0 emery papers and finally degreased with the organic solvent trichloroethylene. The specimens were weighed. After weighing the specimens were immersed in 1 M sulphuric acid with and without inhibitor. After 1 h, the specimens were washed with distilled water, dried and again weighed. The weight loss was noted. From this weight loss value, corrosion rate and inhibition efficiency were determined.

Corrosion rate has been determined from the following relationship.

$$Corrosion\ rate\ (mpy) \quad = \quad \frac{534 \times Weight\ loss\ in\ mg}{Density\ in\ g/cc \times Area\ in\ sq.inches \times Time\ in\ h}$$

Inhibitor efficiency has been determined by using the following relationship.

$$Inhibitor\ efficiency\ (\%) \quad = \quad \frac{W_0 - W_e}{W_0}$$

Where, W_0 is the weight loss without inhibitor and W_e is the weight loss with inhibitor.

Electrochemical studies

Electrode surface preparation

The mild steel rod with an exposed area of 0.785 cm^2 was polished using 1/0, 2/0, 3/0 and 4/0 emery papers and finally degreased with the organic solvent trichloroethylene and immediately used for the experiments.

Electrode cell assembly

Electrochemical measurements were carried out in a glass cell with a capacity of 100 mL. A platinum electrode and a saturated calomel electrode were used as a counter electrode and reference electrode respectively. The mild steel electrode was then placed in the test solution (uninhibited and inhibited solutions) for 10-15 minutes before electrochemical measurements.

Electrochemical impedance spectroscopy (EIS) and Tafel polarization studies were conducted in a electrochemical measurement unit (Model 1280 B Solartron, UK). The EIS measurements were made at corrosion potentials over a frequency range of 10 kHZ to 0.01 Hz with signal amplitude of 10 mV. The Tafel polarization measurements were made after EIS for a potential range of -200 mV to +200 mV with respect to open circuit potential, at a scan rate of 1 m V/sec. The I_{corr}, E_{corr}, R_{ct} and C_{dl} values were obtained from the data using the corresponding "Corr view" and "Zview" softwares. The inhibition efficiency from potentiodynamic polarization was calculated from the value I_{corr} by using the formula.

$$\text{Inhibition efficiency (\%)} = \frac{I_{corr(blank)} - I_{corr(inh)}}{I_{corr(blank)}} \times 100$$

Where, $I_{corr(blank)}$ is the corrosion current in the absence of inhibitor. $I_{corr(inh)}$ is the corrosion current in the presence of inhibitor. The inhibition efficiency from impedance measurements was calculated using the formula

$$\text{Inhibition efficiency (\%)} = \frac{R_{ct(inh)} - R_{tr(blank)}}{R_{ct(inh)}} \times 100$$

Where, $R_{ct(inh)}$ is the charge transfer resistance in the presence of inhibitor. $R_{ct(blank)}$ is the charger transfer resistance in the absence of inhibitor.

Results and Discussion

Mild steel corrosion has been investigated by weight loss method from 1 N HCl, 1 N H_2SO_4 and 1 N H_3PO_4 (1 h). From the weight loss values the corrosion rate and inhibition efficiency were calculated and tabulated in Table 1. From the table, it could be observed that corrosion rate decreased with increase in concentration of inhibitor. The corrosion rate of mild steel in 1 N HCl (blank) = 180 mmpy, 1 N H_2SO_4 (blank) =196 mmpy and 1 N H_3PO_4 (blank) =210 mmpy were obtained.

Table 1. Comparison table of different acids using AV extract at (1 h)

S.No	Conc. of inhibitor, %	Corrosion Rate (mmpy)	Inhibition efficiency %
		1N HCl	
1.	blank	180	-
2.	0.02	108	40.00
3.	0.04	94	47.77
4.	0.06	80	55.55
5.	0.08	58	67.77
6.	0.10	40	77.77
		1N H_2SO_4	
1.	blank	196	-
2.	0.02	124	36.70
3.	0.04	110	43.87
4.	0.06	92	53.06
5.	0.08	70	64.28
6.	0.10	50	74.48
		1N H_3PO_4	
1.	blank	210	-
2.	0.02	138	34.28
3.	0.04	124	40.95
4.	0.06	106	49.52
5.	0.08	82	60.95
6.	0.10	64	69.52

From the table, it could be calculated that inhibition efficiency increased with increase in concentration of inhibitor. Maximum inhibition efficiency of AV (0.1%) was 77.77% for 1 N HCl. It is evident from the graph obtained by plotting concentration of inhibitor against inhibition efficiency as shown in Figure 1.
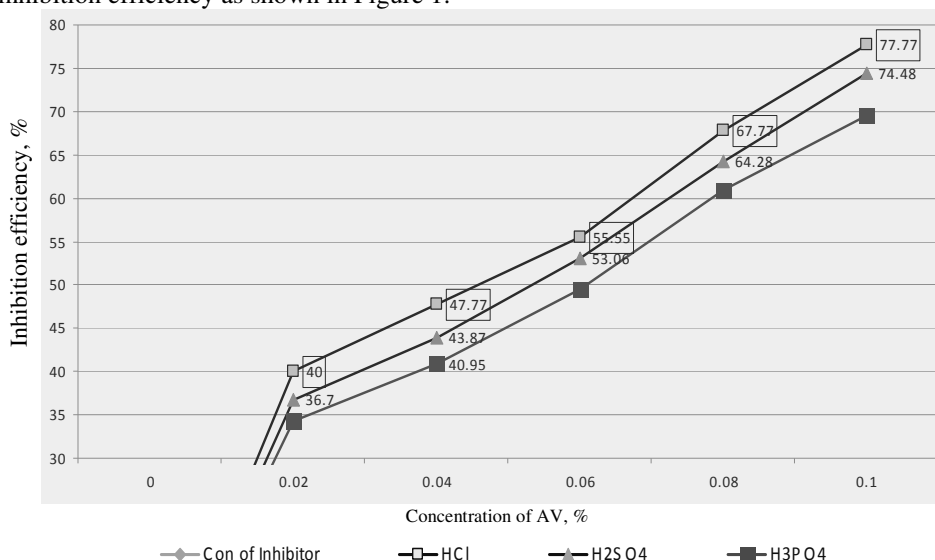

Figure 1. Effect of inhibition efficiency of AV on mild steel corrosion in different acid medium (1 h duration)

The inhibition was essentially based on the coverage of the metal surface by the inhibitor molecules, thus preventing contact of the corroding species with acid[6]. The various polarization parameters such as corrosion current (I_{corr}), corrosion potential (E_{corr}), anodic and cathodic Tafel slopes (ba and -bc) were derived from potentiostatic polarization studies on mild steel in acid solutions. The results of the experiments in the presence and absence of different concentration of inhibitors from the polarization curves for inhibitors in acid at 302 K are depicted in above Figure 2, Figure 3 and Figure 4. The data are presented in Tables 2,3 and 4.
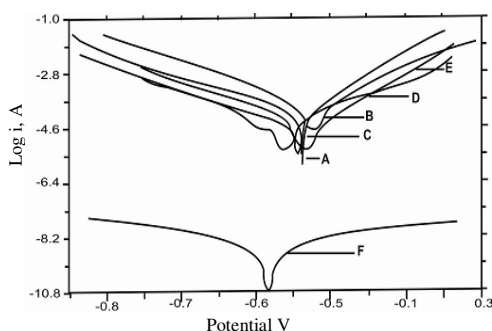

Figure 2. Polarization curves for mild steel corrosion in hydrochloric acid with AV (A-blank, B-0.02%AV, C-0.04%AV, D-0.06%AV, E-0.08%AV, F-0.10%AV)
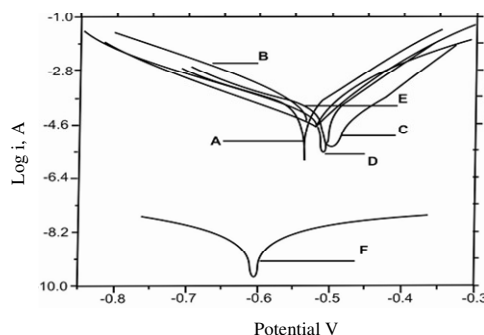

Figure 3. Polarization curves for mild steel corrosion in sulphuric acid with AV (A-blank, B-0.02%AV, C-0.04%AV, D-0.06%AV, E-0.08%AV, F-0.10%AV)
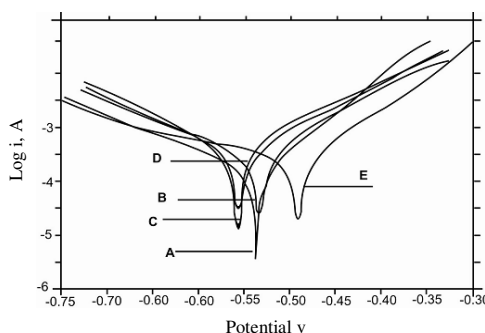
Figure 4. Polarization curves for mild steel corrosion in phosphoric acid with AV (A-blank, B-0.02%AV, C-0.04%AV, D-0.06%AV, E-0.08%AV, F-0.10%AV)

Table 2. Potentiostatic polarization studies for mild steel corrosion in hydrochloric acid with AV

S.No.	Conc. of inhibitor, %	OCP, mV	I_{corr} mA/cm^2	E_{corr} mV	ba mV/decade	-bc mV/decade	Corrosion rate (mmpy)	Inhibition efficiency,%
1.	Blank	-546	1.25×10^{-1}	-540	60	130	1.4175	-
2.	0.02	-505	3.16×10^{-2}	-515	50	80	3.583×10^{-1}	75
3.	0.04	-481	1.58×10^{-2}	-500	60	135	1.791×10^{-1}	87
4.	0.06	-511	7.94×10^{-3}	-510	90	130	9.003×10^{-2}	94
5.	0.08	-598	6.30×10^{-6}	-510	80	90	7.144×10^{-2}	95
6.	0.10	-564	1.33×10^{-6}	-610	90	80	1.508×10^{-5}	99

Table 3. Potentiostatic polarization studies for mild steel corrosion in sulphuric acid with AV

S. No.	Conc. of inhibitor, %	OCP, mV	I_{corr} mA/cm^2	E_{corr} mV	ba mV/decade	-bc mV/decade	Corrosion rate (mmpy)	Inhibition efficiency, %
1.	Blank	-546	1.25×10^{-1}	-540	60	130	1.4175	-
2.	0.02	-532	6.31×10^{-2}	-535	60	90	7.154×10^{-1}	50
3.	0.04	-580	6.30×10^{-2}	-500	90	100	7.144×10^{-1}	51
4.	0.06	-529	3.16×10^{-2}	-520	50	100	3.583×10^{-1}	75
5.	0.08	-512	1.58×10^{-2}	-510	80	100	1.791×10^{-1}	87
6.	0.10	-583	1.41×10^{-2}	-580	60	70	1.598×10^{-1}	89

Table 4. Potentiostatic polarization studies for mild steel corrosion in phosphoric acid with AV

S. No.	Conc. of inhibitor, %	OCP, mV	I_{corr} mA/cm^2	E_{corr} mV	ba mV/decade	-bc mV/decade	Corrosion rate (mmpy)	Inhibition efficiency, %
1.	Blank	-546	1.25×10^{-1}	-540	60	130	1.4175	-
2.	0.02	-528	7.94×10^{-2}	-530	65	145	9.004×10^{-1}	37
3.	0.04	-528	6.30×10^{-2}	-560	90	160	7.144×10^{-1}	50
4.	0.06	-533	5.01×10^{-2}	-560	70	140	5.682×10^{-1}	60
5.	0.08	-532	3.98×10^{-2}	-510	70	210	4.513×10^{-1}	68
6.	0.10	-502	2.41×10^{-2}	-490	60	210	2.546×10^{-1}	70

Popova *et al*[7]. also interpreted the decrease of I.E value with temperature increase as an indication for a physical or columbic type of adsorption. The inhibitive effect of substituted 1,3,4-thiadiazol-2-amines on the corrosion of mild steel in 1 M H_2SO_4 has been studied by weight loss and electrochemical methods[8]. Therefore it can be conclude that thiadiazolines are adsorbed on the mild steel surface by physisorption. It could be observed from the table that the E_{corr} values are shifted slightly towards negative side in presence of inhibitors suggesting that the inhibitors inhibit the corrosion of mild steel in acids solution by controlling both anodic and cathodic reactions due to the blocking of active sites on the metal surface. It is evident that inhibitors bring about considerable polarization of the cathode as well as anode. It was, therefore, inferred that the inhibitive action is of mixed type. The non-constancy of Tafel slopes for different inhibitor concentration reveals that the inhibitor action due to the interference in the mechanism of the corrosion processes at cathode as well as anode. The I_{corr} values were decreased with increase in concentration of inhibitor. The inhibition efficiencies were determined from the values of corrosion current density and the inhibition efficiency values were found to show good agreement with those obtained from weight loss measurements.

Conclusion

Adhatoda vasica (AV) was acted as good inhibitor in HCl, H_2SO_4 and H_3PO_4 for mild corrosion. Since, it contains alkaloids. Corrosion rate decreased with increase in concentration of inhibitor in 1 N HCl, 1N H_2SO_4 and 1 N H_3PO_4 acid solutions. The inhibition efficiency increased with increase in concentration of inhibitor. Maximum inhibition efficiency was obtained for 1 N HCl (1 h) = 77.77% (0.1% of AV). In this investigation AV acted as good inhibitor in HCl than H_2SO_4 and H_3PO_4. From the potentiostatic polarization studies curves, AV acted as mixed type inhibitor.

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