Corrosion Behaviour of Mild Steel in Acidic Medium in Presence of Aqueous Extract of Nelumbo nucifera flower

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Abstract— **The corrosion inhibitive action of flower extracts of Nelumbo nucifera flower on mild steel corrosion in 1 N H_2SO_4 solution was studied using weight loss method, potentiodynamic polarization and EIS measurements. The results obtained indicate that the extracts functioned as good inhibitors in 1 N H_2SO_4 solution. Inhibition efficiency was found to increase with extract concentration. The adsorption of constituents in the plant extract on the surface of the metal is proposed for the inhibition behavior**

Keywords— Inhibitor, Impedance, Polarization, Nelumbo nucifera

1. INTRODUCTION

A wide variety of chemicals ranging from simple ions, such as sulphate, to complex molecules can inhibit the corrosion of metals in neutral aqueous solutions. The properties of these inhibitors depend on the nature of the metal and composition of the environment. Many of the several corrosion problems encountered in chemical inhibitors by inhibitors obtained from natural the industries involves acids and in certain cases due to sources is required to keep the environment more healthy, alkalis and solvents. Hence corrosion inhibition programs safely and under pollution control. Various natural are now required in many industries such as oil and gas products, e.g. Artemisia oil (Bouyanzer and Hammouti, exploration and production, petroleum refining, chemical 2004), Pennyroyal oil taking place on metal surface. Inhibitors are chemicals that from Mentha oulegium (Bouyanzer *et al*., 2006), Occimum often work by adsorbing themselves on the metallic viridis extract (Oguzie, 2006) etc. have been reported to be surface, protecting the metal surface by forming a film. good inhibitors for steel in acidic solutions. The use of plant extracts as inhibitors for the corrosion of metals/alloys, has gained very wide interest among researchers in recent time [1-10].The aim of this study was to investigate the inhibition effect of Nelumbo nucifera flower extract as a cheap, raw and non-toxic corrosion inhibitor on steel corrosion in flower hydrochloric acid. The electrochemical measurements were used to evaluate the inhibition efficiencies.

2. EXPERIMENTAL

2.1. Materials

Mild steel coupons of dimensions 4.0 cm x 1cm x 0.2cm having the composition 0.022% S, 0.038% Mn, 0.027%P, 0.086 C and the remainder being Fe were used for weight loss studies. The mild steel coupons were polished mechanically using the emery papers of grades 220, 400, 600, 800 and 1200, then washed thoroughly with double distilled water. Finally, the specimens were rinsed in acetone and dried.

2.2 Preparation of Nelumbo nucifera flower extract extract:

An aqueous extract of Nelumbo nucifera flower extract was prepared by grinding 5g of plant flower , with distilled water, filtering the suspending impurities, and making up to 100 ml. The extract was used as corrosion inhibitor in the present study.

2.3. Weight loss measurements

Weight loss measurements were carried out according to the ASTM standard procedure described in [11]. The mild steel specimens in triplicate were immersed for a period of 2 hours in 100ml of the corrosive media with and without inhibitors at room temperature. The average weight loss of the three

specimens was used to calculate the inhibition efficiency employing the formula;

$$IE\% = \left(\frac{w-w'}{w}\right) \times 100$$

Where w and w' are the weight losses in the uninhibited and inhibited solutions respectively. In the present study, at room temperature the relative difference between replicate experiments have been found to be less than 5% showing good reproducibility.

2.4 Electrochemical impedance measurements

The impedance measurements were performed using a computer –controlled potentiostat (model Solartron SI-1260) and the data were analysed using gain phase analyser electrochemical interface   (Solartron SI-1287). A three electrode set up was employed with Pt foil as the auxiliary electrode and a saturated calomel electrode as the reference electrode. The Teflon coated mild steel rod, with the surface prepared as described in the weight loss experimental method, served as the working electrode. The measurements were carried out in the frequency range $10^6–10^{-2}$ Hz at the open circuit potential by superimposing sinusoidal AC signal of small amplitude, 10 mV, after an immersion period of 30 min in the corrosive media. The double layer capacitance (C_{dl}) and charge transfer resistance (R_{ct}) were obtained from the impedance plots as described elsewhere [12]. Because R_{ct} is inversely proportional to corrosion current density, it was used to determine the inhibition efficiency (IE%) using the relationship;

$$IE\% = \frac{R_{ct}-R^\circ_{ct}}{R_{ct}} \times 100$$

Where R_{ct} and R^0_{ct} are the charge transfer resistance values in the inhibited and uninhibited solutions respectively.

2.5. Polarization measurements

The potentiodynamic polarization curves were recorded using the same cell setup employed for the impedance measurements. The potentials were swept at the rate of 1.66mV/s, primarily from a more negative potential than E_{ocp} to a more positive potential than E_{ocp} through E_{corr}. The inhibition efficiencies were calculated using the relationship [13];

$$IE\% = \frac{I^\circ corr—Icorr}{I^\circ corr} \times 100$$

Where I^0_{corr} and I_{corr} are the corrosion current densities in the absence and in the presence of inhibitor, respectively

3.RESULTS AND DISCUSSION

3.1 Analysis of results of mass loss method

The corrosion rates and inhibition efficiency values, calculated using weight loss data, for various concentrations of oxystelma esculentum extract in the presence and absence of TBAB the corrosion of carbon steel in 1 N H_2SO_4 solution are presented in Table.1. It is apparent that the inhibition efficiency increased with the increase in inhibitor concentration in the presence and absence of TBAB . This behavior can be explained based on the strong interaction of the inhibitor molecule with the metal surface resulting in adsorption. The extent of adsorption increases with the increase in concentration of the inhibitor leading to increased inhibition efficiency. The maximum inhibition efficiency was observed at an inhibitor concentration of 10 mL. Generally, inhibitor molecules suppress the metal dissolution by forming a protective film adsorbed to the metal surface and separating it from the corrosion medium. The corrosion suppressing ability of the inhibitor molecule originates from the tendency to form either strong or weak chemical bonds with Fe atoms using the lone pair of electrons present on the O and π electrons in benzene ring. It is also seen from table.1 that the leaf extract of oxystelma esculentum at 2mL and 10 mL concentrations shows 54.77 % and 75.31 % inhibition efficiencies respectively, Then the   values   increased to 89.55 % after adding 30 ppm of   TBAB   solution in 1N

H_2SO_4 solutions containing 10mL of flower extract respectively. This showed a good synergistic effect between oxystelma esculentum extract and TBAB.

Table1. Corrosion rate (CR) of mild steel in 0.5M H_2SO_4 solutions the absence and presence of inhibitor and the inhibition efficiency (IE) obtained by weight loss method**.**

. Inhibitor concentration (mL)	TBAB (0) ppm	
	CR (mg cm^{-2} h^{-1})	IE %
0	28.8	-
2	13.02	54.77
4	11.03	61.69
6	9.04	68.61
8	7.63	73.50
10	7.11	75.31

3.2 Influence of TBAB on the inhibition efficiency of flower extracts.

Inhibitor concentration (mL)	TBAB (25) ppm	
	CR (mg cm^{-2} h^{-1})	IE %
10	30.11	89.55

### 3.3 Electrochemical impedance spectroscopic measurements (EIS)

Impedance spectra obtained for corrosion of mild steel in 1N H_2SO_4 contains a semicircle, representing the interaction of metal surface with the corrosive environment.. The -R (CR) model best describes this situation. The semicircle in the impedance plots contain depressed semicircles with the centre below the real axis. The size of the semicircle increases with the inhibitor concentration, indicating the charge transfer process as the main controlling factor of the corrosion of mild steel. It is apparent from the plots that the impedance of the inhibited solution has increased with the increase in the concentration of the inhibitor. The experimental results of EIS measurements for the corrosion of mild steel in 1N H_2SO_4 in the absence and presence of inhibitor are given in Table 3. Said that sum of charge transfer resistance (R_{ct}) and adsorption resistance (Rad) is equivalent to polarization resistance (Rp).

Table 3. Impedance parameters obtained from electrochemical impedance studies.

Inhibitor concentration (mL)	Rct Ohm cm^2	C$_{dl}$ μF	IE%
0	15.8	12.3×10^{-3}	-
10	67.23	2.891×10^{-6}	76.5
10+ 30ppm(TBAB)	158.0	1.23×10^{-6}	90.01

Fig.1 Impedance spectra obtained from electrochemical impedance studies
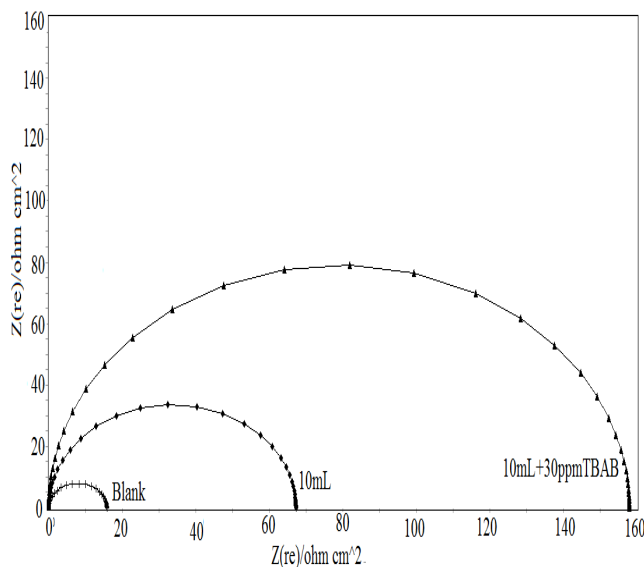
3.3 Polarization measurements:

Fig 2. Potentiodynamic polarization curves of mild steel immersed in 1N H_2SO_4 solution in the absence and presence of inhibitors
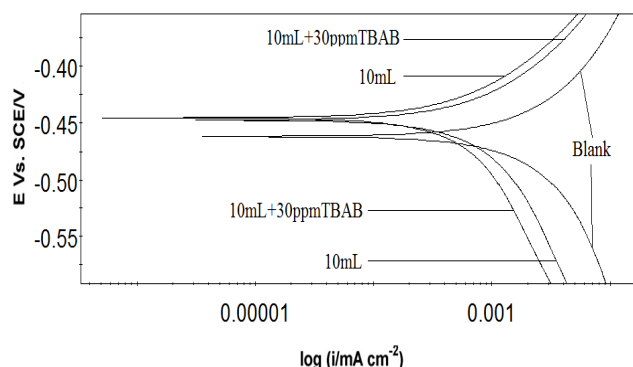

Table. 4 .   Corrosion parameters in the presence and absence of inhibitor obtained from polarization measurements.

Inhibitor concentration mL	$-E_{corr}$ (mV)	β_c (mV/)	β_a (mV)	$I_{corr} \times 10*6$ μA	IE%
0	461	248	105	1.30	-
10	447	207	73	0.311	76.1
10+ 30ppm(TBAB)	445	201	72	0.134	89.7

The polarization curves obtained for the corrosion of mild steel in the inhibited (100 ppm) and uninhibited 1 N H_2SO_4 solution in Fig.2. Electrochemical parameters such as corrosion potential (E_{corr}), corrosion current density (I_{corr}), cathodic and anodic tafel slopes (β_c and β_a) and percentage inhibition efficiency according to polarization studies are listed in table 3. Here I_{corr} decreased with increasing inhibitor concentration. From the figures, it can be interpreted that the addition of this inhibitor to corrosive media changes the anodic and cathodic tafel slopes. The changes in slopes showed the influence of the inhibitor both in the cathodic and anodic reactions. However, the influence is more pronounced in the cathodic polarization plots compared to that in the anodic polarization plots. Even though β_c and β_a values (table.3) change with an increase in inhibitor concentrations, a

high β_c value indicates that the cathodic reaction is retarded to a higher extent than the anodic reaction[14].

From Fig.2 it is also clear that the addition of the inhibitor shifts the cathodic curves to a greater extent toward the lower current density when compared to the anodic curves. The E_{corr} value is also shifted to the more negative side with an increase in the inhibitor concentration. These shifts can be attributed to the decrease in the rate of the hydrogen evolution reaction on the mild steel surface caused by the adsorption of the inhibitor molecule to the metal surface[15]. It has been reported that a compound can be classified as an anodic and cathodic type inhibitor on the basis of shift of E_{corr} value. If displacement of E_{corr} value is greater than 85 mv, towards anode or cathode with reference to the blank, then an inhibitor is categorized as either anodic or cathodic type inhibitor otherwise inhibitor is treated as mixed type [16,17]. In our study, maximum displacement in E_{corr} value was around 15 mV, indicating the inhibitor is a mixed type and more cathodic nature and does not alter the reaction mechanism. The inhibition effect has occurred due to simple blocking of the active sites, thereby reducing available surface area of the corroding metal[18,19,20,21].

3.5 Conclusions:

The effect of acid concentration and the effect of addition the aqueous extract of Nelumbo nucifera flower on the corrosion of Mild steel has been studied. The following conclusions may be drawn:

1) The chemical results showed that the corrosion rate of mild steel sample is increase with increasing acid concentrations 2mL to 10mL.

2) The polarization measurements also showed that, the increase of 1N H_2SO_4 concentration leads to displacement of the anodic and cathodic curves to high current densities ($I_{corr.}$), also increase the corrosion rate will be found.

3) The electrochemical impedance measurements showed that the corrosion of mild steel sample is mainly controlled by charge transfer process.

4) The aqueous extract of Nelumbo nucifera flower acts as good inhibitor for the corrosion of mild steel in 1N H_2SO_4 solution.

5) Electrochemical polarization results indicates that the Nelumbo nucifera flower act as mixed type inhibitor and impedance results showed that the corrosion of mild steel is mainly controlled by a charge transfer process and the presence of Nelumbo nucifera flower extract in acid solution does not alter the mechanism of mild dissolution.

AKNOWELEDGEMENTS

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