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Corrosion Inhibition of Mild Steel in Acid Medium using *MUSA Acuminata* Flower Extract

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Abstract

The corrosive inhibitive effect of Musa acuminata flower [MAN (F)] extract in 1N H_2SO_4 on mild steel was evaluated using conventional weight loss, electrochemical polarization, impedance spectroscopy and scanning electron microscopy methods. The inhibition efficiency of MAN (F) increases with increase in concentration but decreases with increase in temperature. The polarization curves indicate that MAN (F) acts as a mixed type of inhibitor. Electrochemical impedance plots shows change in charge transfer capacitance with change inconcentration of inhibitor. Temkin adsorption isotherm was tested for its fit to experimental data. SEM study shows that inhibited metal surface is smoother than uninhibited surface indicating reduction of corrosion. A mechanism of physical adsorption is proposed for inhibition action.

Keywords: *Acid medium; Adsorption; Flower extract; Mild steel; Weight loss.*

1. INTRODUCTION

Corrosion is a natural process that seeks to reduce the binding energy in metals. The end result of corrosion involves a metal atom being oxidized, whereby it loses one or more electrons. The corrosion manifests itself as a break-up of bulk metal to metal powder. Corrosion degrades the useful properties of materials (Fontana, 2010). Mild steel is extensively used in chemical and allied industries. The acid solutions which are often used in industry for cleaning, descaling and pickling of mild steel structures, processes are normally accompanied by considerable dissolution of metal (Narayan, 1983). Inhibitors are generally used to control metal dissolution. Most of the well known acid inhibitors are organic compounds containing O, S and/or N atoms. The toxic nature and high cost of some chemicals inhibitors make it necessary to develop environmentally acceptable and less expensive inhibitors (Okafor *et al.* 2010). Natural products are good source for this purpose. Extracts of naturally occurring products contain mixture of compounds and are biodegradable in nature (Lebrini *et al.* 2011). All the parts of *Musa acuminata* – a monoecious plant of musa species - have medicinal properties (Radha *et al.* 2007). The flower extract are used to treat dysentery, diarrhoea, ulcers, diabetes and gynecological problems. It is the most nutritious herbal flower rich in vitamins, minerals, essential amino acids and an excellent source of antioxidants. The phytochemical components of *Musa Acuminata* flower have been studied and it is known to have tannins, flavonoids, saponins, alkaloids and phenols (Evans, 2002; Anhwange, 2008) which are responsible for inhibiting corrosion. In this present investigation, the corrosion of mild steel in 1 N sulphuric acid in the absence and presence of MAN (F) at 303 K - 353 K has been studied by weight loss technique. The

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adsorption characteristic of MAN (F) was studied to access mechanism of corrosion inhibition and the adsorption isotherm.

2. EXPERIMENTAL

2.1 Preparation of specimens

The commercially available mild steel was cut into coupons having dimensions of 5 x 1 x 0.2 cm. The coupons were polished by using emery paper 400 and 600 grade and used for weight loss experiments.

2.2 Preparation of flower extract

The flowers were collected from the farm. The slim, nectar-rich, tubular toothed, white flowers were separated from the purple thick, waxy hood like bract and shadow dried at room temperature. About 12.5 gms of the flower powder were refluxed with 1 N H_2SO_4 for about 3 hours and left overnight to obtain the basic nutrients. The solution was filtered and filtrate made up to 250 ml to obtain 5% stock solution which is used in preparing various concentrations of the extract from 0.05% to 2.0% (v/v).

2.3 Weight loss method

2.3.1 Effect of concentration

The prepared mild steel coupons were immersed in 100 ml of the test solution without and with the MAN (F) extract of various concentrations for 1 h, 3 h, 5 h, 7 h, 12 h and 24 h at room temperature. The weight of the coupons before and after immersion was determined. Inhibition efficiency of the mild steel was calculated.

2.3.2 Effect of temperature

The polished and pre-weighed specimens were suspended in 100 ml of the test solution without and with the addition of various concentration of the flower extract for 1 h in the temperature range of 303-353 K using water thermostats. The specimens were removed from the test solution after 1 h and washed with distilled water, dried and weighed. The inhibition efficiency was then calculated from the weight loss.

2.4 Electrochemical measurements

Electrochemical experiments were carried out using computer controlled PARSTAT 2273. A three electrode setup with platinum foil, saturated calomel electrode and mild steel rod was employed. The double layer capacitance (C_{dl}) and charge transfer resistance (R_{ct}) were obtained from the Nyquist plots. The potentiodynamic polarization curves were recorded using the same cell setup employed for the impedance measurements.

2.5 SEM analysis

The surface morphological analysis of mild steel after 1 h immersion in 1 N H_2SO_4 containing 2% v/v MAN (F) extract was studied to understand the changes that occur during the corrosion of mild steel in the presence and absence of flower extract.

3. RESULTS & DISCUSSION

3.1 Weight loss method

The weight loss method was carried out with concentration ranging from 0.05% to 2.0% v/v. The result in Table 1 shows that with rise in concentration of MAN (F) extract from 0.05% to 2.0% v/v, the inhibition efficiency increased. At optimum concentration of 2% v/v it has a maximum inhibition efficiency ofabout 95.0%. This result indicated that MAN (F) act as an excellent corrosion inhibitor. This is attributed to the adsorption of nutrients of the flower on the surface of mild steel which make a barrier for mass and charge transfer and prevent further corrosion.

3.2 Effect of immersion time

Table 1 and Fig.1 show the effect of immersion time on mild steel. The MAN (F) extract has maximum efficiency of 95.0% at 5 h immersion time and the inhibition efficiency was found to decrease from 95.0% to 91.3% as immersion time increased from 3 h to 24 h.

Table 1. IE at various concentrations and different immersion periods

Conc.	IE (%)					
(% v/v)	1h	3h	5h	7h	12h	24h
0.05	68.1	71.8	66.7	64.1	54.0	45.2
0.10	78.1	81.2	79.7	74.6	68.2	60.1
0.50	87.5	89.4	88.1	87.9	86.0	83.7
1.00	88.5	90.7	91.1	90.7	89.5	86.7
1.50	90.2	91.9	92.6	91.2	91.8	91.0
2.00	92.0	94.7	95.0	94.1	92.3	91.3

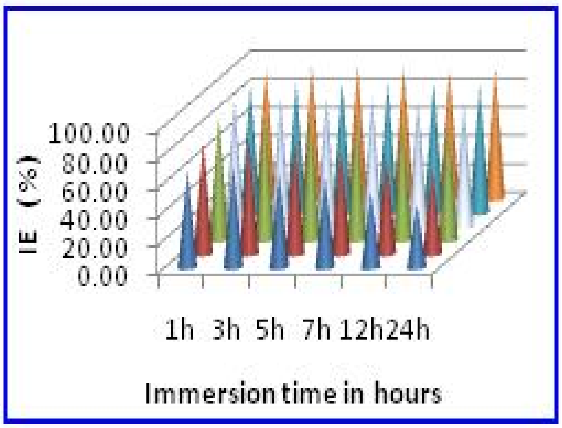

Fig. 1: Influence of immersion time on IE

3.3 Effect of temperature

The effect of temperature on the corrosion inhibition properties of flower extract was studied by exposing the mild steel to 1 N H_2SO_4 containing 0.05, 0.10, 0.50, 1.00, 1.50, 2.00% v/v of the flower extract in the temperature range of 303–353 K. The data in Table 2. indicate that the flower extract is effective as inhibitor for mild steel in 1 N H_2SO_4 up to 313 K and decreases thereafter. The inhibition shows a maximum 93.6% at 313 K flower extract in 1 N H_2SO_4.

3.4 Potentiodynamic polarization

The electrochemical parameters from Tafel plot Fig. 2 are given in Table 3. The lower

Table 2. IE at various temperatures

Conc.	IE (%)					
(% v/v)	303 K	313 K	323 K	333 K	343 K	353 K
0.05	68.1	73.2	65.7	62.5	48.5	34.2
0.10	78.1	78.7	79.5	69.9	63.5	38.9
0.50	87.5	88.2	88.6	85.3	80.7	66.8
1.00	88.5	91.5	89.1	88.3	86.1	72.2
1.50	90.2	92.6	90.8	89.7	88.5	77.8
2.00	92.0	93.6	92.9	91.2	89.0	80.0

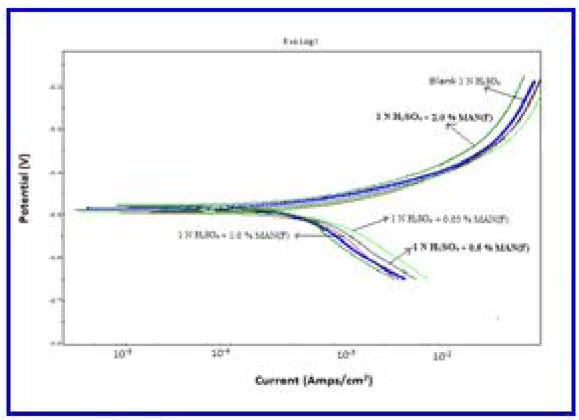

Fig. 2: Potentiodynamic polarization curves for mild steel in presence and absence of inhibitor in acid

Table 3. Potentiodynamic polarization parameters in the absence and presence of MAN (F) in 1N H_2SO_4

Conc. % v/v	- E_{corr} V	Tafel slope (mV/dec)		I_{corr} mAmpcm^2	IE %
		b_a	b_c		
Blank	0.491	81.3	180.7	1005.0	-
0.05	0.485	66.0	179.1	537.9	46.5
0.50	0.484	81.8	178.7	524.0	47.9
1.00	0.477	77.9	180.1	423.6	57.9
2.00	0.475	91.9	182.3	385.9	61.6

corrosion current density (I_{corr}) values in the presence of inhibitor without causing significant changes in corrosion potential (E_{corr}) suggests that the extract is mixed type inhibitor.

3.5 Electrochemical impedance spectroscopy

Nyquist plot obtained for mild steel in 1 N H_2SO_4 in the various concentrations of the inhibitor is represented in Fig.3.

Table 4. Impedance parameters for mild steel in the absence and presence of MAN (F) in 1N H_2SO_4

Conc. (% v/v)	C_{dl} (μFcm^{-2})	R_{ct} Ohmcm^2	IE C_{dl}	IE R_{ct}
Blank	11.070×10^{-5}	18.25	-	-
0.05	8.970×10^{-5}	21.40	18.9	14.7
0.50	6.094×10^{-5}	33.40	44.9	45.3
1.00	4.773×10^{-5}	35.46	56.8	48.5
2.00	4.344×10^{-5}	47.17	60.7	61.3

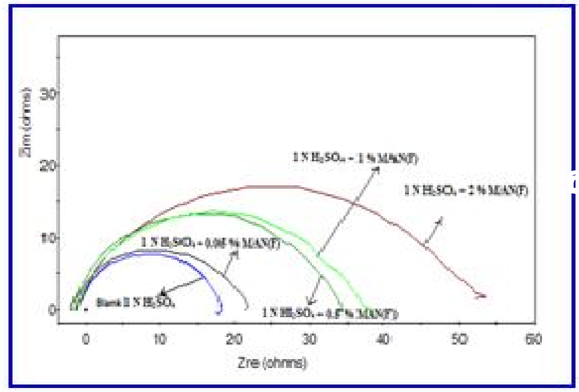

Fig. 3: Nyquist plots in the absence and presence of MAN (F)

The impedance parameters in Table 4 show that as the concentration of inhibitor increases C_{dl} values decrease, which can result from an increase in thickness of electrical double layer suggesting that the inhibitor molecule function by adsorbing at the metal-solution interface.

3.6 SEM analysis

The surface microstructure of specimens after 1 h of immersion in 1 N H_2SO_4 and an optimum concentration of inhibitor 2% v/v were studied to understand the changes that occur during the corrosion of mild steel in the presence and absence of flower, using JEOL Scanning Electron Microscope – Model JSM 6360. Examination of Fig.4 reveals that the specimen immersed in the 1 N H_2SO_4 was highly damaged. Fig.5 clearly showed mild steel is highly covered with protective layer formed by adsorption of nutrients present in the flower extract which prevents the metal from further attack of acid and thus inhibiting corrosion.

4. MECHANISM OF CORROSION INHIBITOR

The mechanism of inhibition can be understood by the mode of adsorption of the flower nutrients on mild steel surface. The surface coverage (θ), (θ = IE /100) values, calculated using weight loss method for various concentrations of the inhibitors were tested graphically by fitting to Temkin isotherm. A plot of θ against log C for various concentrations shows a straight line indicating that the extract follow the Temkin adsorption isotherm.

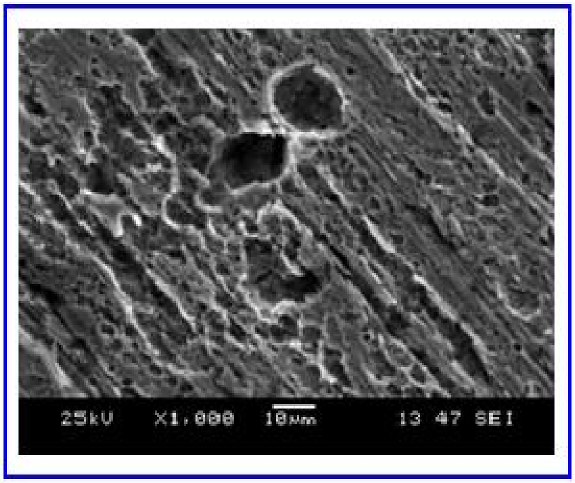

Fig. 4: Mild steel exposed to 1 N H_2SO_4

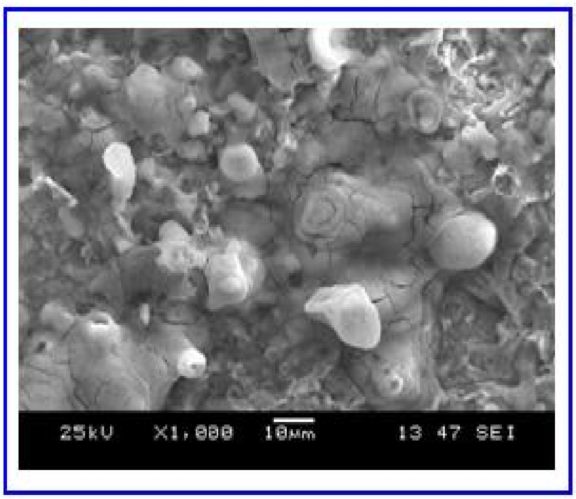

Fig. 5: Mild steel exposed toMAN (F) in 1 N H_2SO_4

Musa Acuminata flower comprise of tannins, flavonoids, saponins, alkaloids, phenols and amino acids. Most of these organic compounds possess heteroatom such as O^- and N^- which strengthen the adsorptive property on the metal surface and hence the anti-corrosive behavior. Moreover N-containing compounds exert their best efficiencies in sulphuric acid. Thus it can be suggested that the high inhibition efficiency of MAN (F) may be due to active nutrients of MAN (F) containing oxygen and nitrogen.

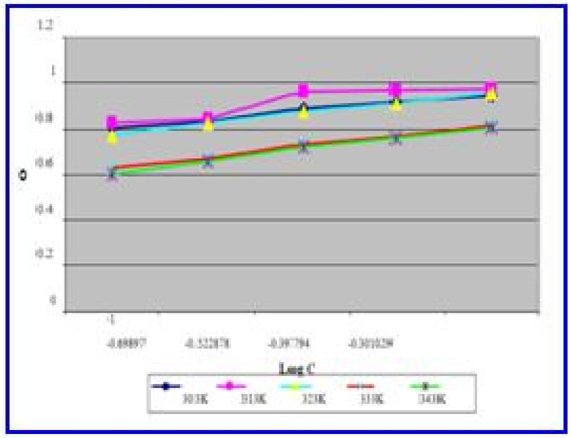

Fig. 6: Temkin adsorption isotherms for corrosion inhibition of mild steel

5. CONCLUSION

Musa Acuminate flower extract acts as good inhibitor for corrosion of mild steel in sulphuric acid medium.Corrosion inhibition action of MAN (F) increased as its concentration increases. The performance of this extract as corrosion inhibitor decreased with temperature. The potentiodynamic polarization curves recorded reveal that MAN (F) acts as a mixed type inhibitor. The adsorption of MAN (F) extract onto the mild steel surface follows Temkin adsorption. Surface studies involving SEM confirmed the efficiency of the flower extract as corrosion inhibitor for mild steel. Inhibition of mild steel in 1 N H_2SO_4 solution by MAN (F) extract is attributed to adsorption of the phytochemical compounds present in the extract onto the active sites on the surface of the mild steel.

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