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Research Article

CORROSION INHIBITION OF MILD STEEL BY NATURAL PRODUCT COMPOUND

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ABSTRACT
There is a growing trend to utilize plant extracts and pharmaceutical compounds as corrosion inhibitors. The inhibitive performance of extract of Leaves *Cissus quadrangularis* (CQ) on the corrosion of mild steel in 0.3 M HCl were studied using mass loss and electro chemical measurements. Characterization of CQ was carried out using GC-MS spectroscopy. Results confirmed that the extract of *Cissus quadrangularis* Leaves (CQ) acts as an effective corrosion inhibitor in the acid environment. Potentiodynamic polarization and electrochemical impedance studies confirmed that the system follows mixed mode of inhibition.

Keywords: Mild steel, *Cissus quadrangularis* Leaves (CQ), corrosion inhibition, electrochemical measurements.

1. INTRODUCTION

The study of corrosion inhibition of mild steel (MS) using green inhibitor in acidic media, containing HCl or H_2SO_4 in particular, is one of the challenging topic of current research in various industries involving chemical cleaning, descaling, pickling, acid oil-well acidizing, etc.,[1–5]. Due to the aggressiveness of these acids a substantial economic loss is suffered by the concerned industries resulting from rapid corrosion of metallic parts. To perform the above processes at a controlled rate of corrosion, a number of organic compounds have been studied and employed as corrosion inhibitors from time to time[6, 7]. However, as a result of their high cost and increasing awareness of health and ecological risks, attention is being drawn towards finding highly efficient, cheaper and non-toxic inhibitors. The present trend in research on environmental friendly corrosion inhibitors is concentrating on products of natural origin due principally to their low cost and eco-friendliness. Among the natural products, plant extracts find a prominent place. The abundant phytochemical constituents of plant extracts possess considerable potential as inexpensive, non toxic and renewable sources of a wide range of organic chemicals of industrial significance. The yield of these natural products as well as the corrosion inhibition abilities of the plant extracts vary widely depending on the part of the plant and its location[8]. Extract of different parts of plant like root, seeds, leaves, stem, flower and fruits can be used as inhibitor to reduce the corrosion rate of various ferrous and non-ferrous metals in acidic media[9]. The present article is concerned with corrosion inhibition studies using *Cissus quadrangularis* leaves extract (CQ) on mild steel in acidic medium using Mass loss and electrochemical measurements.

2. MATERIALS AND METHODS

All chemicals were purchased from Merck, Mumbai, India, Hydrochloric acid, Methanol, mild steel

2.1. Extraction of plant material

20 g of the sample of the *Cissus Quadrangularis* powder was refluxed in 200 ml of 80% methanol at 80 $^{\circ}$C for 6 hours. The refluxed solution was filtered, and the liquor was evaporated to 100 ml dark brown residue, and then degreased with ether and extracted with separating funnel. Thereafter, the solution to almost 50 ml dark brown residue dried in vacuum oven at 60 $^{\circ}$C for one day and filtered with No.1 what Mann papers. The residue was re-extracted continuously until colourless. All the extracts were stored at 40 $^{\circ}$C in refrigerator until further use. It is used as inhibitor for the entire system.

3. RESULT AND DISCUSSION

3.1. GC-MS (Gas chromatography- Mass Spectrometry) analysis

Gas chromatography (GC) – mass spectroscopy (MS) spectra of *Cissus Quadrangularis* extract shown in Fig. 1 and Table.1 identified 3 major compounds, representing about 100% of the compounds in the extract. The high peaks related to low retention times are mainly polar plant compounds while the small peaks may be attributed to compounds. 2-ethoxy-1-(2-Methoxy Phenyl) ethanone (or) Ethyl benzoate. Styrene, 1-Phenylprop-2-en-1-one Toluene, as the major compounds of the extract of *Asterisus gravveolens* utilized for corrosion inhibition of mild steel in sulphuric acidic medium. It is clear from the above that our choice of methanol extract of *Cissus Quadrangularis* is justified for the fact that rention time of majority of compounds is close to each other and it is very difficult to separate them Olive leaves[10-13] have been reported to inhibit the corrosion of metals in acidic media.

Table 1: Chemical composition of *Cissus Quadrangularis* plant

S. No	Component name	Molecular Formula	Molecular weight
1	2-ethoxy-1-(2-Methoxy Phenyl) ethanone.	$C_{11}H_{14}O_3$	194.23
2	Ethyl benzoate.	$C_9H_{10}O_2$	150.17
3	Styrene	C_8H_8	104.15
4	1-Phenylprop-2-en-1-one	C_9H_8O	132.16
5	Toluene	C_7H_8	92.14

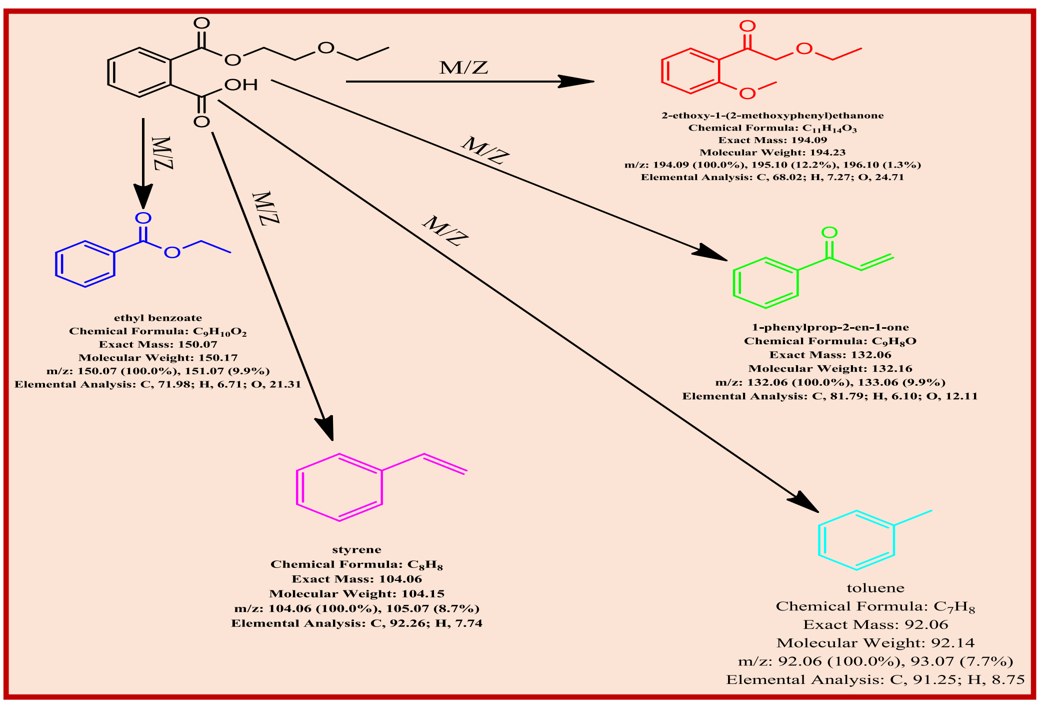

Fig. 1: Chemical compounds of *Cissus Quadrangularis* plant and fragmentations

3.2 Weight loss Measurements

The weight-loss method was done for mild steel in 0.3 M HCl with various concentrations of C.Q extract ranging from 50 ppm to 300 ppm and the corresponding values of inhibition efficiency and corrosion rate are given in table 2. It is observe from the table that the corrosion rate decreased and thus inhibition efficiency increases with increasing concentration of C.Q extract (50 ppm-300 ppm). The maximum inhibition efficiency of about 71.6% was achieved at 300 ppm of C.Q extract. This result indicated that C.Q extract could act as an excellent corrosion inhibitor. At concentration ≥ 300 ppm of C.Q, the protection efficiency decreases of may be due to the fact that these molecules aggregate together to form micelles. They are not uniformly adsorbed on the metal surface. Hence corrosion inhibition efficiency decreases. The weight - loss method was done for mild steel in 0.3 M HCl with various concentrations of C.Q extract ranging from 50 ppm to 300 ppm and the corresponding values of inhibition efficiency and corrosion rate are given in table.2.

3.3. Electrochemical measurements

3.3.1. Electrochemical impedance studies

Nyquist plots for mild steel immersed in control solution of 300 ppm of inhibitor solution of 0.3 M HCl in the absence and presence of formulations are shown in Fig.2. The impedance parameters, charge transfer resistance (Rct), Double layer capacitance (C_{dl}) from the Nyquist plot values are shown in Table.3. When mild steel immersed in 0.3 M HCl medium the Rct value is found to be 36 (Ω cm^2). The C_{dl} value is 36 (µF/cm^2) When 300 ppm of Cissus Quadrangularis are added to 0.3 M HCl medium the Rct value is formed to be 70 (Ω cm^2). The C_{dl} value is 1 (µF/cm^2). When 300 ppm of Cissus Quadrangularis solution are added to 0.3 M HCl medium the Rct value has increased from 36 to 70 (Ω cm^2) and the C_{dl} value decreased from 36 to 13 (µF/cm^2). The increase in Rct value and decreases in double layer capacitance values obtained from impedance studies justify the good performance of a compound as an inhibitor in 0.3 M HCl medium. This behaviour means that the film obtained acts as a barrier to the corrosion process.

Table 2: 0.3 M HCl in various concentration of C.Q at time interval

S. No.	C.Q (ppm)	30 minutes		45 mines		60 mines	
		I.E	CR	I.E	CR	I.E	CR
1	0	0	0.5363	0	0.5363	0	0.2952
2	50	38.46	0.2804	47	0.2804	39.59	0.2952
3	100	41.02	0.2312	56.88	0.2312	44.29	0.2722
4	150	57.69	0.2165	59.63	0.2165	61.07	0.1902
5	200	57.69	0.2017	62.38	0.2017	61.07	0.1902
6	250	64.10	0.1623	69.72	0.1623	67.78	0.1574
7	300	70.51	0.1525	71.56	0.1525	69.12	0.1509

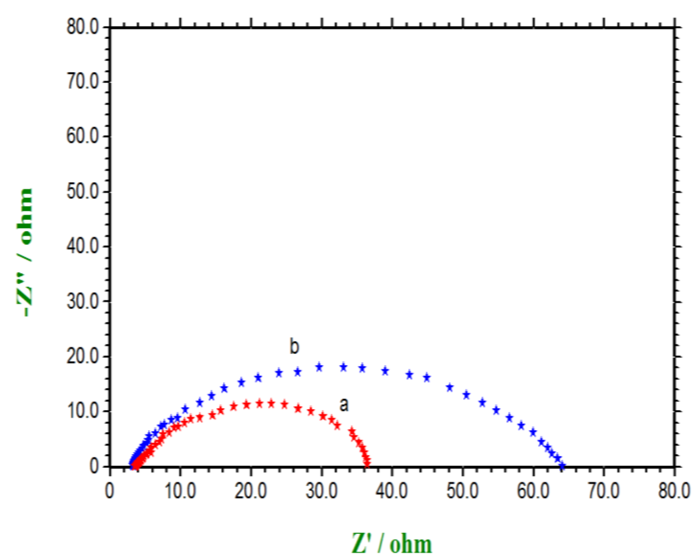

Fig. 2: Impedance spectra curves of mild steel in various test solutions (a) 0.3 M HCl, (b) 300 ppm of C.Q

Table 3: Impedance studies

Concentration of ppm	Rct (Ω cm^{-2})	C_{dl} (μfcm^{-2})	I.E (%)
0.3 M HCl	36	36	_
300 ppm of C.Q	64	13	71

Nyquist plots for mild steel immersed in control solution of 250 ppm of inhibitor solution of 0.3 M HCl in the absence and presence of formulations are shown in Fig.2. The impedance parameters, charge transfer resistance (Rct), Double layer capacitance (C_{dl}) from the Nyquist plot values are shown in Table.3. When mild steel immersed in 0.4 M HCl medium the Rct value is found to be 34 (Ω cm^2). The C_{dl} value is 46 (μF/cm^2). When 250 ppm of Cissus Quadrangularis are added to 0.4 M HCl medium the Rct value is formed to be 77 (Ω cm^2). The C_{dl} value is 14 (μF/Cm^2). When 250 ppm of Cissus Quadrangularis solution are added to 0.4 M HCl medium the Rct value has increased from 34 to 77 (Ω cm^2) and the Cdl value decreased from 46 to 14 (μF/cm^2). The increase in Rct value and decreases in double layer capacitance values obtained from impedance studies justify the good performance of a compound as an inhibitor in 0.3 M HCl medium. This behaviour means that the fim obtained acts as a barrier to the corrosion process .

3.3.2. Potentiodynamic polarization studies

The potentiodynamic polarization studies were carried out to determine the kinetics of the cathodic and anodic reactions. Fig.3 shows the potentiodynamic polarization curves for mild steel electrodes in control solution of 0.3 M HCl in the absence and presence of inhibitor combinations. Electrochemical kinetics parameters, i.e., the corrosion potential (E_{corr}) corrosion current density (I_{corr}), and anodic and catholic Tafel slopes (βa and βc), obtained from extrapolation of the polarization curves are listed in table. when mild steel is immersed in 0.3 M HCl in acid medium, the corrosion potential (E_{corr}) is -0.482 mV/dec and the corrosion (I_{corr}) is 7.426 (μA/ Cm^{-2}), when 300 ppm of inhibitor solution of Cissus Quadrangularis are added to 0.3 M HCl in acid medium the corrosion potential is found to be (E_{corr}) is -0.488 mV/dec and corrosion current (I_{corr}) is 1.500(μA/Cm^{-2}). The corrosion current was decrease from 7.426 (μA/Cm^{-2}) to 1.500 (μA/Cm^{-2}). The shift in the E_{corr} through still less than 85mv was shifted more towards the anodic region.

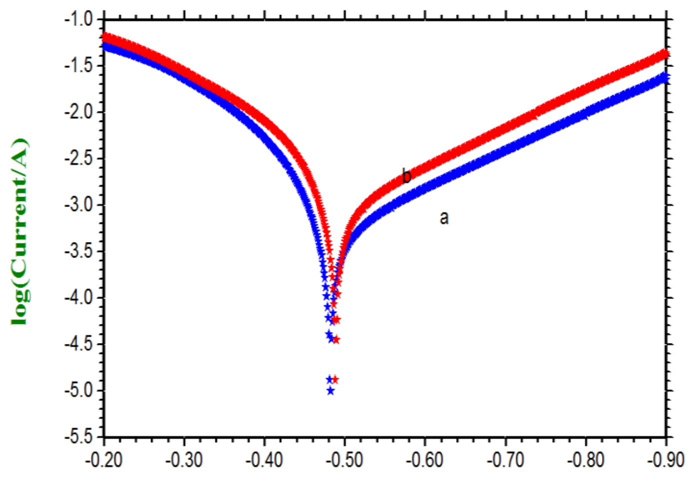

Fig. 3: Polarization Spectra a). 0.3 M HCl. b) 300 ppm of CQ

This shows that the formation of functions as an anodic inhibitor controlling both anodic and cathodic processes but more predominantly anodic process. This suggests, indicate that protective film is formed on the metal surface.

Table.4 Corrosion parameters of mild steel immersed in the absence and presence inhibitor obtained from potentiodynamic polarization studies.

Table 4: Potentiodynamic polarization studies

S. No.	Concentration	E_{corr} (mv/sce)	Icorr ($\mu A_{/cm}^{-2}$)	βa (mv/dec^{-1})	βc (mv/dec^{-1})	I.E(%)
1	0.3 M HCl	-0.482	7.426×10^{-4}	117	210	_
2	300 ppm C.Q	-0.488	1.500×10^{-4}	214	142	70

The potentiodynamic polarization studies were carried out to determine the kinetics of the cathodic and anodic reactions. Fig.3 shows the potentiodynamic polarization curves for mild steel electrodes in control solution of 0.4 M HCl in the absence and presence of inhibitor combinations. Electrochemical kinetics parameters, i.e., the corrosion potential (E_{corr}) corrosion current density (I_{corr}), and anodic and cathodic Tafel slopes (βa and βc), obtained from extrapolation of the polarization curves are listed in table.4 when mild steel is immersed in 0.4 M HCl in acid medium, the corrosion potential (E_{corr}) is -0.471 mV/dec and the corrosion (I_{corr}) is 6.020 (μA/Cm^{-2}), when 250 ppm of inhibitor solution of *Cissus Quadrangularis* are added to 0.4 M HCl in acid medium the corrosion potential is found to be (E_{corr}) is -0.488 mV/dec and corrosion current (I_{corr}) is 1.537 (μA/Cm^{-2}). The corrosion current was decrease from 6.020 (μA/Cm^{-2}) to 1.537 (μA/Cm^{-2}). The shift in the E_{corr}, through still less than 85mv was shifted more towards the anodic region.

4. CONCLUSIONS

The inhibition efficiency increases with increasing inhibitor concentrations to attain maximum value of 93.67% for inhibitor respectively. The formulation consisting of 0.5 M HCl medium, 300 ppm of C.Q plant extract offers 93.67% inhibition efficiency. The synergistic effect was exists between 0.5 M HCl C.Q plant extract system. The inhibitors show better inhibition efficiency than individual. The green inhibitor affects anodic Tafel slopes in HCl media and act as mixed inhibitor. AC impedance spectra prove the protective film formation on the carbon steel.

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