



4-((2,4-Dihydroxyphenyl)Diazenyl)-3-Hydroxy-5-(Phenylamino) Thiophene-2-Carbonitrile as Corrosion Inhibitor for Carbon Steel in Sulfuric Acid Solution and its Biological Activity

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ABSTRACT

4-((2,4-dihydroxyphenyl)diazenyl)-3-hydroxy-5-(phenylamino) thiophene-2-carbonitrile is a new compound used as a corrosion inhibitor for carbon steel (CS) used in cooling towers in industrial processes and studying of inhibition efficiency (%IE) by classical method as weight loss (WL) and electrochemical technique (potentiodynamic polarization technique (PP), electrochemical impedance spectroscopy (EIS), electrochemical frequency modulation (EFM) The results showed the variation in inhibition performance of the inhibitor with varying doses and temperatures. The maximum %IE was found to be 84 % at 2.4×10^{-4} M dose of the inhibitor for the immersion period of 3 h at 25^oC. PP study clearly revealed that this compound acts as mixed type inhibitor. The results of various electrochemical techniques show good agreements with each other. Although thiophene-2-carbonitrile derivative has biological activity on the bacteria extracted from ammonia cooling tower in Delta Company for fertilizers and chemical industries.

Keywords: Carbon steel, EIS, PP, EFM, Biological activity.

INTRODUCTION

Biocorrosion, which is primarily caused by microbial respiration or metabolic products of microbes, has been a major factor in the initiation and acceleration of metal corrosion. A part from the destruction of pipelines and economic losses, biocorrosion has become an important research topic recently given the increasing failures of pipelines [1, 2]. Due to the potential economic losses and environmental issues caused by biocorrosion, thiophene-2-carbonitrile derivative has been tested as corrosion inhibitor and antimicrobial properties. Presence of hetero atoms O, N, S in thiophene-2-carbonitrile derivative encourage us to use it as corrosion inhibitor [3– 6] due to overlapping of π -orbital of hetero atoms with vacant d orbital of metal [6-15]. CS used in multi industries processes and multi usage so, we apply our study on this metal. All investigations of corrosion behavior carried on 0.5 M of H₂SO₄. With regard to CS corrosion in acid medium, a lot of investigations in relation to pickling, acid cleaning, the study of corrosion inhibition has been reported [16]. The mechanism of corrosion inhibition is involved with the

formation of protective film resulted from organic molecules adsorption on the surface of metal from the environment bulk [17]. Since this inhibitor contains sulfur atom and the methyl group in thiophene-2-carbonitrile derivative has induction effect related to increased electron density of donor atom [18]. Several studies concerning the corrosion inhibition of Al by organic compounds in acidic solutions have been conducted [19-22]. Recent studies have been performed with the effects of sulfur-containing compounds such as thiourea and its derivatives on the inhibition of Al corrosion [23]. Most organic inhibitors act by adsorption on the metal surfaces [24]. In the present work, chemical method was used to investigate the inhibition of CS corrosion by thiophene-2-carbonitrile derivative in 0.5 M H₂SO₄, with respect to the effects of inhibitor dose and temperature on the inhibitor efficiency. Bacteria are extracted from cooling tower of ammonia plant in Delta Company for fertilizers - Egypt. Thiophene-2-carbonitrile derivative has an observed effect on bacteria extracted so we can consider that compound has dual effect in both corrosion and bacterial growth.

MATERIALS AND METHODS

Materials: All chemicals were used in analytical grade A. Ethanol with 99.5% purity was purchased from Hayman Ltd., while acetone and H₂SO₄ with 98% purity were ordered from El-Gomhoria Company, Mansoura, Egypt.

Carbon steel samples: Tests were performed on CS of the following composition (weight %): C 0.24, Mn 0.96, S 0.04, P 0.05 and balance Fe.

WL analysis: Seven test pieces of CS were cut into 1 x 3 x 0.2 cm. They were abraded with emery papers (a coarse paper was used initially and then progressively finer grades up to 2000 grit size) degreased in acetone, rinsed with bi-distilled water and finally dried between two filter papers and weighed. WL measurements were performed for 3 hours at the temperature range from 25 – 55 °C by immersing CS pieces into 100 mL acid solution with and without various doses of inhibitors.

Electrochemical measurements: Electrochemical experiments were performed using a typical three-compartment glass cell consisted of the CS specimen as working electrode (1 cm²), saturated calomel electrode (SCE) as a reference electrode and a platinum foil (1 cm²) as a counter electrode. All the measurements were done in solutions open to atmosphere under unstirred conditions. All potential values were reported versus SCE. Prior to every experiment, the electrode was abraded with emery paper, degreased with acetone and washed with bi-distilled water and finally dried.

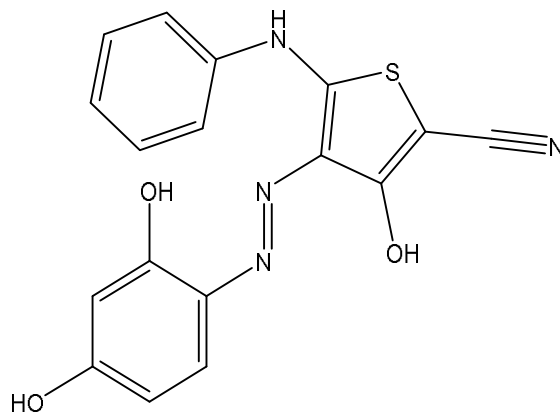
Tafel polarization curves were obtained by changing the electrode potential automatically from (-0.5 to 0.5 V vs. SCE) at open circuit potential (OCP) with a scan rate of 1 mVs⁻¹. The corrosion current is performed by extrapolation of anodic and cathodic Tafel lines to a point which gives log i_{corr} and the corresponding corrosion potential (E_{corr}) for inhibitor free acid and for each dose of inhibitor.

EIS measurements were carried out in frequency range from 100 kHz to 0.1Hz with amplitude of 5 mV peak-to-peak using ac signals at OCP. The experimental EIS was analyzed and interpreted based on the equivalent circuit. The main parameters deduced from the analysis of Nyquist diagram are the charge transfer resistance R_{ct} (diameter of high-frequency loop) and the double layer capacity C_{dl} .

EFM measurements were carried out using two frequencies 2 and 5 Hz. The base frequency was 0.1 Hz, so the waveform repeats after 1 sec. The Intermodulation spectra contain current responses assigned for harmonical and intermodulation current peaks. The larger peaks were used to calculate the corrosion current density (i_{corr}), the Tafel slopes (β_c and β_a) and the causality factors CF-2 and CF-3. All electrochemical measurements were performed using Gamry Instrument (PCI 300/4) Potentiostat/Galvanostat /ZRA.

Microbiological analysis: A number of samples containing bacterial colonies from the cooling towers of The Delta Fertilizer plant, Daqahlia, Egypt were assembled. The samples were transferred to sterilized bottles within half hour under the laboratory condition. Nutrient agar (Oxide CM0003, LOT 1384650, England) was used for culturing bacteria grown on a petri dish.

Chemical structure, names, molecular weight and molecular formula of thiophene-2-carbonitrile derivative was shown in scheme 1 below:



Scheme 1: 4-((2,4-dihydroxyphenyl) diazenyl)-3-hydroxy-5-(phenylamino) thiophene-2-carbonitrile
Mol. Formula = $C_{17}H_{12}N_4O_3S$, Mol. Weight = 352.37

RESULTS AND DISCUSSION

WL method: Figure 1 shows plots of the variation of WL of CS with time in 0.5 M H_2SO_4 containing various doses of thiophene-2-carbonitrile derivative at 25°C. From these plots, it is evident that the WL of CS was also found to decrease with increase in the dose of thiophene-2-carbonitrile derivative. WL of CS in the blank solution was also found to be higher than those obtained for solutions of H_2SO_4 containing various doses of thiophene-2-carbonitrile derivative. The degree of surface coverage (θ) and % IE were calculated using equation (1):

$$\% \text{ IE} = \theta \times 100 = [1 - \text{CR}_{\text{inh}} / \text{CR}_{\text{free}}] \times 100 \quad (1)$$

Where CR_{inh} and CR_{free} are the corrosion rates with and without inhibitor respectively. It can be seen that the maximum of 84.1 % IE is achieved at $24 \times 10^{-5} \text{M}$ of inhibitor dose and %IE increases with growing the thiophene-2-carbonitrile derivative doses. This is mainly due to the active chemical constituent of viz, π bonds, hetero atoms (O, S and N).

Table 1 : (WL), (CR) and (%IE) at different doses of thiophene-2-carbonitrile derivative for the corrosion of CS after 120 min immersion in 0.5 M H_2SO_4 at 25 °C

Conc., ppm	WL, mg.cm^{-2}	CR	%IE
Blank	6.28	0.052	----
40	3.58	0.029	43.0
80	3.12	0.026	50.3
120	2.12	0.018	66.2
160	1.53	0.013	75.6
200	1.28	0.011	79.6
240	1.00	0.008	84.1

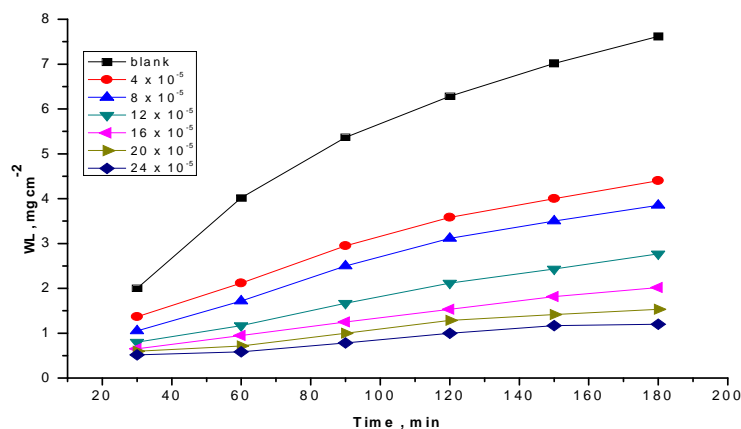


Fig 1. WL-time curves for the corrosion of CS in 0.5 M H₂SO₄ without and with different doses of thiophene-2-carbonitrile derivative at 25°C

Effect of temperature on % IE: % IE for CS corrosion in the presence of various doses of thiophene-2-carbonitrile derivative and at different temperatures was calculated and listed in Table 2. The results of Table 2 illustrate the variation of CR and % IE with thiophene-2-carbonitrile derivative doses at various temperatures. The obtained data revealed that, % IE increased with an increase in the inhibitor dose. This suggests that the inhibitor species are adsorbed on the CS surface where the adsorbed species mechanically form a protected film on the metal surface which inhibits the action of the corrosion. A close comparison between tables 1 & 2 revealed that WL of CS increases with increasing temperature indicating that the rate of corrosion of CS increases with increase in temperature. The value of % IE was decreased with rise in temperature suggests that physical adsorption mechanism [25]. These results indicate that the adsorption of investigated compound shield the metal surface at room temperature [26]. However it may be shielded from the surface with rise in temperature. It is also clear that corrosion rate of CS in the absence and presence of inhibitor obeys Arrhenius type equation as it increases with raising solution temperature. The dependence of corrosion rate (k_{corr}) on the temperature can be expressed by Arrhenius equation 2:

$$k_{\text{corr}} = A \exp(-E_a^*/RT) \quad (2)$$

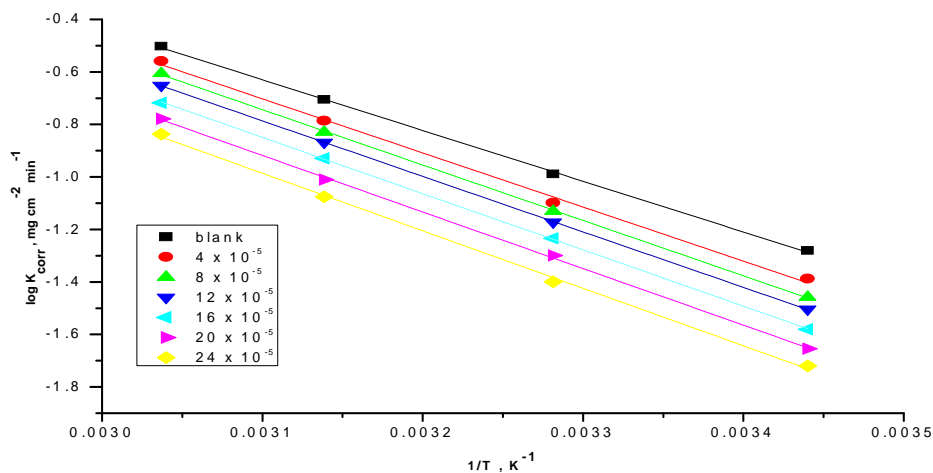
Where A is the pre-exponential factor and E_a^* is the apparent activation energy of the corrosion process. Arrhenius plot obtained for the corrosion of CS in 0.5 M H₂SO₄ solutions in the presence of different doses of thiophene-2-carbonitrile derivative is shown in figure 2. E_a^* values determined from the slopes of these linear plots are shown in table 3. The linear regression (R^2) is close to 1 which indicates that the corrosion of CS in 0.5 M H₂SO₄ solutions can be elucidated using the kinetic model. Table 3 showed that the values of E_a^* for inhibited solution is higher than that for uninhibited solution, suggesting that dissolution of CS is slow in the presence of inhibitor. It is known from Eq. 2 that the higher E_a^* values lead to the lower corrosion rate. This is due to the formation of a film on the CS surface serving as an energy barrier for the CS corrosion. Enthalpy and entropy of activation (ΔH^* , ΔS^*) of the corrosion process were calculated from the transition state theory as given from equation 3 (Table 5):

$$K_{\text{corr}} = (RT/Nh) \exp(\Delta S^*/R) \exp(-\Delta H^*/RT) \quad (3)$$

Where h is Planck's constant and N is Avogadro's number. A plot of $\log(k_{\text{corr}}/T)$ vs. $1/T$ for CS in 0.5 M H₂SO₄ with different doses of thiophene-2-carbonitrile derivative gives straight lines as shown in fig. 3. Values of ΔH^* are positive. This indicates that the corrosion process is an endothermic one. The entropy of activation ΔS^* is large and negative. This implies that the activated complex represents association rather than dissociation step, indicating that a decrease in disorder takes place, going from reactants to the activated complex [27].

Table 2: Variation of (%IE) and (C.R.) for various doses of thiophene-2-carbonitrile derivative at different temperatures after time 120 min. immersion

Temp., °C	Conc., ppm	WL, mg cm ⁻²	CR	% IE
35	Blank	12.29	0.0907	--
	40	5.90	0.0492	51.99
	80	5.82	0.0485	52.64
	120	4.43	0.0369	63.95
	160	3.30	0.0275	73.14
	200	3.08	0.0257	74.93
	240	2.15	0.0179	82.50
45	Blank	23.61	0.1651	--
	40	20.45	0.1603	13.40
	80	17.78	0.1482	24.69
	120	15.38	0.1290	34.85
	160	13.10	0.1092	44.51
	200	10.93	0.1053	53.70
	240	8.74	0.0567	63.00
55	Blank	42.33	0.3528	--
	40	38.68	0.3224	8.62
	80	36.02	0.3001	14.91
	120	34.05	0.2838	19.56
	160	32.57	0.2714	23.05
	200	30.94	0.2525	26.89
	240	29.78	0.2119	29.64

**Fig 2.** Arrhenius plots for CS rates (k_{corr}) after 120 minute of immersion in 0.5 M H_2SO_4 with and without various doses of thiophene-2-carbonitrile derivative**Table 3:** Activation parameters for CS corrosion without and with various doses of thiophene-2-carbonitrile derivative in 0.5 M H_2SO_4

Conc. M	Activation parameters		
	E_a^* , kJ mol ⁻¹	ΔH^* , kJ mol ⁻¹	$-\Delta S^*$, J mol ⁻¹ K ⁻¹
Blank	26.5	21.4	104.4
4×10^{-5}	33.5	27.4	62.8
8×10^{-5}	34.9	28.5	55.9
12×10^{-5}	39.4	32.3	29.1

16×10^{-5}	42.8	35.3	8.6
20×10^{-5}	44.4	35.9	5.9
24×10^{-5}	46.5	37.3	2.2

Open circuit potential (OCP):

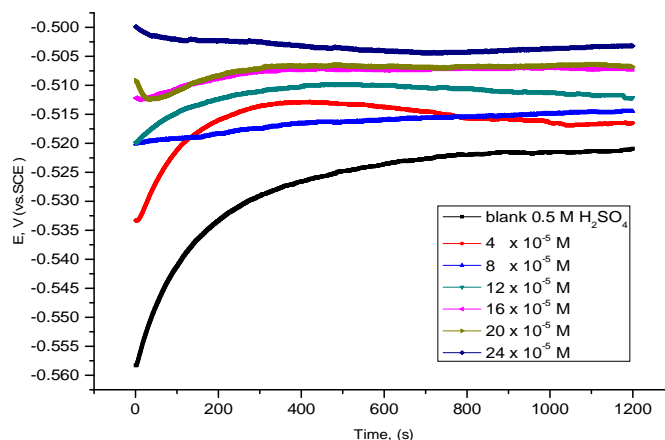


Fig 3. OCP (E_{OCP}) vs time relations for CS in 0.5 M H_2SO_4 without and with thiophene-2-carbonitrile derivative at 25°C

Fig 3 shows the change of E_{OCP} with time obtained at CS in 0.5 M H_2SO_4 both in the absence and presence of various doses of thiophene-2-carbonitrile derivative at 25°C. From this figure we can observe: 1) E_{OCP} in the blank solution started at -558 mV then shifted anodically and the steady state is obtained after 10 min. This indicates the initial dissolution process of the air formed oxide film on the metal surface 2) in the presence of thiophene-2-carbonitrile derivative, the E_{OCP} started at relatively negative potential compared with that in the absence of the inhibitor and then shifted anodically. The steady state is attained rapidly, compared with the blank. According to Riggs [28], the classification of a compound as an anodic or cathodic type inhibitor is based on the E_{OCP} displacement; if the shift in E_{OCP} is at least ± 85 mV compared to the one measured in the blank solution it can be classified as an anodic or cathodic inhibitor. However, from fig 3 the shift in E_{OCP} on adding thiophene-2-carbonitrile derivative is about 50 mV at dose 24×10^{-5} M revealing that the present inhibitor acts as a mixed type inhibitor. The initial negative shift could be attributed to the adsorption of the inhibitor and the partial attraction of electrons by nitrogen and/or oxygen, sulfur atom with high electronegativity in the inhibitor decreasing the electron density on the iron.

Potentiodynamic polarization (PP) measurements: PP was carried out in order to gain a knowledge concerning the kinetics of the cathodic and anodic reactions. Figure-4 presents the results of the effect of thiophene-2-carbonitrile derivative on the cathodic and anodic polarization curves of CS in 0.5 M H_2SO_4 . It could be observed that both the cathodic and anodic reactions were suppressed with the addition of thiophene-2-carbonitrile derivative, which suggested that thiophene-2-carbonitrile derivative reduced anodic dissolution and also retarded the hydrogen evolution reaction. Electrochemical corrosion kinetics parameters, i.e. corrosion potential (E_{corr}), cathodic and anodic Tafel slopes (β_a , β_c) and corrosion current density (i_{corr}) obtained from the extrapolation of the polarization curves were given in Table 4. The parallel cathodic Tafel curves in fig. 4 suggested that the hydrogen evolution is activation-controlled and the reduction mechanism is not affected by the presence of thiophene-2-carbonitrile derivative. The region between linear part of cathodic and anodic branch of polarization curves becomes wider as the inhibitor is added to the acid solution. Similar results were found in the literature [29]. The values of β_a and β_c changed slightly with increasing thiophene-2-carbonitrile derivative dose indicated the influence of thiophene-2-carbonitrile derivative on the kinetics of metal dissolution and of hydrogen evolution. Due to

the presence of some active sites, such as aromatic rings, hetero-atoms in thiophene-2-carbonitrile derivative for making adsorption, they may act as adsorption inhibitors. Being absorbed on the metal surface, thiophene-2-carbonitrile derivative controlled the anodic and cathodic reactions during corrosion process, and then their corrosion %IE are directly proportional to the amount of adsorbed inhibitor. The functional groups and structure of thiophene-2-carbonitrile derivative play important roles during the adsorption process. On the other hand, an electron transfer takes place during adsorption of the neutral organic compounds at metal surface [30]. As it can be seen from table-6, the studied inhibitor reduced both anodic and cathodic currents with a slight shift in corrosion potential (15 mV). According to Ferreira and others [32], if the displacement in corrosion potential is more than 85mV with respect to corrosion potential of the blank solution, the inhibitor can be seen as a cathodic or anodic type. In the present study, the displacement was 15 mV which indicated that the studied inhibitor is mixed type inhibitor. The results obtained from Tafel polarization showed good agreement with the results obtained from WL method. The surface coverage (θ) and % IE were calculated using equation 4.

$$\%IE = \theta \times 100 = [1 - (i_{\text{corr}}/i_{\text{corr}}^{\circ})] \times 100 \quad (4)$$

Where i_{corr} and i_{corr}° are the current densities in presence and absence of thiophene-2-carbonitrile derivative, respectively.

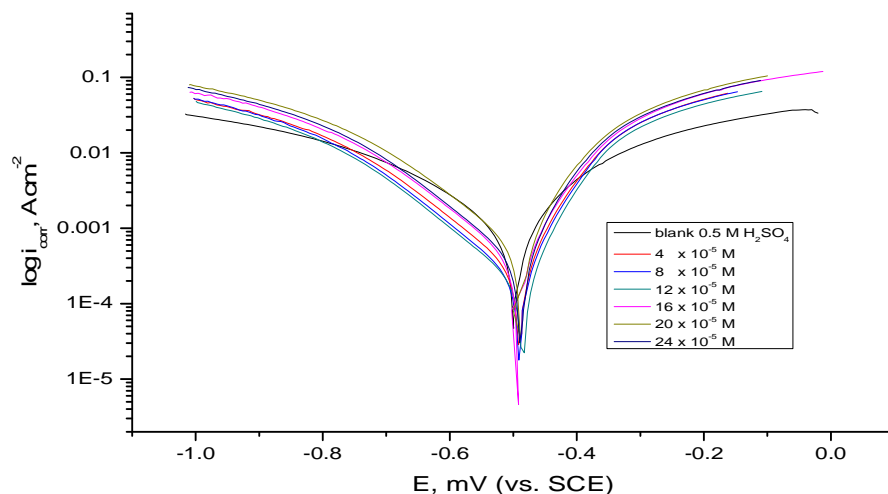


Fig 4. PP curves for the dissolution of CS in 0.5 M H₂SO₄ in the absence and presence of different doses of thiophene-2-carbonitrile derivative at 25°C

Table 4. Effect of doses of tested compound on the free corrosion potential (E_{corr}), corrosion current density (i_{corr}), Tafel slopes (β_c , β_a), corrosion rate (k_{corr}), (θ), and (%IE) of CS in (0.5 M) H₂SO₄

[Inh.] M	$-E_{\text{corr}}$ mV vs SCE	$j_{\text{corr}} \times 10^{-4}$ $\mu\text{A cm}^{-2}$	β_c mV dec ⁻¹	β_a mV dec ⁻¹	k_{corr} mmy ⁻¹	θ	%IE
Blank	499	1260	261	180	577.9	--	--
4×10^{-5}	488	540	189	97	246.7	0.571	57.1
8×10^{-5}	492	391	170	90	178.7	0.690	69.0
12×10^{-5}	490	330	171	82	150.7	0.738	73.8
16×10^{-5}	490	288	175	83	131.7	0.771	77.1
20×10^{-5}	489	253.0	110	61	115.4	0.80	79.9
24×10^{-5}	485	231.0	171	79	105.7	0.817	81.7

Electrochemical impedance spectroscopy (EIS) measurements: Nyquist plots of CS in uninhibited and inhibited acid solutions containing different doses of thiophene-2-carbonitrile derivative are presented in figure-5. EIS spectra obtained consists of one depressed capacitive loop (one time constant in Bode-phase plot). The increased diameter of capacitive loop obtained in 0.5 M H₂SO₄ in presence of thiophene-2-carbonitrile derivative indicated the inhibition of corrosion of CS. The high frequency capacitive loop may be attributed to the charge transfer reaction. Corrosion kinetic parameters derived from EIS measurements and %IE are given in table 5. (C_{dl}) and (R_{ct}) were obtained from EIS measurements as described elsewhere [33]. This decrease in C_{dl} results from a decrease in local dielectric constant and/or an increase in the thickness of the double layer, suggested that inhibitor molecules inhibit the CS corrosion by adsorption at the metal/acid interface [34]. The depression in Nyquist semicircles is a feature for solid electrodes and often referred to as frequency dispersion and attributed to the roughness and other in homogeneities of the solid electrode [35]. Fig. 7 showed the electrical equivalent circuit employed to analyze the impedance spectra. Excellent fit with this model was obtained for all experimental data. (θ) and % IE were calculated using equation 5:

$$\%IE = \theta \times 100 = [1 - (R_{ct}/R_{ct}^{\circ})] \times 100 \quad (5)$$

Where R_{ct} and R_{ct}° are the charge transfer resistances in presence and absence of inhibitor, respectively. The results obtained from WL, PP and EIS techniques are in a good agreement.

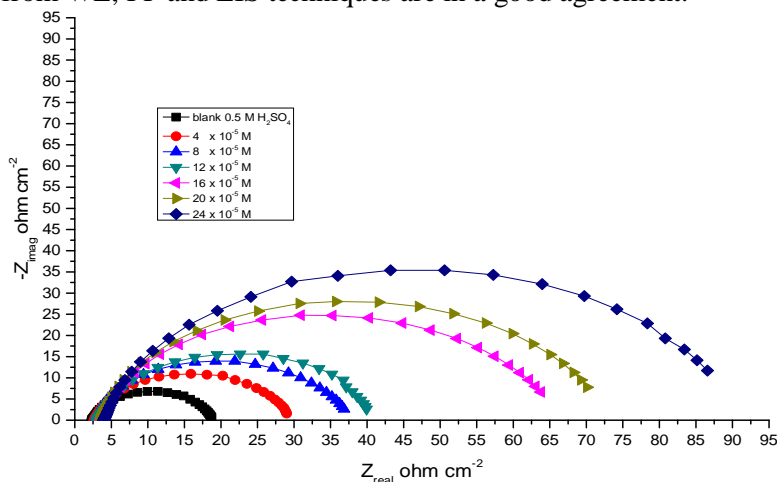


Fig 5. the Nyquist plots for the corrosion of CS in 0.5 M H₂SO₄ without and with different doses of thiophene-2-carbonitrile derivative at 25°C

Table 5: EIS parameters for the corrosion of CS in 0.5 M H₂SO₄ without and with different doses of investigated compound at 25°C

Conc. ppm	C_{dl} $\mu F cm^{-2}$	R_{ct} Ωcm^2	θ	%IE
Blank	87.5	16.47	--	--
4×10^{-5}	78.2	26.65	0.382	38.2
8×10^{-5}	77.3	34.00	0.516	51.6
12×10^{-5}	64.6	37.90	0.565	56.5
16×10^{-5}	62.1	61.58	0.733	73.3
20×10^{-5}	61.9	69.03	0.761	76.1
24×10^{-5}	65.9	85.88	0.808	80.8

Electrochemical frequency modulation (EFM) measurements: EFM is a non-destructive corrosion measurement like EIS; it is a small signal Ac technique. Unlike EIS, however, two sine waves (at different

frequencies) are applied to the cell simultaneously. The great strength of the EFM is the causality factors which serve as an internal check on the validity of the EFM measurement [36]. With the causality factors the experimental EFM data can be verified. % IE calculated from equation 3 increases with increasing the studied inhibitor doses. Intermodulation spectra obtained from EFM measurements were constructed for iron 0.5 M H₂SO₄ solutions as a function of 24×10^{-4} M of thiophene-2-carbonitrile derivative at 25°C. Corrosion kinetic parameters, namely corrosion current density (i_{corr} , Tafel constants (β_a , β_c) and causality factors (CF-2, CF-3) were listed table 6 as a function of doses of thiophene-2-carbonitrile derivative at 25°C. The causality factors in table 6, which are very close to theoretical values according to the EFM theory, should guarantee the validity of Tafel slopes and corrosion current densities. The standard values for CF-2 and CF-3 are 2.0 and 3.0, respectively [37].

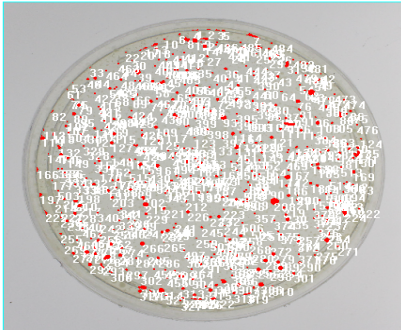
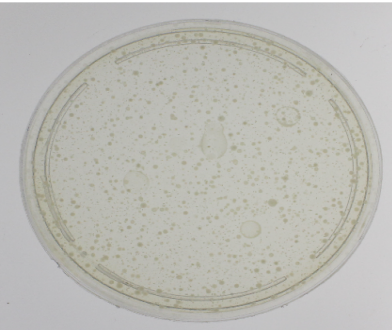
Table 6: Electrochemical kinetic parameters obtained from EFM technique for CS in (0.5 M) H₂SO₄ in the absence and presence of different doses of thiophene-2-carbonitrile derivative

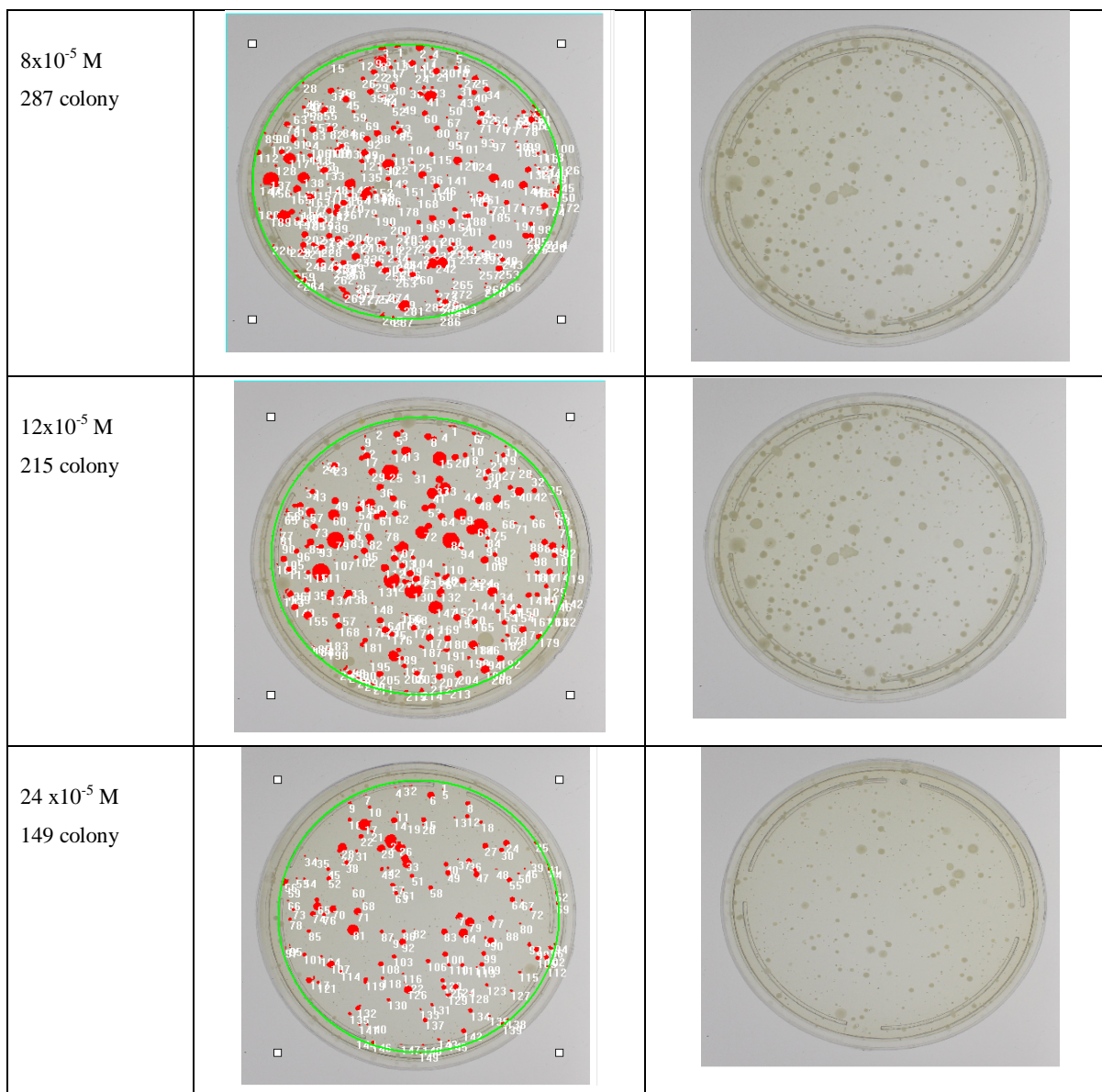
Conc. ppm	i_{corr} , $\mu\text{A cm}^{-2}$	β_a , m V dec ⁻¹	β_c , mV dec ⁻¹	CF-2	CF-3	CR mpy	%IE
Blank	1352	151	183	1.6	5.8	617.6	
4	824.0	89	124	1.9	3.6	376.5	39.1
8	599.9	93	124	1.9	2.9	274.1	55.6
12	574.4	85	113	1.7	2.5	262.4	57.5
16	355.6	88	120	1.9	3.8	162.5	73.7
20	328.3	87	122	1.8	4.6	150.0	75.7
24	236.9	81	112	1.9	3.1	108.2	82.5

APPLICATIONS

Biological Effect of thiophene-2-carbonitrile derivative on bacteria extracted from cooling tower of ammonia plant: After collecting the samples of water from ammonia cooling tower and using bacterial culture media for multiplying bacteria under laboratory conditions. Chemical analysis of sample water using auto analyzer3 (seal analytical) founded presence of amount of nitrite about 4 ppm and that's an evidence of presence of nitrifying bacteria [38, 39]. Preparing a spore suspension of collected bacteria about 0.5 L and use it to prepare a desired dose of Distyryl derivatives. Using a suitable nutrient to cultivation of bacteria in petri dish. Table 9 from table it found that have a good effect in inhibiting bacteria growth. The instrument used in bacterial count is Doc-it colony counter

Table 9. Bacteria clones cultivated in petri dishes counted by instrument

No. of colonies	Instrument counting	Petri dish
518 colony in blank		



Mechanism of Inhibition: Inhibition of the corrosion of CS in 0.5 M H_2SO_4 solution by thiophene-2-carbonitrile derivative is determined by WL, PP, EIS, EFM Studies, it was found that the %IE depends on dose, nature of metal, the mode of adsorption of thiophene-2-carbonitrile derivative and surface conditions. The observed corrosion data in presence of thiophene-2-carbonitrile derivative, namely: i) The decrease of CR and corrosion current with increase in dose of the derivatives, ii) The linear variation of WL with time, iii) The shift in Tafel lines to higher potential regions, iv) The decrease in % IE with increasing temperature indicates that physical adsorption takes place and v) The % IE was shown to depend on the number of adsorption active centers in the molecule and their charge density. It was concluded that the mode of adsorption depends on the affinity of the metal towards the π -electron clouds of the ring system. Metals such as Fe, which have a greater affinity towards aromatic moieties, were found to adsorb benzene rings in a flat orientation. The investigated compound contains 4 N, 3 O and S atoms all these atoms may act as centers of adsorption as well as it contains two benzene rings which increase the electron density on the molecule.

CONCLUSIONS

In this study, corrosion inhibition efficiency of thiophene-2-carbonitrile derivative on in CS in 0.5 M H_2SO_4 was determined by chemical and electrochemical measurements. EIS data revealed that R_{ct} increase which accounted for good %IE, and C_{dl} decrease with increase of inhibitor doses. The polarization studies showed that this compound behaves as mixed type inhibitor. This compound show good biological activity.

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