Estimation of Water-Soluble Polymers (Poloxamer and Pectin) as Corrosion Inhibitors for Carbon Steel in Acidic Medium

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The inhibitory strength of the two soluble polymer compounds namely, poloxamer (PLX) and pectin (PEC) towards the corrosion of carbon steel in 1.0 M HCl solution was elucidated utilizing four techniques. The inhibition efficacy augments with the concentration of the tested polymer and with reducing temperature. The outcome of the corrosion parameter obtained from all utilized measurements emphasizes the inhibiting vigor of these two compounds. The inhibition was interpreted by the formation of an adsorbing coated layer that isolates the steel surface from aggressive solutions. The adsorption of PLX and PEC on the steel surface follows Freundlich isotherm. The adsorption type is a combination of physical and chemical adsorption. Also, PLX and PEC compounds inhibit the pitting corrosion of C-steel in Cl- ions including the solutions by moving the pitting potential in the positive direction. The inhibition efficacy of PET more than PLX due to higher molar mass of PET resulting in greater surface coverage on C-steel surface. There is a clear harmony on the values of the inhibition efficacy resulting from the different techniques.

1. INTRODUCTION

Employing environmentally friendly, non toxic, organic compounds as inhibitors for the corrosion of metals was attracted attention of various research groups in recent times [1-4]. Some of these groups were reported successful utilizing of eco-friendly and relatively cheap polymers as corrosion inhibitors in dissimilar acidic and alkaline media. The use of such polymers as efficient

inhibitors may be ascribed to their less biodegradabilities, stabilities to metallic materials, multiple adsorption sites, capabilities of formation of complexes with metal ions, thereby blanketing the surface and safeguarding the metal from corrosive media [1,2]. A variety of polymers were examined as inhibitors for iron and steel corrosion and showed promising results especially in acidic corrosive media [5-16]. Solomon and others [11-13] have examined the impact of carboxyl methyl cellulose as corrosion inhibitor for mild steel in H_2SO_4 solutions. Chitosan was investigated as inhibitor for mild steel corrosion in different acidic media [14,15]. Abdallah et. al. [16] have also studied the impact of guar gum on carbon steel corrosion in an acidic media. In the previous studies the inhibition impacts of two water-soluble polymers viz., maltodextrin and chitosan on the dissolution of carbon steel in 1.0 M HCl solution were investigated {17}.

Pectin, which extracted from citrus fruits, is an acidic hetero-polysaccharide consisting of esterified D-galacturonic acid resides in an alpha-(1-4) chain as ilustraste in Figure 1. It is employed in food, medicines, cosmetics, and as a source of dietary fiber [18]. Pectin has a molecular weight of about 60,000–130,000 g/mol, depending upon the origin and extraction circumstances. The inhibition efficiency of naturally occurring pectin polymer on the corrosion of Al in acidic media has been studied previously [19,20]. The authors have suggested that the geometrical configuration and functional groups of the inhibitor were the principal factors that affected its inhibition impact. Poloxamers are nonionic triblock copolymers composed of a central hydrophobic chain of poly(propylene oxide) flanked by two hydrophilic chains of poly(ethylene oxide), Fig. 1. Due to their amphiphilic arrangements, such polymers have surfactant properties that make them useful in various industrial applications, cosmetics, and pharmaceuticals.
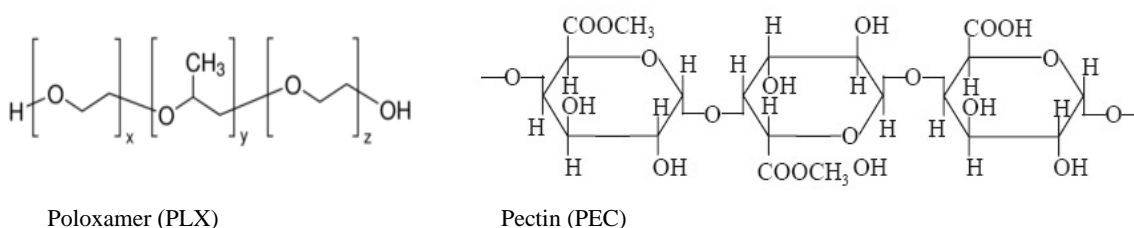

Poloxamer (PLX)   Pectin (PEC)

Figure 1. Chemical structures of poloxamer (PLX) and pectin (PEC) polymers.

In the present investigation, we planned to examine the inhibition impacts of two presumed polymers, viz., poloxamer (PLX) and pectin (PEC) on carbon steel corrosion in hydrochloric acid solution (1.0 M) utilizing different tools, chemical as weight loss measurements (WLM), and electrochemical as galvanostatic polarization (GSP), potentiodynamic anodic polarization (PAP) and electrochemical impedance spectroscopy (EIS). The plan was extended to evaluate the activation thermodynamic parameters of the corrosion process in the absence and presence of the examined polymers.

2. EXPERIMENTAL

2.1. Materials

Pectin and poloxamer polymers were Sigma-Aldrich chemicals. Solutions of both pectin and poloxamer were freshly prepared by dissolving the weighted amounts in double-distilled water. Hydrochloric acid solution was prepared using double distilled water and the prerequisite concentrations were acquired by dilution. The investigated iron alloy was a carbon steel rods which produced by Saudi SABIC company. The chemical composition (wt. %) of carbon steel rods is: 0.11 C, 0.45 Mn, 0.05 S 0.4 P, 0.25 Si, 0.039 Al, and the rest is Fe. All other employed chemicals were also from Sigma and were used as received.

2.3. Techniques

2.3.1. Weight-loss measurements (WLM)

WLM conveyed out in a thermostated system. The investigated carbon steel sample utilized for WL experiments were cylindrical rods (14 cm^2 area). Such rods were prepared for such experiments as mentioned previously [21].

2.3.2. Electrochemical measurements

Electrochemical runs were conveyed out in an electrochemical cell composed of three-electrodes, namely, Pt sheet as a counter electrode (CE), standard calomel electrode (SCE) as the reference electrode (RE) and the investigated working electrode (WE), carbon steel, which was fitted into a Teflon tube. The exposed surface area of the working electrode was abraded with different emery papers down to 2000, rinsed with distilled water, acetone, and then dried. Before measurements the electrode was immersed in the test solution at open circuit potential (OCP) for about 30 min at 25 ºC or until the steady state is obtained. All measurements were performed on a thermostated PGSTAT30 potentiostat / galvanostat.

Both galvanostatic polarization (GSP) and potentiodynamic anodic polarization (PAP) measurements were conveyed out from a cathodic potential of -0.25 V to an anodic potential of +0.25 V regarding to the corrosion potential, E_{corr} at a scan rate of 1.0 mV/s. Electrochemical impedance spectroscopy, EIS, measurements were performed in a frequency range of 100 kHz to 0.1 Hz with an amplitude of 4.0 mV peak-to-peak using AC signals at OCP.

3. RESULTS AND DISCUSSION

3.1. WL technicality

3.1.1. Impact of polymer concentration

The impact of different concentrations of polymer (PEC) on the WL - immersion time curves of CS in 1.0 M HCl solution were elucidated in Figure 2. The same curves were gained in case of the PLX

polymer but not appear. It is evident that with rising the polymer concentration, the WL values reduces suggesting the inhibitory effect of polymer compounds. The straight-line relation of WL with immersion time in an uninhibited and inhibiting 1.0M HCl solution demonstrating the lack of insoluble surface films during corrosion. In the devoid of any surface films, the polymer compounds are initially adsorbed on to the CS surface and afterward inhibit the dissolution reaction [22].
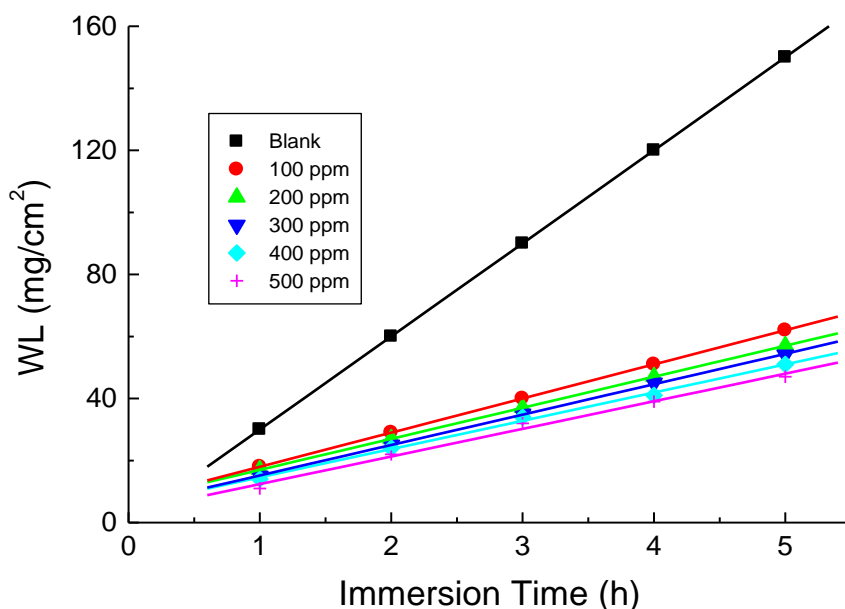

Figure 2. Weight loss– immersion time curves of CS in free 1.0M HCl solution and with different concentrations of PEC

The corrosion rate (R_{corr}) the percentage protection efficiency (%PE) and the surface coverage (Θ) of the polymer compounds were computed from the next relations [23] and given in Table 1.

$$R_{corr} = \Delta W / St \qquad (1)$$
$$\%PE = (R_{un} - R_{in}) / R_{un} \times 100 \qquad (2)$$
$$\Theta = \%IE / 100 \qquad (3)$$

where, ΔW is the change in WL, A is the surface area of CS coupons, t is the immersion time in minutes, R_{un} and R_{in} is the corrosion rate of CS in free HCl solution of and with polymer compounds, consecutively.

The calculated corrosion functions are registered in Table 1. It is evident that as the concentration of the two polymers compounds (PLX & PEC) increases the values or R_{corr} reduces and the values of Θ and %PE increases. These data demonstrate the inhibitory strength of the polymeric compounds. Then the area covered by inhibitor molecules increased and forming a more adsorbent layer on the CS surface, At the same of the concentration of polymer compounds the %PE decreases as follows PEC > PLX.

3.1.2. Influence of elevated temperature

The influences of high temperature on the corrosion rate of CS in blank 1.0 M HCl solution and including 500 ppm of the two polymer compounds (PLX & PEC) was examined by WL technicality over a temperature range from 25 to 55°C. Like curves to Fig.1 are obtained but invisible and the corrosion parameters were included in Table 2. Clearly from these data, the $R_{corr.}$ values increase and therefore the %PE decreases. The highest %PE is observed at 25°C.

Table 1. Corrosion parameters obtained from weight loss for the dissolution of C-steel in blank 1.0 M HCl solution and contains different concentrations of polymer compounds.

Polymer	Polymer Conc. (ppm)	R_{corr} (mg cm^{-2} min^{-1})	% PE	θ
Blank	0	**0.58**	-	-
PLX	100	0.13	77.76	0.78
	200	0.12	79.65	0.80
	300	0.12	80.17	0.80
	400	0.11	80.68	0.81
	500	0.11	81.38	0.81
PEC	100	0.10	83.62	0.84
	200	0.08	86.38	0.86
	300	0.071	87.76	0.88
	400	0.068	88.83	0.89
	500	0.062	89.31	0.89

The activation functions of the corrosion operation such as activation energy (E_a^*), enthalpy (ΔH^*) and entropy (ΔS^*) of activation of the corrosion process was determined using Arrehenius and transition state equations [24,25]:

$$\ln R_{corr.} = \ln A - E_a^*/RT \qquad (4)$$

$$R_{corr.} = RT/Nh \, \exp^{(\Delta S^*/R)} \exp^{(-\Delta H^*/RT)} \qquad (5)$$

where, A is Arrhenius constant, R is the gas constant, h is Planck's constant and N is Avogadro's number.

The values of E_a^* are determined from the slope of the straight lines that occurred in the Arrhenius relation (log R_{corr} vs 1/T) in Figure 3 for CS in free 1.0 M HCl solutions and include 500 ppm of polymer compounds. It is found that the value of E_a^* is equal to 18.20 kJ mol^{-1} for free 1.0 M HCl solution and equal to 23.41 and 29.32 KJ mol^{-1} in the presence of a 500 ppm of two polymer compounds (PLX & PEC), respectively. The presence of two polymer compounds increase the values of the E_a^* than in the free HCl solution, These data suggest that the polymer compounds act as inhibitors by increasing E_a^* of CS dissolution by constitute a barrier to mas and charge transfer by their adsorption on CS surface. This indicates the adsorption of the polymer compounds on the C-steel surface is physical.

Fig. 4 demonstrates a plot of (log $R_{corr.}$ vs 1 / T) against (1/T). A straight lines are obtained with a slope of ($-\Delta H^*/2.303R$) and an intercept of (log R/Nh + $\Delta S^*/2.303$ R). The computed values of ΔH^* are equal to 16.90 kJ mol^{-1} for blank 1.0 M HCl solution and equal to 19.45 and 27.85 KJ mol^{-1} in the

presence of a 500 ppm of two polymer compounds (PLX & PEC), respectively. The positive sign of ΔH^* reflect that the adsorption of polymer compounds on the CS surface is endothermic process.

Table 2. Impact of high temperature on the corrosion parameters for C-steel in blank 1.0 M HCl solution and included 500 ppm of polymer.

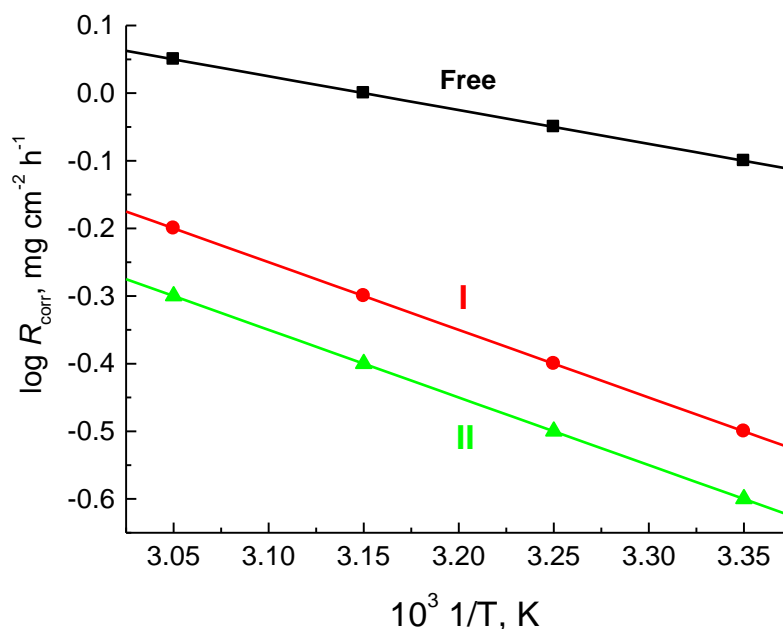| Medium	T, K	R_{corr} mg cm^{-2} h^{-1}	% PE
Blank	298	0.68	--
	308	0.84	--
	318	1.02	--
	328	1.14	--
Blank + 500 ppm of PLX	298	0.11	81.38
	308	0.18	78.83
	318	0.25	75.93
	328	0.31	72.68
Blank + 500 ppm of PEC	298	0.06	89.31
	308	0.11	86.68
	318	0.20	80.63
	328	0.25	78.37

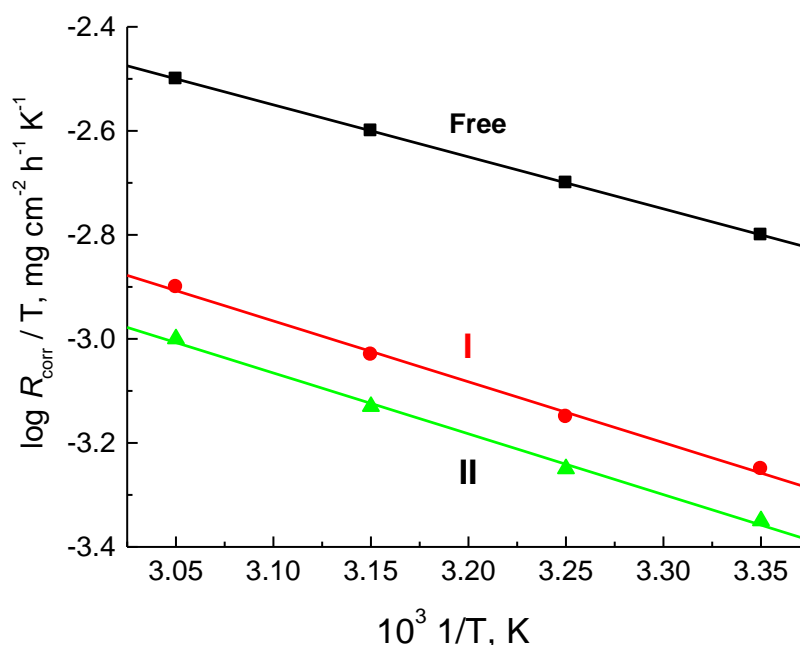**Figure 3.** Arrhenius relation for C-steel in free 1.0 M HCl solution and includes 500 ppm of: 1) PLX 2) PEC.

Figure 4. Transition state relation for C-steel in free 1.0 M HCl solution and includes of 500 ppm of: 1) PLX, 2) PEC

The calculated values of ΔS^* are equal to -102.34 J mol^{-1} K^{-1} in the free 1.0 M HCl solution and equal to -111.42 and -142.81 J mol^{-1} K^{-1} in presence of a 500 ppm of a 500 ppm of two polymer compounds (PLX & PEC), respectively. The values of ΔS^* in the free acid solution and the inhibitory solutions are negative. This means that the activation complex is a rate determining step represents correlation rather than dissociation, which indicates a reduce in disorder when moving from reactant to the activated complex [26].

The %*PE* arrangement of the two polymer compounds as collected from the augmentation in E_a^* and ΔH^* values and the ΔS^* values decrease are as follows: PEC > PLX.

3.2. Galvanostatic polarization measurements

The influence of increasing concentration of polymer (PEC) on the galvanostatic polarization curves of CS in 1.0 M HCl solution is represented in Fig 5. The same curves are obtained in case of polymer (PLX) but are not visible. The general features of these curves. We can observe in the first transition region where the potential increases or lowered (anodic and cathode polarization) with the current density applied after this region, there is a rapid linear accumulation of potentials with the current density.

The corrosion current density (I_{corr}) are computed by the intersection of the anodic and cathodic Tafel lines with corrosion potential (E_{corr}). The protection efficacy (%PE) was evaluated from the subsequent relation:

$$\%PE = [I_{un} - I_{in} / I_{un.}] \ 100 \qquad (6)$$

where, I_{un} and I_{in} are the corrosion current densities in the blank 1.0 M HCl and includes PLX and PEC compounds. The assigned values of the cathodic and anodic Tafel slopes (β_a & β_c), E_{corr}, I_{corr} and %PE are registered in Table 3.

By examining this table, it became clear to us that with increasing polymer compounds concentrations, they indicate the following:

1- The acquired cathodic and andic curves display Tafel-type behavior.

2- The values of Tafel slopes (β_a & β_c) were changed slightly indicating the PLX and PEC compounds are considered as mixed type inhibitors [27]. That is, these compounds influenced both cathodic hydrogen evolution and anodic steel corrosion reactions

3- E_{corr} values moved to less negative and I_{corr} values decreases indicating that the inhibiting strength of PLX and PEC compound.

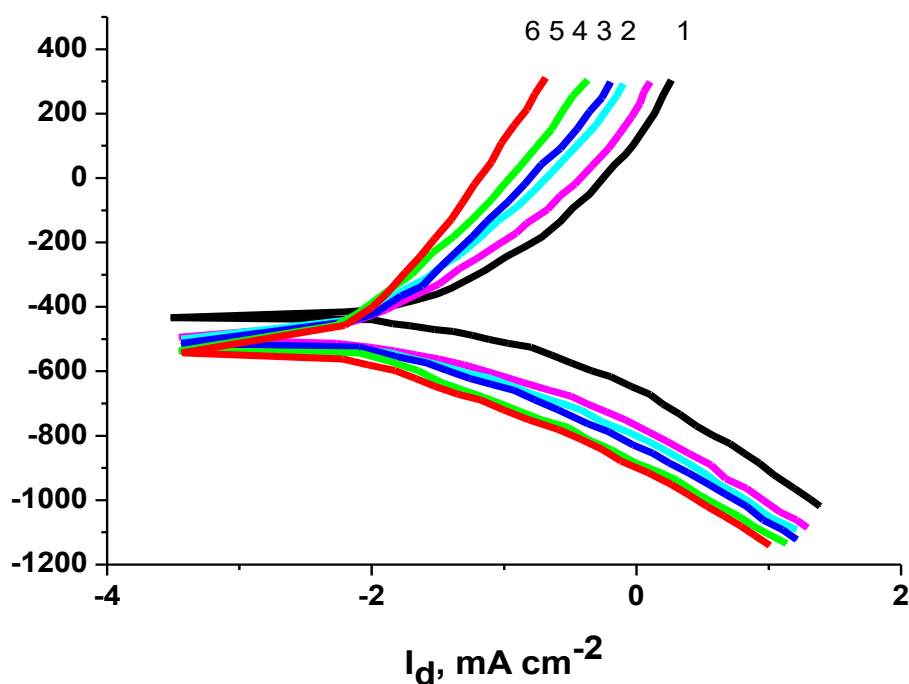4- At the same concentration of the polymer compounds, the %PE decreases as follows PEC > PLX.

Figure 5. Galvanostatic polarization curves of CS in free 1.0 M HCl solution and with different concentrations (ppm) of PEC compounds: 1) 0.00   2) 100   3) 200   4) 300   5) 400   6) 500.

Table 3. Corrosion data acquired from the galvanostatic polarization curves of CS in 1.0 M HCl solution includes different concentrations of PLX and PEC compounds.

Inhibitor	Conc. (ppm)	β_a mV dec^{-1}	β_c mV dec^{-1}	E_{corr} V(SCE)	I_{corr} (mA cm^{-2})	%PE
PLX	0	78	113	-434	1.78	-
	100	80	118	-440	0.791	79.10
	200	81	120	-454	0.8045	80.45
	300	98	133	-487	0.8247	82.47
	400	102	134	-492	0.8393	83.93
	500	120	145	-498	0.8426	84.26
PET	100	119	108	-471	0.8247	82.47
	200	147	122	-488	0.8876	88.76
	300	149	175	-491	0.8966	89.66
	400	171	194	-494	0.9056	90.56
	500	188	203	-499	0.9140	91.40

3.3. Potentiodynamic anodic polarization measurements

The two polymer compounds have been tested as pitting corrosion inhibitors by potentiodynamic anodic polarization measurements. Fig. 6 elucidated the potentiodynamic anodic polarization curves of CS in in 1.0 M HCl + 0.1 M NaCl solution containing dispersive concentrations of PET compound at a sweep rate of 1m V sec^{-1}.like curves are obtained in case in the presence of PLX polymer. It is evident form this Figure there is no any anodic peak. The cathodic current increases and remains constant at zero current until the current increase suddenly at definite potential defined as pitting corrosion potential (E_{pitt}) [28,29]. With increasing the concentration of the polymer compounds, the E_{pitt} moved to more positive (noble) direction. Fig .7 represents the relationship between E_{pitt} and logarithm of concentration of the polymer compounds. Straight lines relationship was obtained in accordance with the following equation [30,31]:

$$E_{pitt} = Y + Z \log C_{inh.} \qquad (7)$$

where, Y and Z are constants depend on both the composition of polymer and the nature of the electrode. There is a noble shift of E_{pitt} proving the PLX and PEC compounds acted pitting inhibitors. At the same of the concentration of the polymer compounds the shift in the noble direction decrease in the following sequence: PEC > PLX.
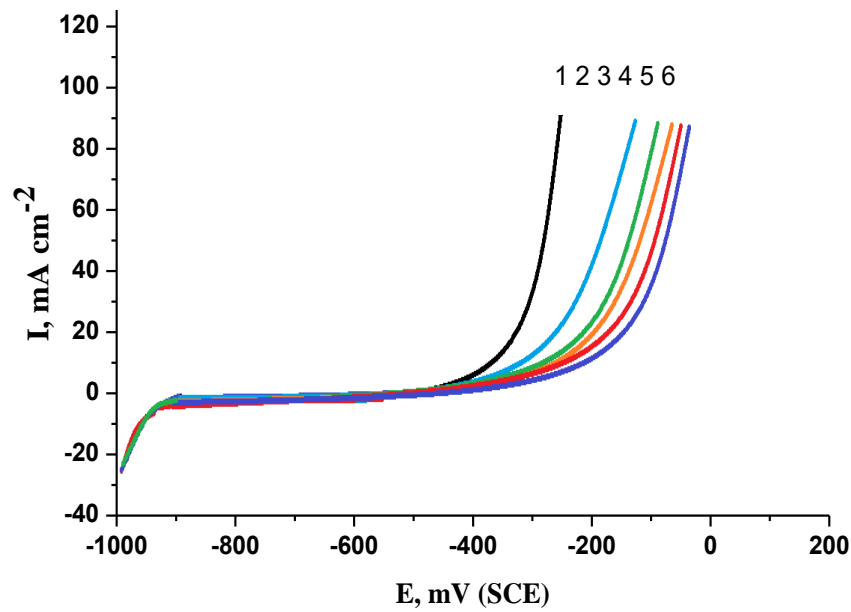
Figure 6. Potentiodynamic anodic polarization curves of CS electrode in 1.0 M HCl + 0.1 M NaCl solution containing different concentrations (ppm) of PET compound at a sweep rate of 1.0 m V sec^{-1}. 1) 0.00   2) 100   3) 200   4) 300   5) 400   6) 500.
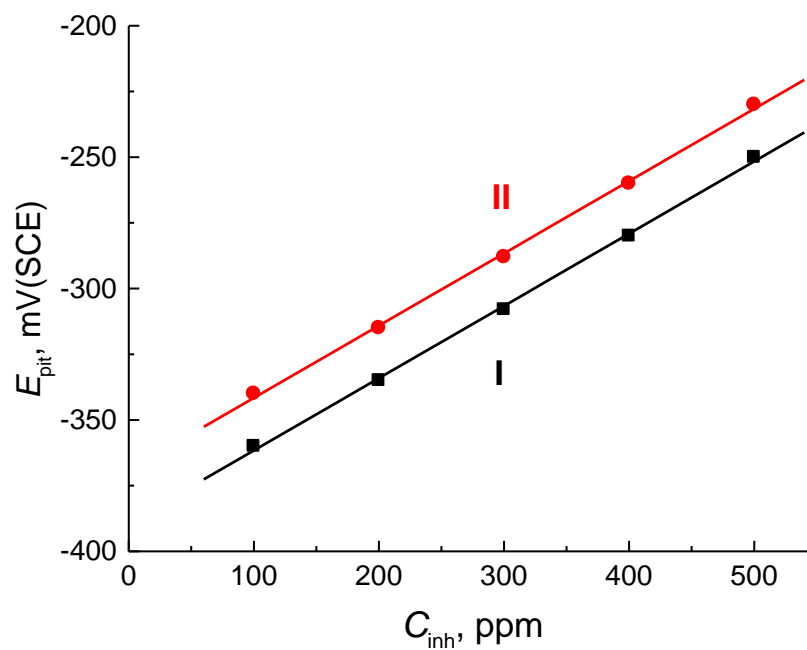

Figure 7. The relationship between E_{pit} and concentration of polymer compounds: 1) PLX, 2) PET

3.4. Electrochemical impedance spectroscopy measurements

The influence of different concentrations of polymer (PEC) on the Nyquist diagrams of CS in a 1.0 M HCl solution was demonstrated in Figure 8. The same curves were gained in the PLX polymer but did not appear. This figure indicate that the impedance diagram does not show ideal semicircles. This behavior can be attributed to the frequency dispersion due to roughness and heterogeneity of the electrode surface [32]. The increase in the radius of the semicircles with the increase in the concentration of the polymer indicates that the increase in the protective properties of the surface of CS. Thus, the capacitive semicircle is associated with the dielectric properties and the thickness of the adsorbed film layer.

The values of solution resistance (R_s) and charge transfer resistance (R_{ct}) can be determined from the intercepts of the semicircle with the axis of the real component. The capacity of double layer (C_{dl}) was computed from the angular frequency ($\omega = 2\pi f$) at the maximum imaginary component and the charge transfer resistance according to the subsequent equation:

$$C_{dl} = [1/\omega_{max} \cdot R_{ct}] = [1/2\pi \cdot f_{max} \cdot R_{ct}] \tag{8}$$

where, f is frequency, ω is the angular velocity.

The protection efficiency (% PE) is calculated using R_{ct} as follow [33]:

$$\% \ PE = [(R_{ct(in)} - R_{ct(un)})/R_{ct(in)}] \ x100 \tag{9}$$

where, $R_{ct(un)}$ and $R_{ct(in)}$ are the charge transfer resistance values in the free and inhibited CS respectively. The computed values of R_s, R_{ct}, C_{dl} and %PE are recorded in Table 4.
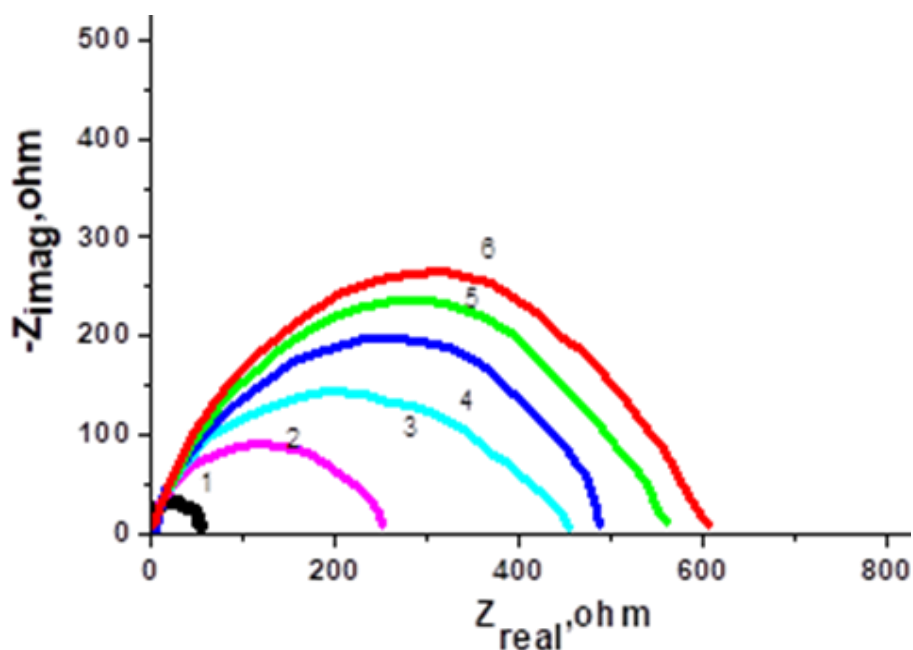

Figure 8. Nyquist plot of CS in free 1.0 M HCl solution and including different concentrations of PEC compounds

Table 4. Corrosion parameters resulted from the electrochemical impedance spectroscopy measurements for CS in free 1.0 M HCl solution and including different concentrations of the examined PLX and PET compounds.

| Polymer	Polymer Conc. (ppm)	R_s (Ω cm²))	C_{dl}, μF cm^{-2}	R_{ct}, Ω cm^{-2}	%PE
Blank	0.0	1.46	187	58	-----
PLX	100	1.43	151	206	71.84
	200	1.40	147	249	76.70
	300	1.38	139	271	78.60
	400	1.35	132	286	79.72
	500	1.23	126	320	81.87
PEC	100	1.53	142	258	77.51
	200	1.50	138	466	87.55
	300	1.48	133	498	88.35
	400	1.42	124	570	89.82
	500	1..40	120	602	90.36

By examining this table, it is evident that, with increasing the PLX and PET compounds the C_{dl} values lowered due to the progressive exchange of water molecule by adsorption of the polymer compounds that form adherent layer on the surface of the CS and resulting in a decrease in the local dielectric constant of the CS solution interface. The values of R_{ct} increase with increasing the concentration of the inhibitors and this in turn leads to the increase of the inhibition efficacy due to the construction of adherent layer on the CS/solution interface. Impedance diagrams for two polymers examined have a semicircular appearance; these diagrams indicate that the corrosion of carbon steel in 1.0 M HCl solution is fundamentally controlled by a charge transfer process. The computed values of %PE decreases in the following sequence: PEC > PLX. The effectiveness of the protection obtained from electrochemical impedance spectroscopy was arranged in strict accordance with that obtained from weight loss, galvanostatic polarization and potentiodynamic anodic polarization. This validates these instruments in the measurements of the polymer compounds examined.

3.5. Adsorption isotherm and inhibition mechanism

Polymer compounds operate as corrosion protection for CS corrosion in a 1.0 M HCl solution through adsorption onto the steel surface. The adsorption strength is influenced by several factors e.g., the chemical composition of the polymer used, the concentricity of aggressive electrolyte solutions, the acidity of the solution, temperature, the presence of the electro donating or electro repelling groups, and other factors [34]. The inhibition efficiency of PLX and PET compounds is determined by their molecular absorbability of its main component in the polymer molecule on the surface of CS.

The values of θ determined from weight loss measurements conformable to various concentrations of polymer were used to choose the better isotherm to determine the adsorption process

.The adsorption of polymer adsorbate at CS solution interface can be represented as replacement adsorption process between the polymer compound in the aqueous phase (Polymer)$_{sol}$ and water molecules adsorbed on the CS surface (H$_2$O)$_{Surf}$.

$$Polymer_{(sol)} + xH_2O_{(ads)} \leftrightarrow Polymer_{(ads)} + xH_2O_{(sol)} \qquad (10)$$
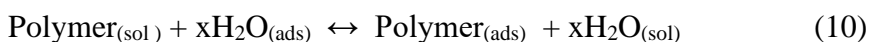
where, polymer$_{(sol)}$ and polymer $_{(ads)}$ are the polymer compounds in the aqueous solution and adsorbed on the CS surface, respectively, H$_2$O$_{(ads)}$ is the water molecules on the CS surface, x is the size ratio symbolizing the numbers of water molecules substitutes by one molecule of polymer examined.
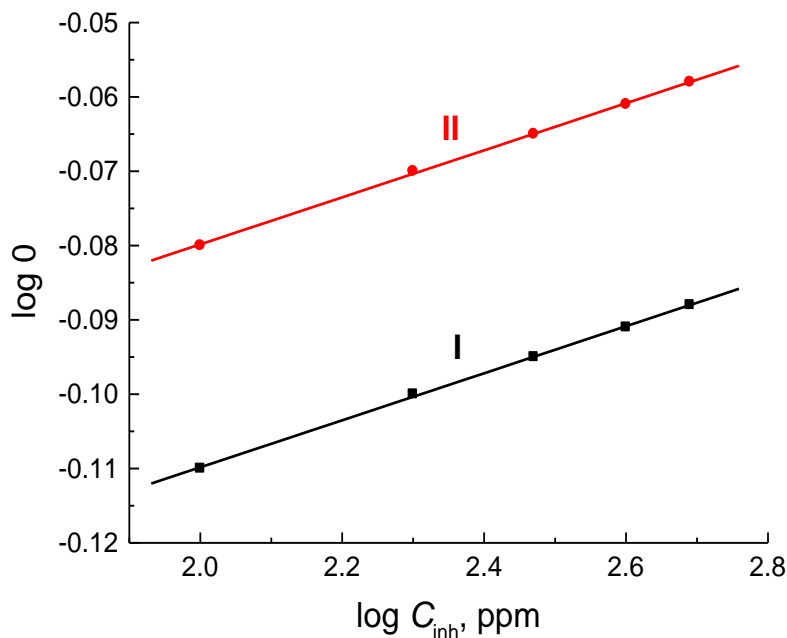

Figure 9. Freundlich isotherms for C-steel in 1.0 M HCl solution. I) PLX,   II) PEC

Trials have been carried out to accommodate the values of θ for many isotherms. So, far the best fit with Freundlich isotherm has been obtained approving to the subsequent equation [35]:

$$\log \theta = \log K_{ads} + n \log C_{inh.} \qquad (11)$$

where, K_{ads} and C_{inh} are the equilibrium constant for the adsorption and concentration of the polymer, respectively.

A plot of Freundlich isotherm (log θ versus log C_{inh}) for CS in 1.0 M HCl solution and including some concentrations of six polymer compounds is represented in Fig. (9). A straight lines relationship was obtained with intercept log K_{ads}. This mention that the adsorption of polymer compounds on the C-steel surface follows Freundlich isotherm. The equilibrium constant of adsorption K_{ads} is calculated from the intercept of the straight lines and is concerning to the standard free energy of adsorption (ΔG°$_{ads}$) by the relation [36]:

$$55.5\ K_{ads} = \exp[-\Delta G°_{ads} / RT] \qquad (12)$$

where, R is the gas constant, the value 55.5 is the concentration of water in the solution in mole. The values K are equal to (9.2 and 10.7) 10^{-1} for PLX and PET compounds, respectively. The large values

of K_{ads} imply the efficient adsorption of the polymer compounds on CS surface and hence higher inhibition efficiency.

The values of $\Delta G°_{ads}$ are equal to -37.12 and -39.75 kJ mol^{-1} for PLX and PET compounds, respectively. The negative signs of $\Delta G°_{ads}$ confirm that the adsorption of the tested polymer compounds on the C-steel surface is carried out spontaneously and is accompanied by high-efficiency adsorption [37].

It is well known that the values of $\Delta G°_{ads}$ in the order of -40 kJmol^{-1} or higher involve the sharing of the charge or its transfer from the polymer molecules to CS surface to form coordinate type bond(chemisorption). While the values of $\Delta G°_{ads}$ reach -20 kJ mol^{-1}, the adsorption types were considered as physisorption, the, the inhibition action was caused by the electrostatic interaction between the charged molecules and the charged metal [38]. The computed values of $\Delta G°_{ads}$ are in the range -36.42 to -40.18 kJ mol^{-1} for PLX and PET compounds suggesting that the adsorption of the polymer compounds on the C-steel surface functions by physicochemical adsorption (mixed of physical and chemical adsorption).

The inhibitory strength of PLX and PET compounds towards the dissolution of CS in a 1.0 M HCl solution as determined by chemical and electrochemical measurements. It can be interpreted by the adsorption of these compounds onto the carbon steel interface. The nature of the inhibitor interaction on the carbon steel surface during corrosion inhibition can be explained in terms of adsorption properties. The %*PE* depends on many factors such as the molar mass and the molecular structure of the polymer, the number of adsorption active centers in the molecule, the presence of electro donating or repelling groups, mod of adsorption, temperature, and the ability to the formation of metallic complexes. The adsorption of these compounds on the metal surface cans retards the anodic or the cathodic reaction by formation of physical barrier layer between CS surface and polymer compounds

The order of % PE of the polymer compounds depending on the chemical structure of the polymer compounds and decreases in the following sequence: PET > PLX.

Obviously from the above arrangement, the percentage inhibition efficiency is related with the molar mass of the tested polymer compounds. The compound PET has the highest inhibition efficiency owing to the higher molar mass than PLX. This leads to covering a large area of the CS surface due to the strong spontaneous adsorption of it, as evidenced by the values of computed free energy of adsorption $\Delta G°_{ads}$. The existence of some hetero oxygen atoms and OH group facilitates the adsorption process by forming a coordination bond between the polymer compound and the carbon steel by transferring lone pairs of electrons from hetero oxygen atoms to the steel surface.

The inhibition of pitting corrosion of CS solution by the polymer compounds due to the competitive adsorption of between the polymer compounds and the chloride ions until the polymer compounds are the predominant than chloride ions. Therefore, the polymer compounds is faster adsorbed than chloride ions onto the surface of the CS, and thus the pitting corrosion is inhibited by shifting the pitting corrosion potential into positive (noble) direction.

4. CONCLUSIONS

1. The two polymer compounds poloxamer and pectin act as efficient inhibitors of the corrosion of C-steel 1.0 M HCl solution.

2. The inhibition efficacy increased at high concentrations of poloxamer and pectin compounds and reduced at elevated temperature.

3. The inhibition was interpreted by the formation of an adsorbing coated layer that isolates the steel surface from aggressive solutions.

4. The adsorption of poloxamer and pectin on the steel surface obeys Freundlich isotherm and the adsorption type is a mixture of physical and chemical adsorption.

5. Galvanostatic polarization has proven that the polymer compounds act as mixed inhibitors.

6. Poloxamer and pectin polymers inhibit the pitting corrosion of C-steel.

7. The effectiveness of pectin inhibition more than poloxamer.

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