Effect of Henna and Rosemary Extracts on the Corrosion of 304L Stainless Steel in 3.5% NaCl Solution

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The inhibitive action of two natural compounds – henna and rosemary extracts, on the corrosion of 304L stainless steel in 3.5% NaCl solution has been investigated through electrochemical techniques and surface analysis. Polarization measurements indicate that the investigated compounds are mixed-type inhibitors, and the higher the inhibitor concentration, the higher the inhibition efficiency. Maximum inhibition efficiencies of 92.7% and 90.2% of henna and rosemary extracts are obtained at 1.0 g/L, respectively. The polarization curves show that henna and rosemary extracts act as a cathode-type and an anodic-type inhibitor, respectively. The results show that these additives in saline media are adsorptive inhibitors and their adsorption obeys the Langmuir adsorption isotherm.

Keywords: corrosion, green inhibitor, henna extract, rosemary extract, stainless steel 304L.

УДК 620.197.3

INTRODUCTION

Nowadays corrosion is considered to be one of the most serious problems for metals and alloys. The total metallic corrosion cost is estimated at an impressive annual figure of over billion dollars. Stainless steel is one of the major construction materials and is also extensively used in many important industries, in particular, in petroleum, energetics, food, medical, chemical and electrochemical sectors. But it suffers from corrosion in certain media. Several successful efforts have been made in corrosion prevention tactics, one of them being usage of corrosion inhibitors. These are substances prohibiting or decreasing the corrosion process. Their action depends on the inhibitor ability to react and adsorb on the metals surface to form a protective layer against aggressive ions. Most frequent inhibitors are Cr (VI) compounds [1]. Their efficiency/cost ratio has made them standard corrosion inhibitors. Unfortunately these compounds are highly toxic, which can cause cancer, polute the environment if not properly treated, therefore an intense effort is being undertaken to replace them [2–6]. The recent trend is to use green inhibitors, because they are economical and non-toxic [7]. Extracts of plant materials are on the top of the list. Henna and rosemary extracts components seem to meet the basic requirements for consideration as alternative corrosion inhibitors: the ions form insoluble hydroxides, which makes it possible to use them as cathode and anodic inhibitors, respectively; they are non-toxic and relatively abundant in nature. The study of plant materials as corrosion inhibitors is of great practical significance. The effect of henna extract, as doped inhibitor, in corrosion inhibition of mild steel in 1M HCl solution was studied by A. Ostovari et al. [8]. Yee [9] determined the inhibitive effects of rosemary extract on four different metals–aluminum, copper, iron, and zinc, each polarized in two different solutions, that is, sodium chloride and sodium sulfate.

The aim of the given paper is to analyze the effect of using henna and rosemary extracts in order to improve the corrosion resistance of stainless steel in 3.5% NaCl solution. In addition, these inhibitors are compared on different parameters, and the inhibition mechanism and adsorption action of inhibitors are discussed. The results of the tests showed a good agreement all together.

1. EXPERIMENTAL METHODS

1.1. Specimen preparation

Specimens of 304L stainless steel (0.025% C, 1.86% Mn, 0.037% P, 0.024% S, 0.71% Si, 18.56% Cr, 9.36% Ni and Fe balance) were used in the given work. AISI 304L samples (12 mm diameter and 4 mm thickness), exposed area (1 cm^2) of specimens were mechanically abraded with 220–1500 grades of sand paper and polished by 0.3 micron alumina powder to approach the mirror surface, then degreased, hand washed with distilled water, and rinsed in ethanol, finally they were used as working electrodes for polarization and Electrochemical Impedance Spectroscopy (EIS) measurements and used for weight loss measurements, too.

1.2. Solution preparation

The 3.5% NaCl solution was prepared from NaCl (Merck) and distilled water. The concentration range of henna and rosemary extracts varied from 0.1 to 1 (g/L) and the electrolyte used was 200 ml for each experiment.

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1.3. Weight loss measurements

Experiments were performed at 25°C with different concentrations of henna and rosemary extracts. The immersion time for the weight loss test is 360 h. The results of the weight loss experiments are the mean of three runs, each with a fresh specimen and 200 ml of fresh NaCl solution. The inhibition efficiency (*IE*%) (If you introduce this abbreviation, you must use it further in the text) was calculated using the following equation:

$$IE\% = [(W_2 - W_1)/W_2] \times 100$$

where W_1 and W_2 are the weight losses of stainless steel in the absence and presence of inhibitors, respectively.

1.4. Polarization measurements

Polarization measurements were conducted at room temperature in NaCl solution using an electrochemical unit (model PARstat 2273). Bare AISI 304L was used as blank. A three-electrode cell was employed using a graphite of convenient area as counter electrode and a saturated calomel electrode (SCE, Radiometer Copenhague) as reference electrode. Potentiodynamic tests were conducted from -0.25 to 0.7 V vs. OCP, with a scan rate of 0.001 V s^{-1}. Before recording the polarization curves, the solution was de-aerated for 20 min and the working electrode was maintained at its corrosion potential for 10 min until a steady state was obtained. The *IE*% was calculated using the following equation:

$$IE\% = [(I_0 - I)/I_0] \times 100$$

where I_1 and I_0 are the corrosion current densities of 304L stainless steel in the presence and absence of inhibitors, respectively.

1.5. Electrochemical impedance spectroscopy

Electrochemical Impedance Spectroscopy (EIS) test was carried out in a frequency range of 100 kHz to 10 mHz and peak-to-peak a.c. amplitude of 10 mV. This test was performed after 1 h and 21 days of immersion in the electrolyte. Impedance fitting was performed using ZView software. The *IE*% was calculated using the following equation:

$$\%IE = (R_2 - R_1)/R_2 \times 100$$

where R_1 and R_2 are polarization resistance of stainless steel in the absence and presence henna and rosemary extracts, respectively. The double layer capacity was calculated using the following equation:

$$C_{dl} = 1/(R_p \times 2\Pi\, F_{max})$$

where C_{dl} and R_p and F_{max} are double layer capacity, polarization resistance and frequency maximum, respectively.

1.6. Surface analysis

The surface morphology of stainless steel specimens after polarization measurements in 3.5% NaCl solution in the absence and presence of henna and rosemary extracts was evaluated by Scanning Electron Microscopy (SEM) using VEGA//TESCANE model. The working sample was analyzed in five different locations to ensure reproducibility.

2. RESULTS AND DISCUSSION

2.1. Weight loss measurements

The corrosion rate and *IE*% for 304L stainless steel in 3.5% NaCl solution at 25°C in the absence and presence of henna and rosemary extracts are given in Table 1. It is evident that the *IE*% of stainless steel increases with the increase (at 25°C) of henna and rosemary extracts concentrations up to 88% and 81%, respectively. Hence, in high concentrations, both of these inhibitors are good for stainless steel in this medium.

Table 1. Efficiency of henna and rosemary extracts calculated from weight loss measurements

Concentration/(g/L)		0.1	1
IE/%	Henna extract	48	88
	Rosemary extract	63.7	81

2.2. Potentiodynamic polarization tests

Potentiodynamic polarization plots for 304L stainless steel specimens in 3.5% NaCl solution, at room temperature, in the absence and presence of different concentrations of henna and rosemary extracts are shown in Fig. 1 and Fig. 2, respectively. The results of polarization measurements are given in Table 2. The respective kinetic parameters including corrosion current density (I_{corr}), corrosion potential (E_{corr}), the cathode Tafel slope (β_c), the anodic Tafel slope (β_a), inhibition efficiency (*IE*%) and potential difference (ΔE) are given in Table 2. It is clear from the data in Table 2 that the addition of henna and rosemary extracts decreases the corrosion current density. It is also vivid that the *IE*% of henna and rosemary extracts increases at higher inhibitor concentrations. The maximum inhibition efficiencies of henna and rosemary extracts were obtained as 92.7 and 90.2, respectively. The difference between the corrosion potential and the break down potential can be used to evaluate the local corrosion resistance of the materials [10]; the mathematical presentation can be expressed by:

$$\Delta E = E_b - E_{corr}.$$

With the increase of inhibitors concentration, the corrosion rate (mpy) is shifted to a lower value, surface occupied degrees (θ) is shifted to a higher value

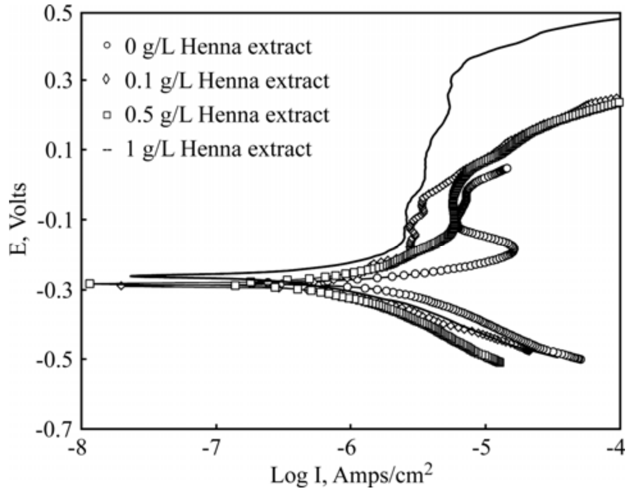


Fig. 1. Polarization curves for 304L stainless steel in 3.5% NaCl with henna extract at different concentrations.

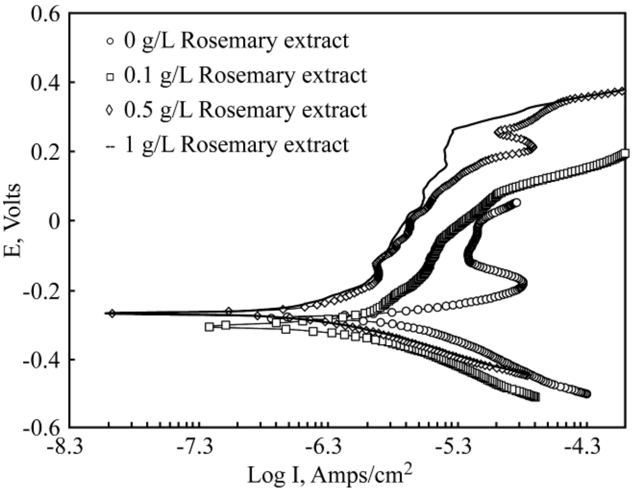


Fig. 2. Polarization curves for 304L stainless steel in 3.5% NaCl with rosemary extract at different concentrations.

Table 2. Polarization parameters for 304L stainless steel in 3.5% NaCl at 298K

inhibitor	C/(g/L)	E_{corr}/mV	I_{corr}/μAcm^{-2}	β_c/mV	β_a/mV	%IE	θ	ΔE	mpy
blank	0	-275	2.745	135	138	–	0	0.284	1.271
henna extract	0.1	-281	1.590	125	135	42.1	0.421	0.291	0.736
	0.5	-280	0.920	65.8	106	66.5	0.665	0.357	0.426
	1	-254	0.210	70	95	92.7	0.927	0.624	0.17
rosemary extract	0.1	-300	0.710	118	115	74.1	0.741	0.385	0.328
	0.5	-263	0.363	105	98	86.8	0.868	0.443	0.167
	1	-261	0.276	104	82	90.2	0.902	0.521	0.125

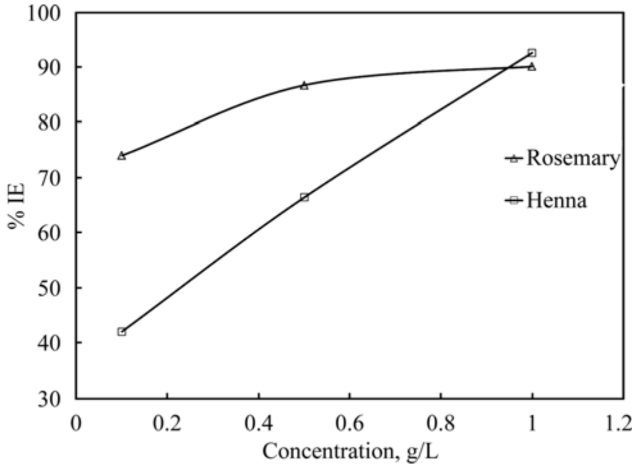


Fig. 3. Comparison of inhibition efficiency of henna and rosemary extracts in 3.5% NaCl solution at various concentrations of inhibitor.

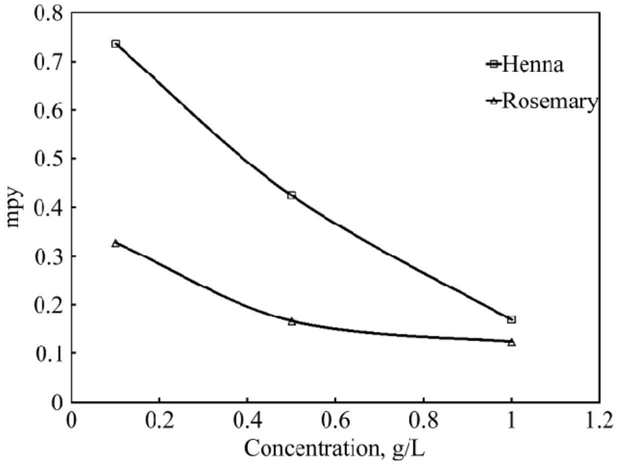


Fig. 4. Comparison of corrosion rate of stainless steel in 3.5% NaCl solution at various concentrations of henna and rosemary extracts.

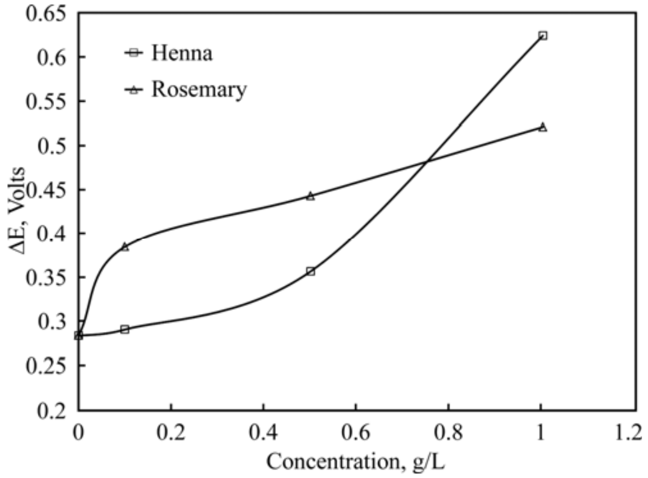


Fig. 5. Comparison between (ΔE) of stainless steel in 3.5% NaCl solution at various concentrations of henna and rosemary extracts.

and breakdown potential (E_b) enhanced to the positive amounts. It is the demonstration of the fact that henna and rosemary extracts act as good inhibitors for the corrosion of the 304L stainless steel in 3.5% NaCl solution at room temperature. Addition of henna extract reduces the cathode current density without affecting the active anodic dissolution in the polarization curves. But the presence of rosemary extract results in a marked shift in the anodic branches and to a lesser extent in the cathode branches of the polarization curves. Moreover, in the presence of henna and rosemary extracts the values of corrosion potential E_{corr} are nearly constant; therefore, henna extract could be classified as a mixed-type inhibitor with the predominant cathode effectiveness and rosemary extract could be classified as a mixed-type inhibitor with the predominant anodic effectiveness. The response graphs for these two inhibitors reflecting the results of electrochemical measurements such as potential difference, *IE*% and corrosion rate vs. inhibitor concentration are shown in Fig. 3 and Fig. 4. According to the figures, at low concentrations, rosemary extract can better inhibit the corrosion of the 304L stainless steel than henna extract in a saline medium, but with the increase in the inhibitors concentration, henna extract enhances the corrosion *IE*% faster than rosemary extract. Figure 5 shows the increase of ΔE related to C (g/L) that indicates the increase of E_b.

2.3. Surface analysis

SEM images of stainless steel in the absence and presence of two inhibitors in 3.5% NaCl solution after potentiodynamic tests are shown in Fig. 6. As is clear from the figure, the presence of the studies inhibitors leads to better corrosion resistance of stainless steel in a saline solution. Figures 6b,c show smooth surfaces with the deposited extracts for the specimens after the electrochemical test in 3.5% NaCl solution. This is because of the formation of adsorbed films of henna and rosemary extracts on the surfaces.

2.4. Electrochemical impedance spectroscopy measurements

The EIS measurements are particularly useful in long time tests because they do not perturb the system dramatically. The typical Nyquist and Bode plots, i.e., impedance and phase angle plots of 304L stainless steel in the absence and presence of henna and rosemary extracts with different concentrations of inhibitors in 3.5% NaCl solution, are shown in Fig. 7. The Nyquist plots of 304L stainless steel in the absence of inhi-bitors are characterized by a depressed semicircle, while the plots of 304L stainless steel in the presence of both inhibitors at different concentrations, are depicted as the depressed semicircle with a long tail in a low frequency region. The tails appears as straight lines with a slope of 45° at a very low frequency. This circuit models a cell where polarization is due to a combination of kinetic and diffusion processes. The diffusion process of ions takes place on the surface of a metal specimen after the addition of henna and rosemary extracts. Diffusion can also create impedance called the Warburg impedance. The impedance depends on the frequency of the potential perturbation. At high frequencies, the Warburg impedance is small since diffusing reactants do not have to move very far. At low frequencies, the reactants have to diffuse farther, increasing the Warburg-impedance. The Bode plots for the stainless steel in the presence of inhibitors show higher impedance magnitudes at low frequency than the plain steel in test solution [11]. Nevertheless, these values tend to go to upper extent with the increase of concentration of inhibitors. Moreover, in the phase angle, when adding the inhibitors, the range of circles is increased. This means improvement of the corrosion resistance of stainless steel in NaCl solution. These results support the results of polarization measurements showing that the inhibitor improves the corrosion resistance of the 304L stainless steel in 3.5% NaCl solution.

For the interpretation of the electrochemical behavior of a system from the EIS spectra, an appropriate physical model of the electrochemical reactions occurring on the electrodes is necessary. The electrochemical response to impedance tests for the 304L stainless steel under consideration was best simulated with the equivalent circuit (Simplified Randles Cell) depicted in Fig. 8. This widely accepted scheme has been deduced to represent the electrochemical behavior of the 304L stainless steel. It includes a solution resistance, a double layer capacitor (C_{dl}) and a polarization resistance (R_p). The double layer capacitance is in parallel with the polarization resistance. The *IE*% of the 304L stainless steel in the presence and absence of henna and rosemary extracts at different concentrations in 3.5% NaCl solution was evaluated by R_p and C_{dl} values of the impedance. The values are given in Tables 3 and 4. As is clear from these tables, the values of R_p increase with adding inhibitor to the solution, while those of C_{dl} tend to decrease. A large R_p is associated with lower corroding systems.

Furthermore, a better protection provided by an inhibitor is associated with a decrease in C_{dl}, which results from a decrease in the local dielectric constant and/or an increase in the thickness of the electrical double layer. It follows from the data in Tables 3 and 4 that C_{dl} is decreased upon adding an

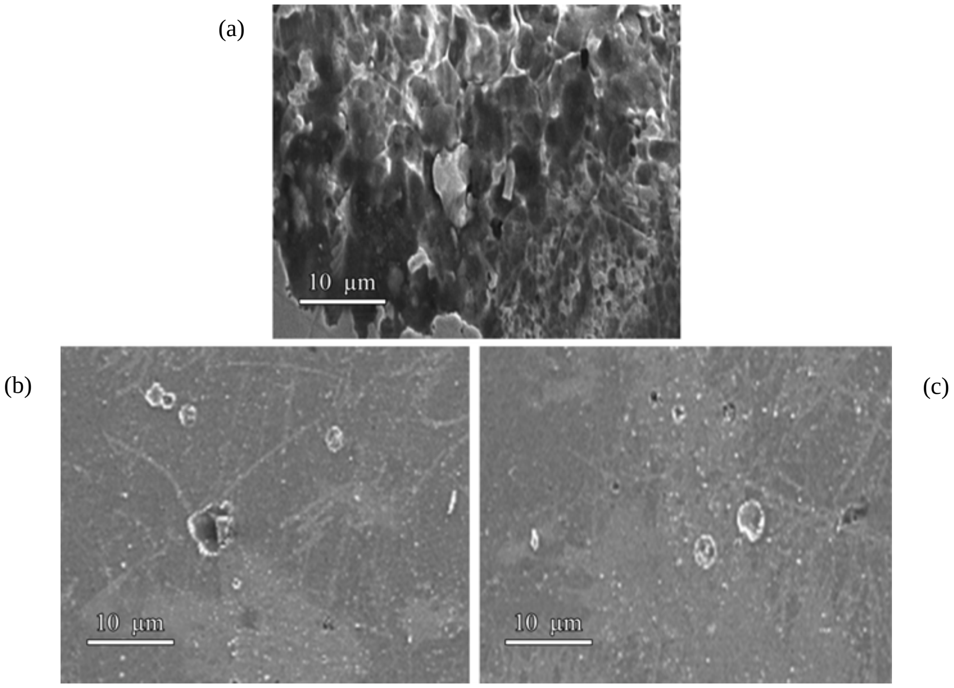
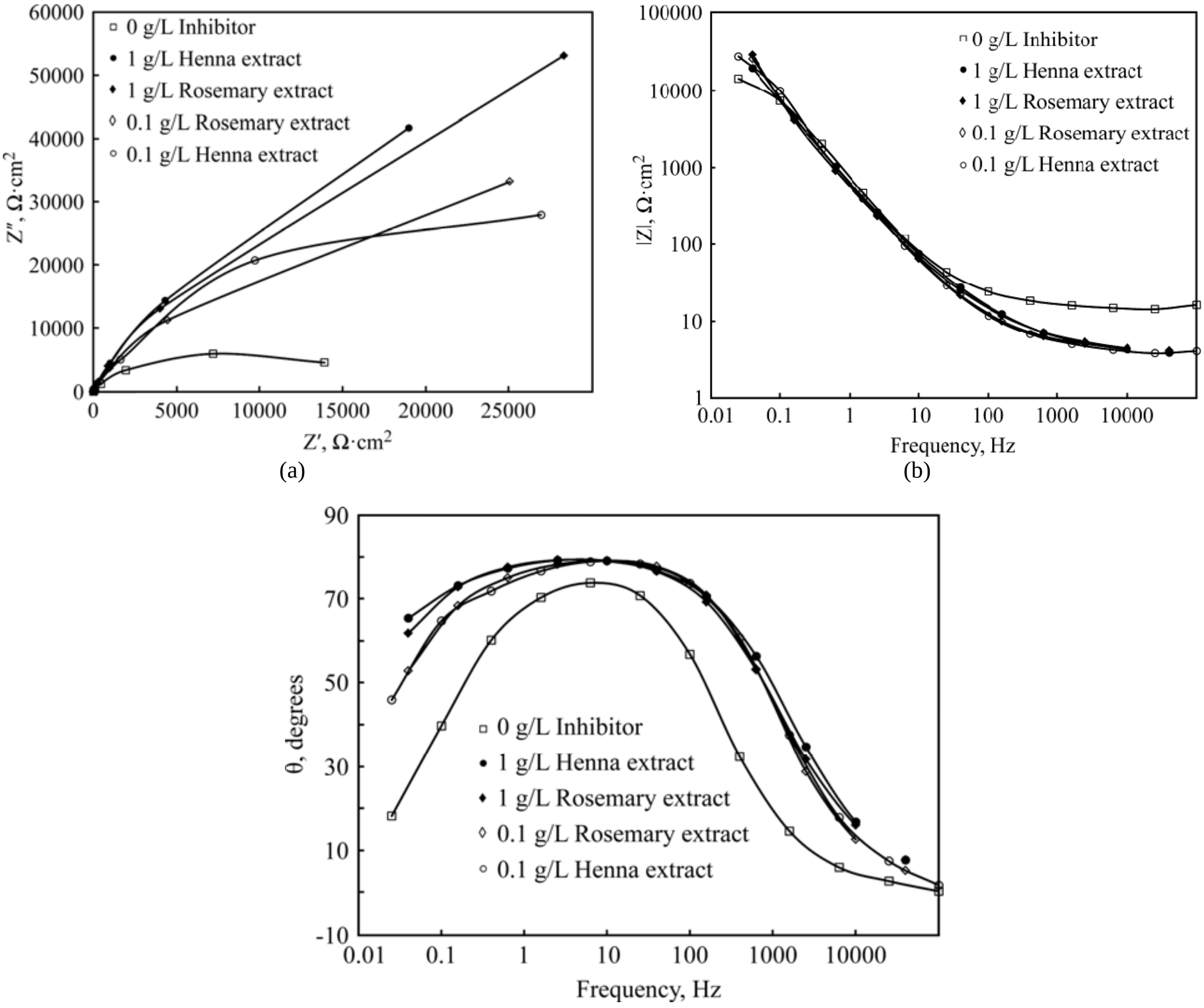


Fig. 6. SEM micrographs of 304L stainless steel after immersion in 3.5% NaCl: (a) Blank; (b) 1000 mg/L henna extract; (c) 1000 mg/L rosemary extract, after potentiodynamic tests.



(a) (b)

(c)

Fig. 7. Nyquist and Bode plots (log/Z/vs.log frequency and phase angle vs. log frequency) for 304L stainless steel in 3.5% NaCl solution containing henna and rosemary extracts.

inhibitor to the coating. These results suggest that henna and rosemary extracts enhance the corrosion protection of 340L stainless steel in 3.5% NaCl solution.

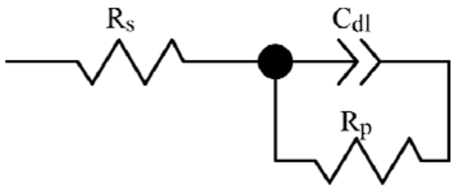


Fig. 8. The equivalent circuit model used to fit EIS experiment data.

Table 3. Impedance data of 304L stainless steel in 3.5% NaCl at different inhibitor concentrations

inhibitor	C/(g/L)	R_p (kΩ cm²)	C_{dl} (μF/cm²)	%*IE*
blank	16.397	61	–	16.397
henna extract	0.1	56	48	70
	1	212	18	92
rosemary extract	0.1	100	38	83
	1	193	20	91.5

Table 4. Equilibrium constant and standard free energy of adsorption of henna and rosemary extracts at 25°C

inhibitor	K_{ads}(mol^{-1})	$\Delta G^{\mathrm{o}}_{\mathrm{ads}}$ (KJmol^{-1})
henna extract	1000	-27.0653
rosemary extract	11100	-33.0312

2.5. Adsorption isotherms

Basic information on the interaction between inhibitors and a metal surface can be provided using the adsorption isotherms [12]. The adsorption of an organic adsorbate at the metal–solution interface can occur as a result of the substitution adsorption process between organic molecules presented in the aqueous solution (Org (sol)), and the water molecules previously adsorbed on the metallic surface (H_2O (ads)) [13]:

$$\mathrm{Org}_{(\mathrm{sol})} + x\mathrm{H_2O}_{(\mathrm{ads})} \rightarrow \mathrm{Org}_{(\mathrm{ads})} + x\mathrm{H_2O}_{(\mathrm{sol})}$$

where $\mathrm{Org}_{(\mathrm{sol})}$ and $\mathrm{Org}_{(\mathrm{ads})}$ are the organic species in the bulk solution and those adsorbed on the metallic surface, respectively. $H_2O_{(\mathrm{ads})}$ is the water molecule adsorbed on the metallic surface and x is the size ratio representing the number of water molecules replaced by one organic adsorbate. In order to obtain the adsorption isotherm, the degree of the surface coverage, θ, for different concentrations of an inhibitor in NaCl solution has been evaluated by the following equation [14]:

$$\theta = 1 - (I/I_0)$$

where I_0 and I are corrosion current density of 304L stainless steel in 3.5% NaCl in the absence and presence of an inhibitor, respectively.

The θ values are presented in Table 2. According to the Langmuir isotherm, the surface coverage (θ) is related to the inhibitor concentration (C) by the following equation [14]:

$$C/\theta = (1/K_{\mathrm{ads}}) + C$$

where K_{ads} is the equilibrium constant of the inhibitor adsorption process. As seen from Figs. 9 and 10, the plot of C/θ versus C yields a straight line with a correlation coefficient more than 0.99, showing that the adsorption of these inhibitors in NaCl solution is fitted to the Langmuir adsorption isotherm. These results prove that the inhibition of 304L stainless steel in NaCl solution by henna and rosemary extracts is an adsorptive process. This isotherm assumes that the adsorbed molecules occupy only one site and there are no interactions between the adsorbed species [15].

The K_{ads} values can be calculated from the intercept lines on the C/θ axis. This value is also related to the standard free energy of adsorption (ΔG°) by the following equation [12, 15]:

$$\Delta G^{\circ}_{\mathrm{ads}} = -RT\mathrm{Ln}\left(55.5K_{ads}\right)$$

where R is the gas constant and T is the absolute temperature. The constant value of 55.5 is the concentration of water in solution in mol·dm^3. The values of K_{ads} and $\Delta G^{\circ}_{\mathrm{ads}}$ of henna and rosemary extracts in 3.5% NaCl solution are given in Table 4. The negative sign of $\Delta G^{\circ}_{\mathrm{ads}}$ indicates that the inhibitors are spontaneously adsorbed on the metal surface [6, 7]. Generally, the magnitude of $\Delta G^{\circ}_{\mathrm{ads}}$ around – 20 kJ mol^{-1} or less negative can be assumed as due to an electrostatic interaction between the inhibitor and the charged metal surface (i.e. physisorption). The standard free energy of adsorption ($\Delta G^{\circ}_{\mathrm{ads}}$) around – 40 kJ mol^{-1} or more negative indicates a charge sharing or transferring from organic species to the metal surface to form a coordinate type of a bond (i.e. chemisorptions) [14, 16]. According to Table 4, the adsorption of both inhibitors indicated chemisorption.

2.6. Inhibition mechanism

2.6.1. Inhibition mechanism of henna extract

Henna extract used as an inhibitor leads to changes in the Tafel slopes of polarization curves, decrease of the corrosion current density and increase of the corrosion potential via interference in cathode and anodic reactions. The inhibition mechanism is described by the chemisorption of inhibitor molecules on the surface. The presence of an inhibitor results in a marked shift in the cathode branches to a lower extent than in the anodic branches of the

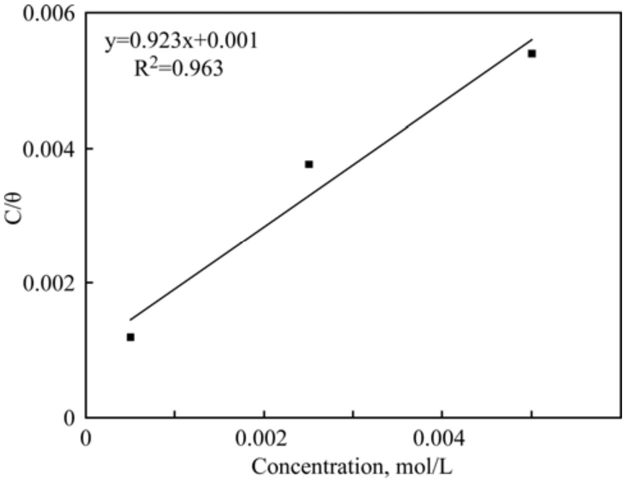


Fig. 9. Langmuir adsorption isotherm of henna extract on 304L stainless steel in 3.5% NaCl solution.

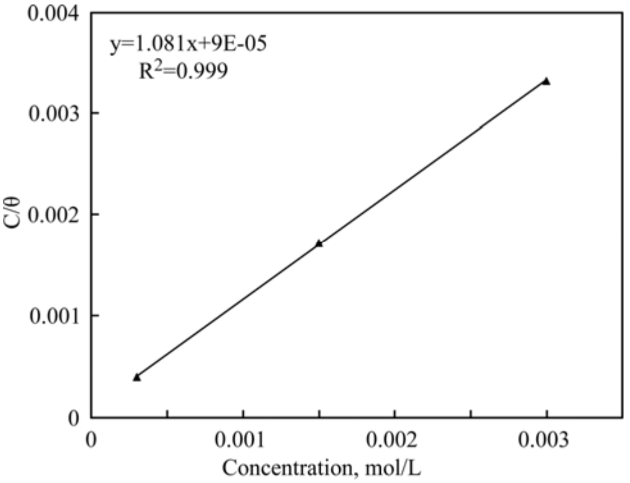


Fig. 10. Langmuir adsorption isotherm of rosemary extract on 304L stainless steel in 3.5% NaCl solution.

polarization curves; therefore, henna extract could be classified as a mixed type inhibitor with the predominant cathode effectiveness. As can be seen from the data (Table 2), the cathode Tafel slopes β_c decreased from 135 mV/dec to 70 mV/dec. Most of the henna constituents are hydroxyl aromatic compounds such as lawsone, gallic acid and tannin. The lawsone molecule, as ligand, can form complex compounds via chelating with various metal cations. Lawsone is considered the major active component of henna. The inhibitive effect of lawsone was attributed to the formation of insoluble complex compounds combined with the metal cations [8]. The lawsone molecule adsorbs on the stainless steel surface, thus prohibiting the adsorption aggressive ions such as Cl^-. Aromatic compounds whose structure includes a cyclic delocalized π-electron system are susceptible to the electron delocalization in saline media, especially a ring containing only carbon (e.g., benzene). It is delocalization of π-electrons (their participation in several bonds) that stabilize the molecule. The importance of the planarity of the benzene ring is shown by the orbital approach. Because of the trigonal (sp^2) bond angles of carbon, the ring is flat. These angles just fit the 120° angles of a regular hexagon; this flatness permits the overlap of the π-orbital in both directions that lead to the delocalization and stabilization. In the case of the lawsone molecule, a pair of electrons on a hydroxyl group is delocalized in saline solution leading to the rearrangement shown in Fig. 11. That arrangement occurs because of the migration of the hydrogen atom with a pair of electrons from an adjacent carbon to the carbon bearing the positive charge. The carbon that loses the migrating group obtains the positive charge. This is the most common kind of rearrangement known as the 1,2-rearrangement: rearrangements in which the substituent group moves from one atom to the next atom in a chemical compound. This arrangement is intra-molecular and the starting compound and the reaction product are structural isomers (Fig. 11). It can be concluded that the complex formation reaction after addition of henna extract can be improved by this rearrangement. High *IE*% in saline media for stainless steel can be explained by the formation of these stabilized complexes between Llwsone molecules and Fe^{2+} cations, moreover, henna extract modifies the defects of coating and thus improves the IE% [8].

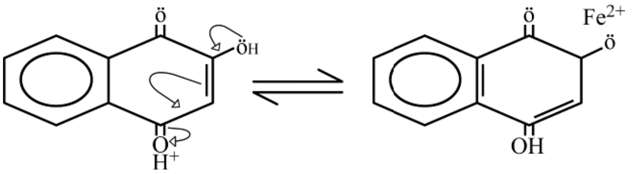
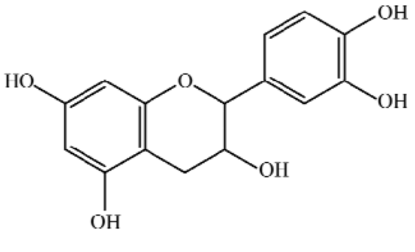


Fig.11. Process of electron delocalization on Lawson molecule.

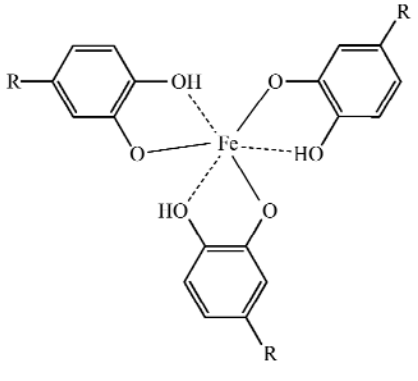
2.6.2. Inhibition mechanism of rosemary extract

Rosemary extract is an anodic inhibitor with an effect on the anodic curve. Most of the rosemary consti-tuents are hydroxyl aromatic compounds such as Cineol-1,8, Borneol, Campher, Bornyl acetate, α–pinene, β–pinene, Genkwanin, Luteolin and (+)-Catechin. Because these components are ligands, they can form complex compounds due to chelation with various metal cations. Cineol-1,8, Borneol, Campher, Bornyl acetate, α–pinene, β–pinene, Genkwanin, Luteolin and (+)-Catechin are major rosemary components. The inhibitive action of these components was attributed to the formation of stable complex compounds combined with the metal cations [8]. The literature indicates that natural polyphenolic compounds containing a catechol group in their B-ring (Fig. 12) (vicinal hydroxyl groups) readily form complexes with di- and tri-valent metal ions [17, 18]. The inhibitory action of these compounds could be explained by the formation of complexes in the form of chelates with (Fe) ions in the solution and subsequent precipitation of the complex formed at the surface of the alloy in places where the oxide film has been destroyed. For example, the reaction between (+)-catechin and Fe is shown in

Fig. 12. A thin layer is a physical barrier preventing the electrolyte action on the metal surface. Namely, the adsorption on the surface of a metal, or, more precisely, at defective sites in the oxide film already existing on the surface, resulting in its healing and strengthening. The experimental observations show that the components alter the electrochemical reactions responsible for corrosion. They inhibit corrosion primarily through its adsorption on the metal surface. If the concentration of an inhibitor is optimum, a compact and coherent oxide-inhibitor layer is formed on the surface of the alloy, acting as a physical barrier to impede the attack of the medium [19]. Some of these molecules are adsorbed on the stainless steel surface and hereby prevent the adsorption of aggressive ions such as Cl^-, this action leading to the stabilization of the metal surface in saline media. The presence of these components, via interference in anodic reactions, leads to a decrease of the reaction rate and of β_a in polarization curves and the increase of corrosion resistance. In addition, rosemary extract modifies the defects of a coating, thus improving the *IE*%.



(+)-catechin



Iron (III) chelate

Fig. 12. Molecular structure of main rosemary extract component (+)-Catechin and reaction between (+)-Catechin and Fe.

3. CONCLUSIONS

Henna and rosemary extracts in 3.5% NaCl solution show inhibitive properties for 304L stainless steel, therefore both of them are considered appropriate inhibitors for stainless steel in saline solutions. In addition, an increase of concentrations of these inhibitors results in a higher corrosion resistance of stainless steel in corrosive media. That is, the higher the concentration of inhibitors, the lower the corrosion current density and the corrosion rate. In addition, a higher concentration of inhibitors leads to the localization of the corrosion resistance of stainless steel in NaCl solution. Henna and rosemary extracts in saline media are adsorptive-type inhibitors and their adsorption obeys the Langmuir adsorption isotherm. Moreover, adsorption of both inhibitors indicated chemisorptions. Henna and rosemary extracts act as mixed-type inhibitors for corrosion of mild steel in 3.5% NaCl solution.

ACKNOWLEDGMENTS

This research has been supported financially by Najafabad Branch, Islamic Azad University.

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Received 11.04.13
Accepted 08.08.13

Реферат

Ингибирующая активность двух природных соединений экстрактов лавзонии и розмарина на коррозию стали 304L в 3,5% растворе NaCl была исследована электрохимическими методами и методом исследования поверхности. Поляризационные измерения показывают, что исследуемые соединения являются ингибиторами смешанного типа и зависят от концентрации экстракта: чем больше концентрация, тем больше ингибирующая активность. Максимальная ингибирующая активность экстрактов лавзонии (92,7%) и розмарина (90,2%) наблюдалась при их концентрации 1 г/л. Поляризационные кривые показывают, что экстракты лавзонии и розмарина являются ингибиторами катодного и анодного типа соответственно. Указанные добавки в солевой среде являются адсорбционными ингибиторами и их адсорбция подчиняется адсорбционным изотермам Лэнгмюра.

Ключевые слова: коррозия, природные ингибиторы, экстракт лавзонии, экстракт розмарина, сталь 304L.