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Esomeprazole Magnesium Trihydrate drug as a potential non-toxic corrosion inhibitor for mild steel in acidic media

ABSTRACT

The inhibiting effect of Esomeprazole Magnesium Trihydrate drug on the corrosion of mild steel (MS) in 1 M HCl was performed by chemical tests (weight loss (WL)) and electrochemical methods (Tafel polarization (TP), electrochemical frequency modulation (EFM) and AC impedance spectroscopy (EIS)). The adsorption isotherm of Esomeprazole Magnesium Trihydrate drug on the MS surface was found to follow Temkin adsorption isotherm. Some thermodynamic parameters were computed and discussed. The obtained data showed that the inhibition efficiency (IE) rises with increasing the dose of the Esomeprazole Magnesium Trihydrate and with raising the temperature. The morphology of MS surface was analyzed by using scanning electron microscope (SEM), atomic force microscopy (AFM), and Fourier transforms infrared spectroscopy (FTIR) techniques. All test methods were in good agreement with each other.

Keywords: *Acid corrosion, Mild steel, SEM, AFM, FTIR, Esomeprazole Magnesium trihydrate.*

1. INTRODUCTION

Corrosion is an essential procedure playing a significant role in safety and economics , particularly for metals [1]. MS corrosion causes short shelf life, safety issues (hydrogen gas evolution), self-discharge and loss of valuable capacity, to reduce these undesirable effects, MS corrosion must be controlled [2]. Numerous inhibitors in utilized are either synthesized from cheap raw material or chosen from composite having heteroatoms in their aromatic or long-chain carbon system [3-4]. The studies prove that the inhibition influence of these organic composite occurring by its adsorption on surface of MS. Organic heterocyclic composite have utilized for the corrosion inhibition of carbon steel (CS) [5-13], copper [14], aluminum [15-17], and other metals [18,19] in various aqueous solution. The drug adsorbed assisted to protect the metal surface [20-22]. The select of some medication for inhibitor of corrosion is taking due to contain active centers, ecofriendly environmentally and simply purified and formed [23].

In recent years, the drugs were utilized as corrosion inhibitors for different metals as result to their high solubility in water, with high molecular size and containing electronegative atoms such as N, O S atoms in their molecules and nontoxic nature of these compounds should be good corrosion inhibitors [24,25]. Adsorption of the drug molecules on the metal surface facilitates its inhibition [26-37].

The scope of this paper is to examine the inhibitive effect of Esomeprazole Magnesium Trihydrate towards the corrosion of MS in 1M HCl utilizing electrochemical and non-electrochemical tests. The surface examination of the MS specimens was also analyzed.

2. MATERIALS AND METHODS

2.1. Metal Sample

MS contain of iron alloyed with less than 0.3 % C, most commonly among 0.1 to 0.25 %. The building industry always utilized MS in construction due to its ductility and malleability (Fe = 99.77%, C= 0.06495).

2.2. Chemicals

Inhibitor – Esomeprazole Magnesium Trihydrate is the investigated drug which has been used as inhibitor. Absolute ethanol (99 %) were supplied from Gamhoria Company and used for the preparation of ethanolic-aqueous mixtures with bi-distilled water.

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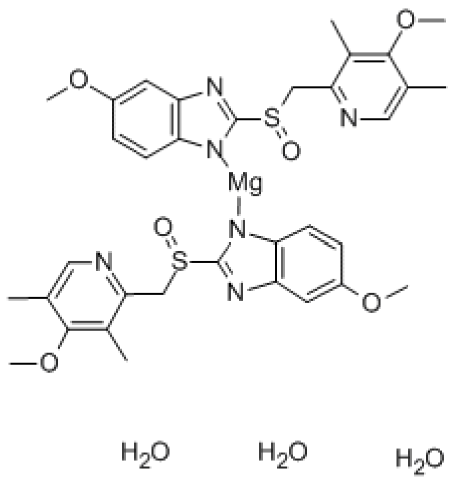


Magnesium,5-methoxy-2-[(4-methoxy-3,5-dimethylpyridin-2-yl)methylsulfinyl] benzimidazol-1-ide;trihydrate $C_{34}H_{42}MgN_6O_9S_2$, M.Wt = 767.168 g/mol

2.3. Solutions

The aggressive solution was 1M HCl. Solutions of Esomeprazole Magnesium Trihydrate in ethanol-water mixed solvents with different ethanol mole fractions (x_1 = 0 to 1.0 by weight) were prepared for density and refractive index measurements.

2.4. Weight Loss (WL) Measurements

For WL tests, square coins of surface area 2.6 x 2.8 cm were exposed to the corrosive medium for 3 h. The coins have abraded with emery papers with grit sizes (250,600 and 2000) and cleaned with acetone and finally dried by filter papers. The WL tests have taken in 100 mL glass beaker. The coins were then immediately immersed in the test solution with and without various doses of the investigated drug and all dipped in a water thermostat. The average WL for MS coins will achieve. The (%IE) and the (θ) of Esomeprazole Magnesium Trihydrate for the corrosion of MS were measured as next [38]:

$$\% IE = \theta \times 100 = [1 - (W/W^0)] \times 100 \qquad (1)$$

where W^0 and W are the WL with and without adding various doses of investigate drug, correspondingly.

2.5. Electrochemical Measurements

Potentiodynamic polarization (PP) method was taken in a typical three compartments glass cell [39].The potential range was (-800 to +200 mV vs. SCE) at OCP with a scan rate 1 mVs^{-1}. Then i_{corr} was calculated for the measurements and was used to calculate the %IE and the θ from Eq. (2) as below:

$$IE \% = \theta \times 100 = [1 - (i_{corr(inh)} / i_{corr(free)})] \times 100 \qquad (2)$$

where $i_{corr(free)}$ and $i_{corr(inh)}$ are the current densities in the absence and presence of Esomeprazole Magnesium Trihydrate, correspondingly.

Impedance measurements were done by AC signs of 10 mV peak-to-peak amplitude and at a range of frequency of 10^7 Hz to 0.1Hz [40]. The capacitance of the double layer C_{dl} , (% IE) and θ were founded from Eqs. (3) & (4) which are defined as:

$$C_{dl} = 1/ (2 \pi f_{max} R_{ct}) \qquad (3)$$

where f_{max} is the maximum frequency

$$IE \% = \theta \times 100 = [1 - (R°_{ct}/R_{ct})] \times 100 \qquad (4)$$

where R^o_{ct} and R_{ct} are the charge transfer resistances without and with drug, respectively.

EFM technique used two frequencies of range 2 and 5 Hz depending on three conditions. The (i_{corr}), (β_c and β_a) and (CF-2, CF-3) (Causality factors) [41] were measured by the higher two peaks. The % IE_{EFM} was calculated as in Eq. (2)

(TP), (EFM) and (EIS) techniques were performed utilizing the similar manner as earlier with a Gamry framework system rely on ESA400. Gamry apparatus includes software EFM140 for EFM tests and EIS300 for EIS method; the computer has used for summation value. Echem Analyst 5.5 Software had utilized for drawing and fitting data.

2.8. Surface Examinations

The MS coins utilized for analysis of morphology surface were set in 1M HCl acid (blank) and in presence of 30 ppm of Esome-prazole Magnesium Trihydrate at room tempe-rature for one day after abraded mechanically utilizing various emery papers up to 1200 grit size. Then, after this exposure time, the examination was carried out by utilizing (SEM), AFM and FTIR tests.

3. RESULTS AND DISCUSSION

3.1. Weight Loss (WL) Measurement

Weight loss of MS, in mg cm^{-2} of the surface area, was measured at different time periods with and without various doses (10-60 ppm) of the Esomeprazole Magnesium Trihydrate. The curves obtained with different doses of drug fall considerably below that of free acid as shown in Figure 1. The % IE's are recorded in Table 1. In all cases, the efficiency of the drug was improved with raising doses of the Esomeprazole Magnesium Trihydrate and the rate of corrosion was lowered. These results indicated that, the Esomeprazole Magnesium Trihydrate is good efficient inhibitor for MS dissolution in HCl solution.

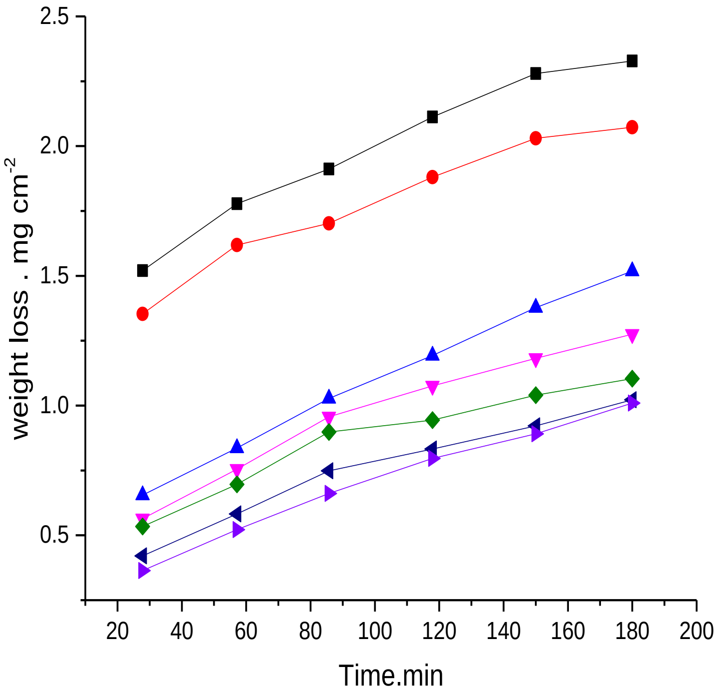


Figure 1. WL-time diagrams for the MS in 0.5 M HCl without and with various doses of Esomeprazole Magnesium Trihydrate at 25°C

Slika 1. Dijagrami WL- vreme za MS u 0,5 M HCl bez i sa različitim dozama Esomeprazole Magnesium Trihydrate na 25°C

Table 1. %IE of different doses of Esomeprazole Magnesium Trihydrate at different temperatures after 120 min exposed in 1M HCl solution

Tabela 1. %IE različitih doza Esomeprazole Magnesium Trihydrate na različitim temperaturama nakon 120 min izloženo u 1M rastvoru HCl

Conc., ppm	%IE				
	25°C	35°C	45°C	55°C	65°C
10	30.9	77.5	80.2	83.6	85.5
20	48.0	79.8	82.5	87.4	91.6
30	49.0	80.7	83.4	88.2	91.7
40	55.3	82.2	85.2	90.1	92.2
50	60.5	82.8	87.8	91.5	93.4
60	68.0	85.4	89.4	92.0	93.2

3.2. Adsorption Isotherms

The adsorption isotherms were used to explain the adsorption mechanism of the inhibitors on the metal surfaces. The best fitting isotherm for our data is the Temkin isotherm. Figure 2 shows the plotting of θ against log C at 25°C for Esomeprazole Magnesium trihydrate drug. This plot gave straight lines indicating that the adsorption of Esomeprazole Magnesium Trihydrate on MS surface obeys Temkin isotherm:

$$\Theta = (1/f) \ln K_{ads} C \quad (6)$$

C_{inh} is the inhibitor dose, K_{ads} is the adsorption equilibrium constant, and "a" is a parameter of lateral interaction which describes the molecular interactions in the adsorbed layer

Table 2. Temkin adsorption isotherm of Esomeprazole Magnesium Trihydrate drug on MS surface in 1 M HCl at various temperatures

Tabela 2. Temkinove adsorpcione izoterme leka Esomeprazole Magnesium Trihydrate na površini MS u 1 M HCl pri različitim temperaturama

Temp °C	a	$-\Delta G^o_{ads}$, *kJ mol⁻¹*	ΔH^o_{ads} *kJ mol⁻¹*	ΔS^o_{ads} *J mol⁻¹ K⁻¹*
25	12.5	29.7		99
35	11.9	35.3		114
45	10.8	36.6	49	115
55	10.9	39.6		120
65	10.5	40.8		121

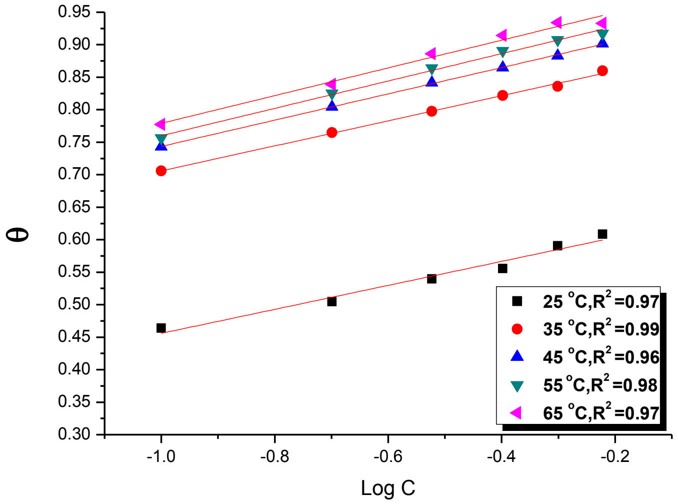


Figure.2. Temkin curves of Esomeprazole Magnesium Trihydrate on MS in HCl at various temperatures

Slika 2. Temkinove krive leka Esomeprazole Magnesium Trihydrate na MS u HCl pri različitim temperaturama

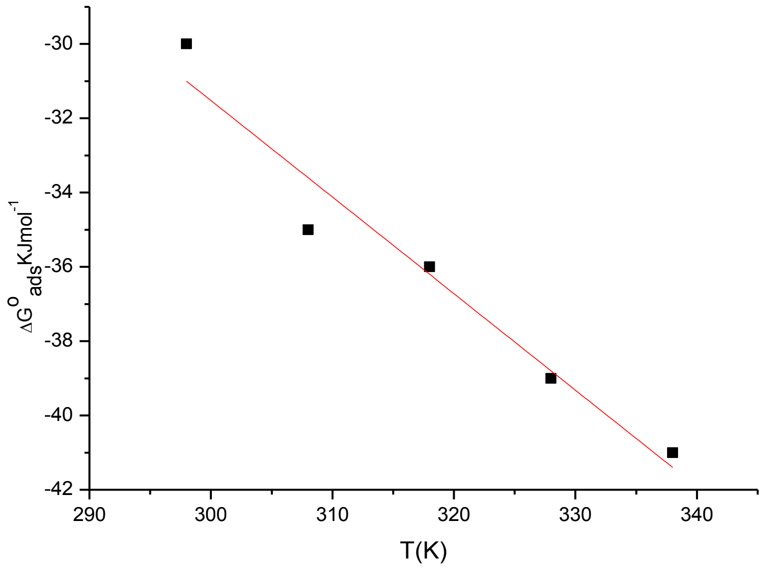


Figure 3. Curve ΔG°_{ads} vs (T) for corrosion of MS in 1M HCl in the presence of Esomeprazole Magnesium Trihydrate

Slika 3. Kriva ΔG◦ADS vs (T) za koroziju MS u 1M HCL u prisustvu Esomeprazole Magnesium Trihydrate

As reported in the literature if the value of ΔG^{o}_{ads} is between -20 and -40 kJ mol^{-1}the adsorption of the inhibitor on the metal surface is mixed one (i.e. physisorption and chemisorption). So the adsorption of the investigated drug on MS surface is mixed one (ΔG^{o}_{ads}, between -20 and -40 kJ mol^{-1}). The negative sign data of ΔG°_{ads} means that adsorption occurs spontaneously. The standard enthalpy ΔH°_{ads} and ΔS°_{ads} can be measured using the following Eq. (7):

$$\Delta G^{\circ}_{ads} = \Delta H^{\circ}_{ads} - T\Delta S^{\circ}_{ads} \qquad (7)$$

The ΔH°_{ads} data was evaluated from the intercept of the plot of ΔG°_{ads} versus T see Figure (3). The positive sign data of ΔH°_{ads} ensures that the process of adsorption is an endothermic, the ΔS^{o}_{ads} obtained from the slope of the line of Fig.3. The negative sign on ΔS^{o}_{ads} indicates that the adsorption of the drug accompany by ordering of the drug on the MS surface.

3.3. Effect of Temperature

WL tests were used to prove the temperature effect on MS corrosion rate (k_{corr}) in Aggressive solution. Figure 1 shows WL of MS in corrosive solution with different Esomeprazole Magnesium Trihydrate doses at various temperatures (298–338K). Table .1 illustrate the adsorption is aided by raising the temperature. This performance demonstrates that the adsorption of inhibitors on MS surface happens among chemical adsorption. Ivanov [42], considers the rise of %IE with temperature rise, MS chemisorption is preferred as higher temperature. Other authors [43-45] reported similar explanations.

3.4. Kinetic–Thermodynamic Corrosion Parameter

Activation energies for corrosion process (E^*_a) were obtained from Arrhenius relation as follows:

$$\log k_{corr} = \log A - (E^*_a / 2.303R)\,(1/T) \qquad (8)$$

where A is constant, R is universal gas constant, and T is temperature in Kelvin [46-49]. Plots of log k_{corr} and 1000/T were illustrated in Figure 4. Enthalpy of activation for the corrosion process (ΔH^*) and entropy of activation for corrosion process (ΔS^*) were determined by plotting log k_{corr}/T against 1/T (Figure 5), according to the following equation:

$$\log k_{corr}/T = \log (R/Nh + \Delta S^*/2.303R) + $$
$$+ (-\Delta H^*/2.303R)\,(1/T) \qquad (9)$$

where h is constant and N is number of Avogadro. Increasing of E^*_a and $\Delta H^*$with Esomeprazole Magnesium Trihydrate was because energy barrier that created in existence of Esomeprazole Magnesium Trihydrate. ΔH^* values were found to have positive signs, indicating anodic dissolution reaction of MS. Negative ΔS^*indicated that from reactants to the activated complex, the disorder lowered [50].

Figure 5 shows a plot of (log k_{corr}) against (1/T) in the case of inhibitor Esomeprazole Magnesium Trihydrate in 1M HCl. A straight line is obtained with a slope equals to (ΔH^*/2.303R) and the intercept is [log (R/Nh + ΔS^*/2.303R)] are calculated (Table 3).

Table 3. Parameters from activation process for MS in corrosive solution without and with various drug doses Esomeprazole Magnesium Trihydrate

Tabela 3. Parametri procesa aktiviranja za MS u korozivnom rastvoru bez i sa raznim dozama leka Esomeprazole Magnesium Trihydrate

Activation parameters			C inh. ppm
$-\Delta S^*$ (J mol^{-1}K^{-1})	ΔH^* (kJ mol^{-1})	E_a^* (kJ mol^{-1})	
167.5	32.7	58.8	blank
208	21.1	22.4	10
223	17.7	19.3	20
224	17.6	19.1	30
226	17.4	19.0	40
228	17.2	18.9	50
229	17.2	18.8	60

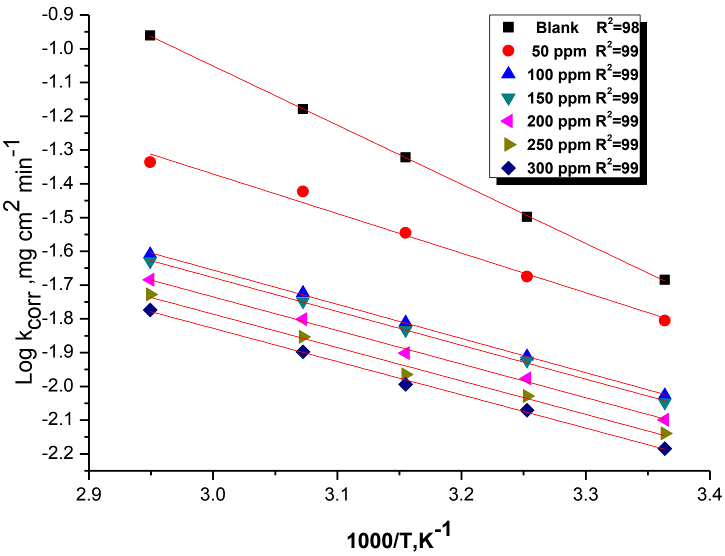


Figure 4. Curves (log k_{corr}/T) against (1000/T) in 1M HCl without and with various doses of drug Esomeprazole Magnesium Trihydrate

Slika 4. Krive (log kcorr/T) prema (1000/T) u 1M HCl bez i sa raznim dozama leka Esomeprazole Magnesium Trihydrate

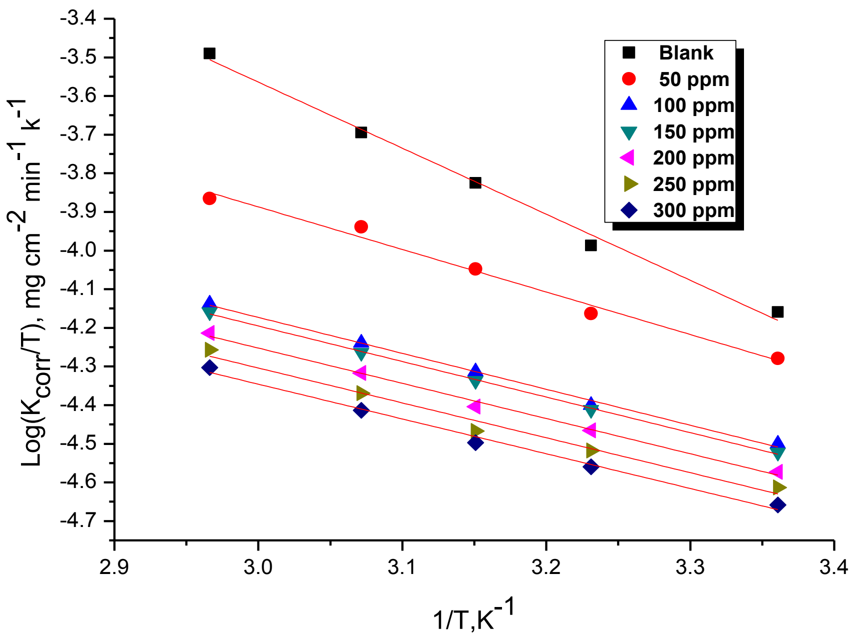


Figure 5. Log (k_{corr}/T) vs (1000/T) curves for MS immersed in 1M HCl with and without various doses of the drug Esomeprazole Magnesium Trihydrate

Slika 5. Krive Log (kcorr/T) vs (1000/T) krive za MS uronjene u 1M HCl sa i bez različitih doza leka Esomeprazole Magnesium Trihydrate

3.5. Electrochemical Frequency Modulation (EFM) Measurements

EFM is characterized by speed and greatly accuracy in calculating the current data [51,52]. Figure 6 indicate the EFM of MS in 1M HCl solution and at 30 ppm of Esomeprazole Magnesium Trihydrate drug. The EFM parameters such as (CF-2 and CF-3), (β_c and β_a) and (i_{corr}) can be measured from the higher current peaks (Tabel 4). The CF is closer to the standard data proved the validity of the calculated data. The IE% increase with the raising of Esomeprazole Magnesium Trihydrate doses. The % IE_{EFM} rise by raising the drug doses and was measured as in Eq. (2)

Table 4. Parameters of EFM diagrams for MS corrosion without and with various doses of the drug Esomeprazole Magnesium Trihydrate in 1M HCl at 25°C

Tabela 4. Parametri EFM dijagrama za koroziju MS bez i sa raznim dozama leka Esomeprazole Magnesium Trihydrate u 1M HCl na 25°C

%IE	Θ	CF3	CF2	CR mpy	β_c mV/dec	β_a mV/deade	i_{corr} uA	
		2.7	1.7	192.10	92	86	420.4	blank
55.7	0.557	1.50	2.90	49	126	114	186	5
59	0.59	1.90	2.27	57.80	121	107	172.2	10
72.8	0.728	2.40	2.80	57.1	12.3	110	114.1	15
76.5	0.765	1.89	2.21	45.02	879	82	98.76	20
72.8	0.728	1.98	2.47	43.20	735	71	81.99	25
80.5	0.805	2.19	2.07	39.91	59.1	56	57.67	30

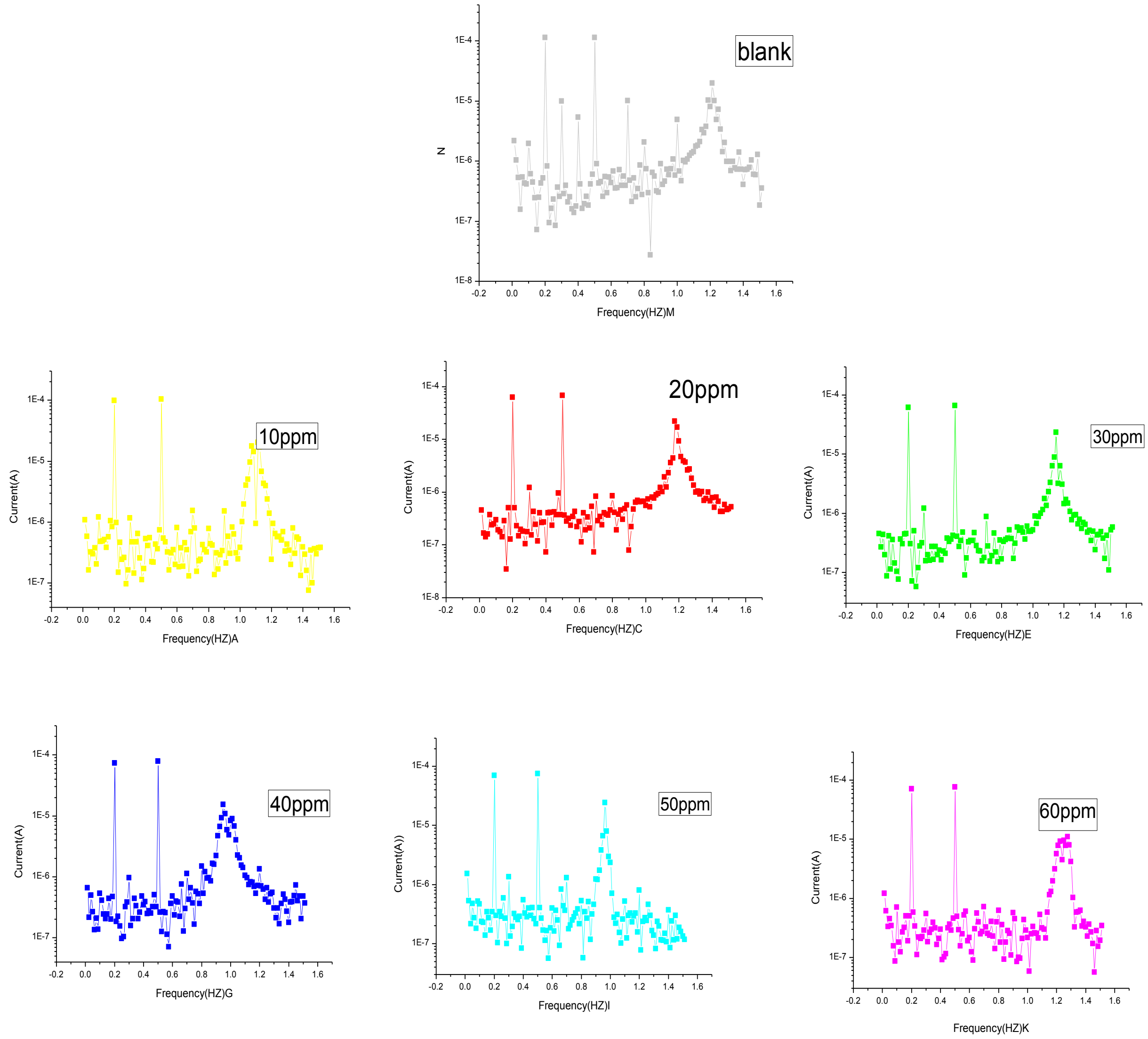


Figure 6. EFM spectra for MS in 1M HCl (blank) and the presence of various doses of the drug Esomeprazole Magnesium Trihydrate

Slika 6. EFM spektar za MS u 1M HCl (prazan) i prisustvo različitih doza leka Esomeprazole Magnesium Trihydrate

3.6. Electrochemical Impedance Spectroscopy (EIS) Measurements

Both Nyquist and Bode bends for MS corrosion in 1M HCl only and also in acid in existence of varied dose of Esomeprazole Magnesium Trihydrate were obtained by EIS procedure and shown in Figure 7(a, b). It is noticed from Nyquist figure that the curves appear semicircular. The frequency dispersion is responsible for the shape of the curve. The special shape of the Nyquist curves confirms that the MS corrosion is controlled by charge transfer process [53]. It was found that in the Nyquist diagrams the existence of inhibitor leads to raise the diameter of capacitive loop. Charge transfer resistance (R_{ct}) is responsible for high frequency capacitive loop. The double layer capacitance (C_{dl}) is the frequency at which the component of the impedance is maximum and could be measured according to the next equation:

$$C_{dl} = 1 / 2\pi \; F_{max} R_{ct} \qquad (10)$$

where R_{ct} is the charge transfer resistance and f is the frequency at the maximum altitude of the semicircle. The parameters obtained by EIS procedure was report in (Table 5). Figure 8 showed the fiting equivalent circuit for EIS data, which consists solution resistance (R_s), resistance charge transfer (R_{ct}), and a CPE instead of a pure capacitor signifying the interfacial capacitance. From the results calculated, it was observe that the R_{ct} values increases with increasing Esomeprazole Magnesium Trihydrate dose but C_{dl} data lowered. The adsorption of Esomeprazole Magnesium Trihydrate on the MS surface leads to this result. The results obtain proves that the Esomeprazole Magnesium Trihydrate works by forming the protective layer on the MS surface which modifies the MS/acid interface.

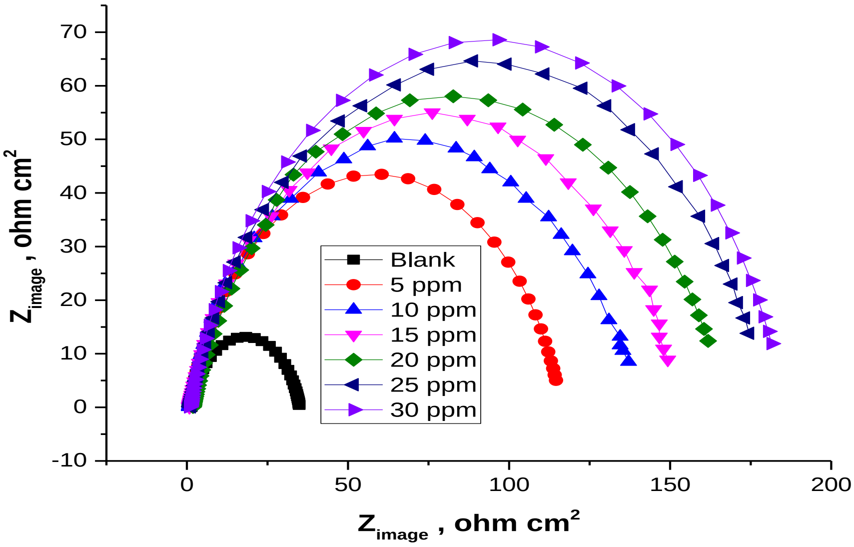


Figure 7a. Nyquist curves for the MS corrosion in 1M HCl with and without various doses of the drug Esomeprazole Magnesium Trihydrate at 25 °C

Slika 7a. Nyquist krive za MS koroziju u 1M HCl sa i bez različitih doza leka Esomeprazole Magnesium Trihydrate na 25 °C

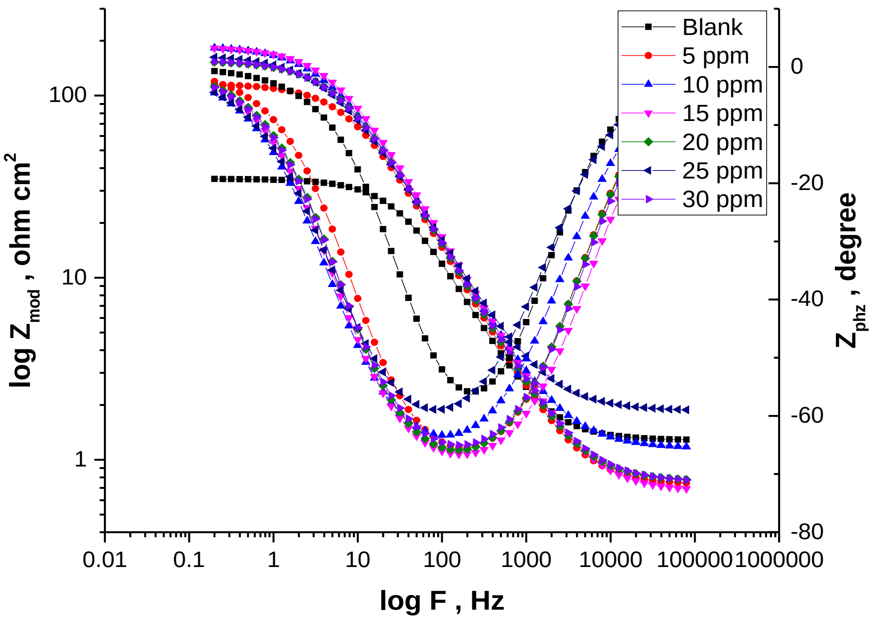


Figure 7b. The Bode curves for the corrosion of MS in 1M HCl with and without various doses of Esomeprazole Magnesium Trihydrate at 25 °C

Slika 7b. Bode-krive za koroziju MS u 1M HCl sa i bez različitih doza Esomeprazole Magnesium Trihydrate at 25 °C

Table 5 The obtained data from EIS tests for MS in 1M HCl with and without various doses of Esomeprazole Magnesium Trihydrate

Tabela 5. Dobijeni podaci iz EIS testova za MS u 1M HCl sa i bez različitih doza Esomeprazole Magnesium Trihydrate

%IE	Θ	C_{dl}	R_{ct}, ohm cm^2	Conc., ppm
-----	-----	237	33.7	blank
70.8	0.708	200	115.4	5
78.2	0.782	191	154.8	10
78.5	0.785	176	156.4	15
79.6	0.796	172	165.6	20
81.8	0.818	165	185.3	25
82.0	0.820	162	187.3	30

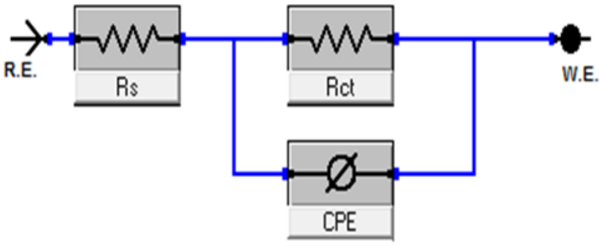


Figure 8. Circuit applied to fit the impedance data

Slika 8. Strujno kolo primenjeno za ispitivanje impedance

3.7. Tafel Polarization (TP) Measurements

Figure 9 shows Tafel plots at 25°C for MS in corrosive solution without and with many Esomeprazole Magnesium Trihydrate concentrations. As indicated from the figure, increasing Esomeprazole Magnesium Trihydrate concentration leads to decrease cathodic "H_2 reduction" and anodic "metal dissolution" reactions. This behavior illustrated that a mixed type inhibitor mechanisms are present. %IE and θ from TP tests were calculated using Eq. (2). Table 6 shows the determined values of $i_{corr.}$ $E_{corr.}$ Tafel slopes (β_a and β_c), k_{corr}, θ and %IE. The data indicated that i_{corr} decreased with raising Esomeprazole Magnesium Trihydrate dose and β_a & β_c remained almost unchanged with addition of Esomeprazole magnesium Trihydrate, indicating that the adsorbed inhibitor decreases k_{corr} without affecting the reaction mechanism.

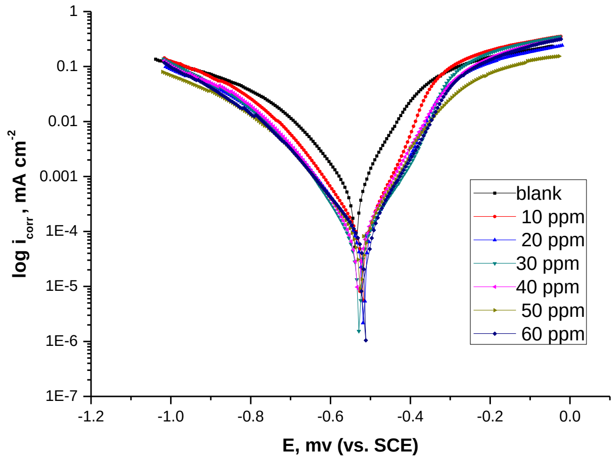


Figure 9. Tafel plots for CS in corrosive solution without and with different doses of the drug Esomeprazole Magnesium Trihydrate at 25°C

Slika 9. Tafelove krive za CS u korozivnom rastvoru bez i sa različitim dozama leka Esomeprazole Magnesium Trihydrate na 25°C

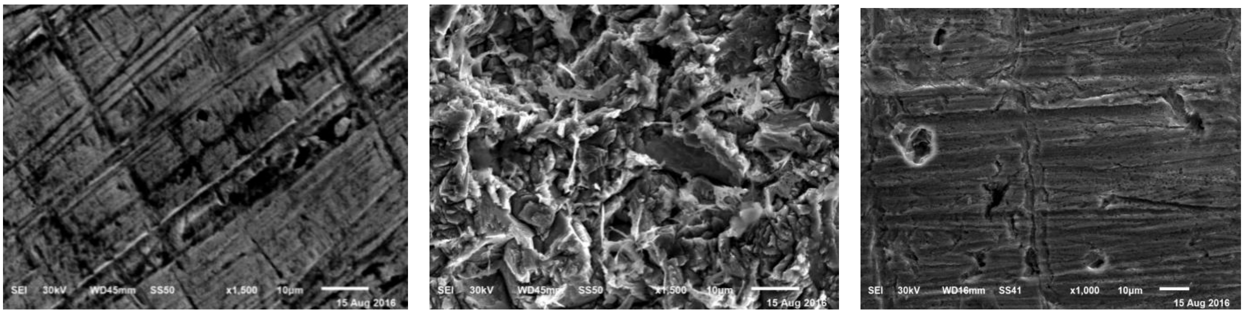
Table 6. i_{corr}, E_{corr}, β_c, β_a, k_{corr}, θ, and %IE for CS in the corrosive solution without and with different doses of the drug Esomeprazole Magnesium Trihydrate

Tabela 6. i_{corr}, E_{corr}, β_c, β_a, k_{corr}, θ i %IE za CS u korozivnom rastvoru bez i sa različitim dozama leka Esomeprazole Magnesium Trihydrate

%IE	Θ	C R mpy	β_c mV dec^{-1}	β_a mV dec^{-1}	$-E_{corr}$ mV vs SCE	i_{corr} μA cm^{-2}	Conc., ppm
----	----	261.7	118	81	573	542.0	blank
82.9	0.829	42.4	115	85	542	92.8	5
84.1	0.841	39.4	110	82	530	86.2	10
88.4	0.884	28.7	105	74	518	62.9	15
89.7	0.897	25.4	103	84	529	55.7	20
92.4	0.924	18.8	108	68	512	41.3	25
93.4	0.934	16.3	74	54	521	35.8	30

3.8. SEM Analysis

Figure 10a-c shows MS after surface treatment before electrochemical measurements; 10b after corrosion in HCl without and 10c with addition of 30 ppm Esomeprazole Magnesium Trihydrate. Presence of Esomeprazole Magnesium Trihydrate minimizes corrosion surface damage and make surface smoother of MS. This might be due to formation of a passive layer through Esomeprazole Magnesium Trihydrate adsorption on the MS surface that blocks the active sites and minimizes metal contact with corrosive solution.



(a) Free sample *(b) Blank* *c) 1M HCl + 30ppm of Esomeprazole Magnesium Trihydrate*

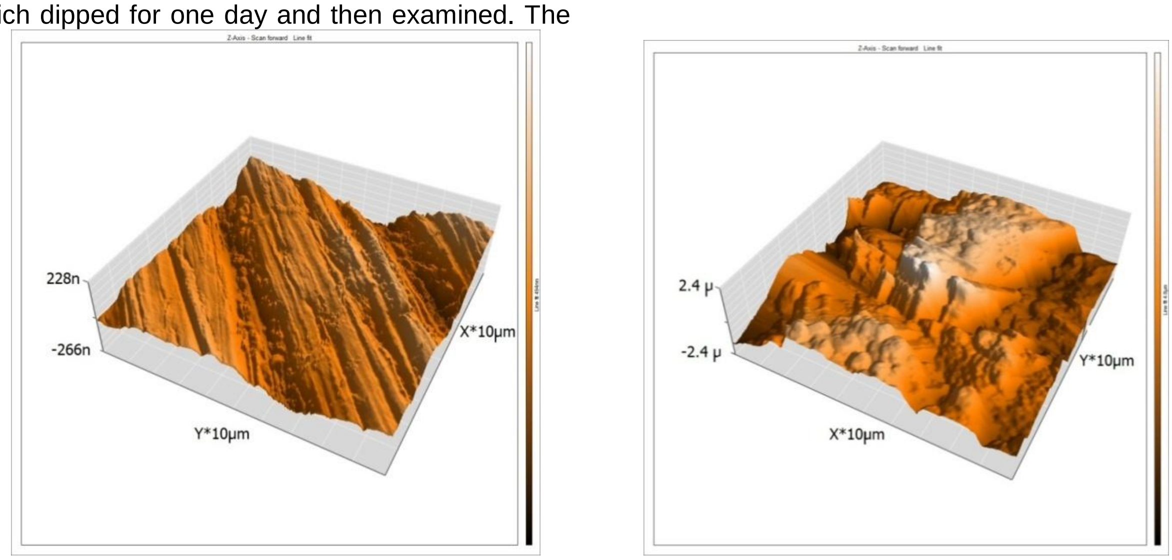
Figure. 10. SEM micrographs for MS with and without of 30 ppm of drug Esomeprazole Magnesium Trihydrate after immersion for one day

Slika 10. SEM mikrografije za MS sa i bez 30 ppm leka Esomeprazole Magnesium Trihydrate nakon potapanja tokom jednog dana

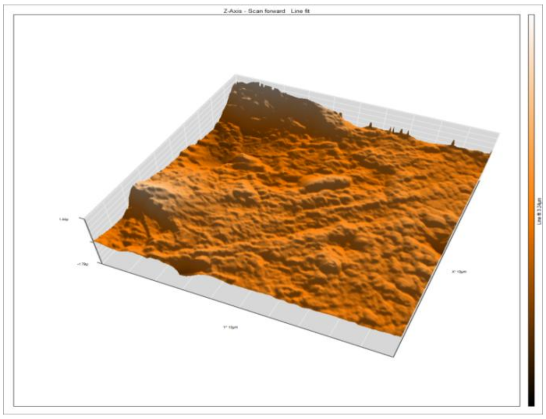
3.9. Atomic Force Microscopy (AFM) Analysis

AFM is a remarkable technique used for measuring the surface roughness with high resolution. Many details about MS surface morphology can be obtained from AFM measurements which help explaining the corrosion process. The three dimensional AFM images were represented in Figure 11.

The mean roughness is given (17.67) nm for MS free, (553 nm) for the blank in acid solution which dipped for one day and then examined. The observation of the MS surface which dipped in 1M HCl in existence of 30 ppm of Esomeprazole Magnesium Trihydrate given (332 nm) compared to the blank solution. The values showed that the roughness rises with adding HCl due to the corrosion occurs on the MS surface but decreased with adding the Esomeprazole Magnesium Trihydrate [54] due to the formation of a film of drug on MS surface.



(a) Free *(b) Blank*



(c) Inhibitor

Figure.11. The 3D of optical images of AFM in free sample of metal (a) and blank (b) and Esomeprazole Magnesium Trihydrate inhibitor (c)

Slika 11. 3D optičke slike AFM: uzorka metala (a) prazan (b) i sa inhibitorom Esomeprazole Magnesium Trihydrate (c)

3.10. FTIR Analysis

Figure 12 shows the FTIR spectra of the Esomeprazole Magnesium Trihydrate drug. The finger print spectra of the drug and the MS surface after immersion in 1M HCl + 60 ppm of Esomeprazole Magnesium Trihydrate was obtained and compared to each other it was obviously clear that the same finger print of meloxicam stock solution present on MS surface except the absence of some functional group and it suggested to be due to reaction with HCl. From Figure there are small shift in the peaks at MS surface from the original peak of the stock inhibitor solution, these shifts indicate that there is interaction between MS and some of the inhibitor's molecules.

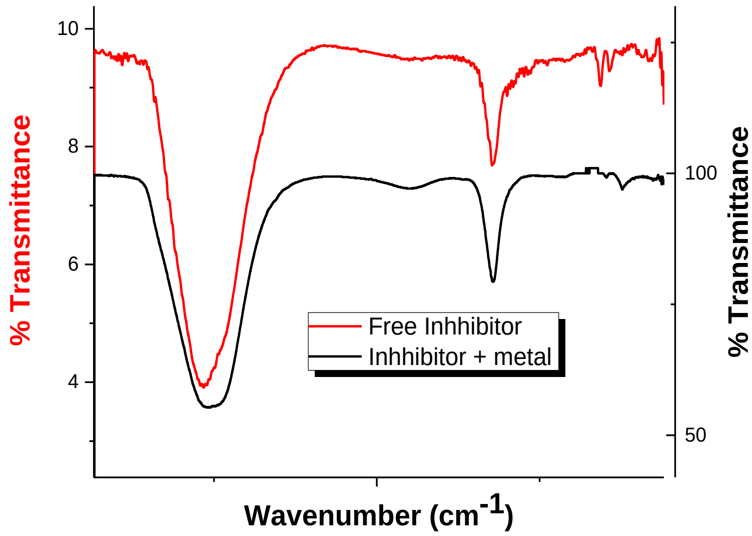


Figure 12. FTIR spectra of the Esomeprazole Magnesium Trihydrate drug

Slika 12. FTIR spektri leka Esomeprazole Magnesium Trihydrate

3.11. Mechanism of Corrosion Inhibition

The inhibition mechanism includes the inhibitor adsorption on the MS surface dipped in aqueous HCl. Four natures of adsorption [55] may occurring contain organic molecules at the interface among MS/solution interface: 1) Electrostatic attraction among the charged metal and the charged molecules; 2) Interaction of unshared electron pairs in the molecule through the metal; 3) Interaction of π-electrons with the metal; 4) Summation of all the above. From the observations drawn from the various tests, corrosion protection of MS in 1 N HCl solutions by Esomeprazole Magnesium Trihydrate as designated from WL, PP and EIS tests were found to rely on the dose and the nature of the protection. Molecules of the Esomeprazole

Magnesium Trihydrate can suppress anodic and cathodic processes either by physisorption or by chemisorption, where interactions of metal and inhibitors may due to electrostatic interaction or electron transfer process, respectively. Moreover, the negative value of ΔG^o_{ads} with the range -29.7 to -40.8 kJ mol^{-1} confirms the spontaneous adsorption of the drug on MS surface by both physisorption and chemisorption processes. In the acid medium the drug molecules may be protonated or may be neutral. Physisorption mechanism is due to: In the acid medium the drug molecules are protonated so, there is difficult for these protonated molecules to adsorb on the positive MS surface [56]. Chloride ions get first adsorbed on MS surface, the MS surface becomes negatively charged, and then the protonated Esomeprazole Magnesium Trihydrate molecules get adsorbed on the chloride layer. Chemisorption mechanism is due to: the neutral molecules can be adsorbed onto the MS surface via electron transfer from adsorbed species to the vacant electron orbital of low energy in the metal to form co-ordinate link.

A comparative study showing IE performance of some of the drugs reported before in the literature is illustrated in Table 7. The present drug shows considerably significant corrosion protection compared to some other drugs. Thus, it can be clearly understood that the present drug (Esomeprazole Magnesium Trihydrate) can be used for corrosion inhibition application with promising results. The higher inhibition efficiency of the investigated drug can be explained on the basis of strong interaction between metal and drug molecules through several polar groups (such as SO_2,C=O), heteroatoms (N, O, S), and aromatic as well as hetero-aromatic rings.

Table 7. A comparative chart listing the performance s of some drugs as corrosion inhibitors for MS in acidic solutions

Tabela 7. Uporedna lista u kojoj su navedene performanse nekih lekova kao inhibitora korozije za MS u kiselim rastvorima

Drug	medium	IE%	Reference
Penciillin G	H_2SO_4	73.7	[57]
Penciillin V	H_2SO_4	63.3	[58]
Cefalexin	HCl	67.5	[59]
Ceftriaxone	HCl	90.0	[60]
Cefotaxime	HCl	90.0	[61]
Cefixime	HCl	90.0	[62]
Quinoline	HCl	88.7	[63]
Esomeprazole Magnesium Trihydrate	HCl	88-93.2	Present work

4. CONCLUSIONS

Esomeprazole Magnesium Trihydrate drug was acting as effective inhibitor for MS in HCl solution. By analyzing the data it can be noticed that corrosion protection increased with increasing the doses of the drug and with raising the temperature. The adsorption of Esomeprazole Magnesium Trihydrate molecule obeyed Temkin adsorption isotherm. The polarization data revealed that this drug inhibits both anodic and cathodic reactions. The data obtained from different techniques are in good agreement.

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IZVOD

LEK *ESOMEPRAZOLE MAGNESIUM TRIHYDRATE* KAO POTENCIJALNI NEOTROVNI INHIBITOR KOROZIJE ZA MEKI ČELIK U KISELIM MEDIJIMA

Inhibitorski efekat leka Esomeprazole Magnesium Trihydrate na koroziju mekog čelika (MS) u 1M HCl ispitan je hemijskim testovima (gubitak težine (VL)) i elektrohemijskim metodama (Tafelova polarizacija (TP), elektrohemijska frekventna modulacija (EFM) i AC impedansna spektroskopija (EIS)). Otkriveno je da je adsorpciona izoterma leka Esomeprazole Magnesium Trihydrate na površini MS praćena Temkinovom adsorpcionom izotermom. Neki termodinamički parametri su izračunati i diskutovani. Dobiveni podaci pokazali su da se efikasnost inhibicije (IE) povećava s povećanjem koncentracije Esomeprazole Magnesium Trihydrate i povećanjem temperature. Morfologija MS površine analizirana je korišćenjem skenirajućeg elektronskog mikroskopa (SEM), atomske mikroskopije (AFM) i FTIR tehnikom. Rezultati svih metoda ispitivanja bili su u međusobnom slaganju.

Ključne reči: *kisela korozija, meki čelik, SEM, AFM, FTIR, Esomeprazole Magnesium Trihydrate.*

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