Shakul Hameed Musthafa Kani[1], *Mohamed Kani Anwar Sathiq*[1]*, *Syed Mohamed Syed Ismail Syed Abuthahir*[1], *Hameed Mohamed Kasim Sheit*[1], *Maharajan Raja*[2]

[1]*Affiliated to Bharathidasan University, PG and Research Department of Chemistry, Jamal Mohamed College (Autonomous), Tiruchirappalli-India,*
[2]*Affiliated to Bharathidasan University, Department of Chemistry, Sudharsan College of Arts and Science, Pudukottai, Tiruchirappalli, India*

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Anti-corrosion properties of expired ropinirole (ERN System) drug as inhibitor for mild steel in 1M HCl

ABSTRACT

Ropinirole is utilized to forestall sickness and spewing brought about by disease chemotherapy and radiation treatment. It works by hindering serotonin, a characteristic substance in the body that causes queasiness and retching. After lapse, they can be utilized as consumption added substances or inhibitors. The consumption obstruction activity of terminated Ropinirole drug (ERN) on the erosion of mild steel in 1M HCl medium has been assessed by the weight reduction strategy. The weight reduction estimations showed that erosion restraint effectiveness expanded with expanding the convergence of the inhibitor, with greatest security productivity at 0.001 M. The temperature influences the pace of erosion; at high temperatures, the consumption restraint effectiveness diminishes, and erosion is noticed. The robotic parts of consumption obstruction have been concentrated by the potentiodynamic polarization method and electrochemical impedance spectroscopy (EIS). The potentiodynamic polarization strategy uncovers that the inhibitor framework capabilities as a cathodic kind of inhibitor, controlling cathodic responses. An inhibitor can decrease corrosion current due to inhibited reaction rate and increase Linear polarization resistance due to the formation of a barrier on the electrode surface. time., since, within the sight of an inhibitor framework, the charge moves opposition esteem increments and the twofold layer capacitance esteem diminishes. The surface morphology of repressed gentle steel was dissected by filtering electron microscopy (SEM). The natural constituents on the gentle steel surface have been portrayed by energy dispersive X-beam spectroscopy (EDAX). The harshness of the gentle steel surface in cleaned MS, clear MS, and inhibitor frameworks has been described by nuclear power microscopy (AFM). The outcomes have obviously shown that ERN has a repressing limit with regards to decreasing the erosion of gentle steel submerged in hydrochloric corrosive medium.

Keywords: *Acidic solutions, Ropinirole, Mild steel, EIS, Isotherm, SEM-EDAX and AFM.*

1. INTRODUCTION

Erosion is the obliteration of metals because of compound collaboration or electrochemical response with their current circumstance. Mild steel is a combination that can be utilized in enterprises for useful and stylish purposes. It is to a great extent utilized in assembling applications, for example, hardware and ventures because of its functionality without deserts and financial possibility [1,2]. Hydrochloric corrosive is generally utilized in the pickling, cleaning, and descaling of steel and ferrous composites. Corrosive arrangements are for the most part utilized for the evacuation of rust and scale in modern cycles. Inhibitors are in many cases utilized in these cycles to control the metal disintegration [3-5]. Corrosion Inhibition of Mild Steel in Different Acid Medium by Using Various Acidic Groups of Organic Compounds has been investigated by Suraj B. Ade [6]. Khaled Saad Miled Ferigita has examined the corrosion inhibition of mild steel in acidic media using new oxo-pyrimidine derivatives: Experimental and theoretical insights [7] synthesis, characterization, experimental and theoretical study of the inhibitory power of new 8-hydroxyquinoline derivatives for mild steel in 1.0 M HCl has been determined by M. Rbaa [8]. Esseddik Elqars has investigated the synthesis, experimental, theoretical, and molecular dynamic studies of 1-(2,5-dimethoxy-4-methylphenyl) ethan-1-thiosemicarbazone as green inhibitor for carbon steel corrosion [9]. Corrosion inhibition study of expired acetazolamide on Mild Steel in dilute hydrochloric acid solution has been reported by

*Corresponding author: M. Anwar Sathiq
E-mail: anwarchemsathiq@gmail.com
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Chaudhari, L.P [10]. Cefuroxime axetil: A commercially available drug as corrosion inhibitor for aluminum in hydrochloric acid solution has been examined by Paul O [11]. Recent progresses in thiadiazole derivatives as corrosion inhibitors in hydrochloric acid solution has been analysed by H.S. Aljibori [12]. H.S. Aljibori has studied the corrosion inhibition effects of concentration of 2-oxo-3-hydrazonoindoline in acidic solution, exposure period, and temperature [13]. The corrosion resistance of mild steel in 1M HCl solution before and after emulsion coating has been repoted by N.Anitha [14]. N.A. Abdul-Rida has examined the Synthesis, characterization, efficiency evaluation of some novel triazole derivatives as acid corrosion inhibitors [1**5**]. As of late, many lapsed drugs have been accounted for to be extremely successful erosion inhibitors for the security of gentle steel in acidic media to advance an eco-accommodating climate [16-19]. The greater part of the medications work successfully in the destructive blood climate of our body. This prompted the inspiration for our current review: to figure out the impact of terminated Ropinirole drug (ERN) in corrosive answer for the security of mild steel.

In the current exploration study, the consumption opposition properties of the ERN were examined on gentle steel drenched in hydrochloric corrosive arrangements by the weight reduction strategy, electrochemical techniques, and surface morphologies of SEM, EDAX, and AFM procedures. The great of this medication as an erosion inhibitor or added substance depends on its ecological benevolence; its particle has nitrogen and oxygen as dynamic focus iotas.

2.EXPERIMENTAL TECHNIQUES

2.1.Materials

The mild steel specimens were made from the same sheet of the following composition: Carbon - 0.1 %, Sulphur - 0.026 %, Phosphorus - 0.06 %, Manganese - 0.4 % and the balance iron. Mild steel specimen of the dimension 1.0 × 4.0 × 0.2 cm were polished to mirror finish, degreased with trichloroethylene and used for weight – loss and surface examination studies.

Mild steel specimen encapsulated in Teflon with an exposed cross section of $1cm^2$ was used as the working electrode in potentiodynamic polarization studies. The surface of the electrode was polished to mirror finish and degreased with trichloroethylene. The medium (1M HCl) was prepared by dilution of an analytical grade hydrochloric acid with double distilled water. Mild steel cylindrical rods of the same composition embedded in polytetrafluoroethylene (PTFE) with exposed area of 1 cm^2 were used for potentiodynamic polarization and impedance measurements. The electrode was polished using a sequence of emery papers of different grades and then degreased with acetone.

All chemicals used in this work were of analytical grade, and the solutions were prepared using distilled water. Stock solutions from the examined EGS were ready by liquefying the suitable weight of the utilized chemically pure solid drug in second distilled water. The testing solution was prepared using 1M HCl solution with various amount of inhibitor. The solution in absence of inhibitor was considered as blank for comparison. All tests have been done at room temperature in magnetically stirred solutions.

2.1.1. Characteristics of Inhibitor

The inhibitor compound was purchased as Ropinirole drug from pharmaceutical store. The name and molecular structure of studied ERN inhibitor is given in Figure 1.

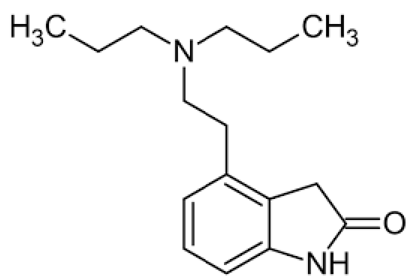

Figure 1. 4-[2-(Dipropylamino) ethyl]-1,3-dihydro-2H-indol-2-one

Drugs Name: Ropinirole

Formula: $C_{16}H_{24}N_2O$

Molecular weight: 260.37

Solubility: Ethanol, Methanol

Ropinirole, sold under the brand name Requip among others, is a medication used to treat Parkinson's disease (PD) and restless legs syndrome (RLS). In PD the dose needs to be adjusted to the effect and treatment should not be suddenly stopped. It is taken by mouth.

Common side effects include sleepiness, vomiting, and dizziness. Serious side effects may include pathological gambling, low blood pressure with standing and hallucinations. Use in pregnancy and breastfeeding is of unclear safety.It is a dopamine agonist and works by triggering dopamine D2 receptors. It was approved for medical use in the United States in 1997. It is available as a generic medication. In 2020, it was the 156th most commonly prescribed medication in the United States, with more than 3 million prescriptions.

Ropinirole is a member of indolones and a tertiary amine. It has a role as a dopamine agonist, an antiparkinson drug, a central nervous system drug and an antidyskinesia agent. Ropinirole, also known as ReQuip, is a non-ergoline dopamine agonist used in Parkinson's disease and restless legs syndrome [20].

2.1.2. Preparation of inhibitor

Double distilled water was used wherever necessary in the preparation of solutions. Analytical grade HCl is taken as such and they were diluted to the required concentration. The required concentration of the inhibitor stock solution was prepared by dissolving inhibitor in minimum amount of ethanol and making up to the desired volume with double distilled water. Then the required volume from the inhibitor stock solution was added to the HCl solution to obtain the desired concentration. For all the studies same volume of the ethanol was used to dissolve inhibitor.

2.1.3. Weight loss measurements

Weight of the three polished mild steel specimens were measured before and after immersion in various test solutions (1M hydrochloric acid with different extract concentrations) for two hours. The inhibition efficiencies were calculated from the relation [21,22].

$$IE = \frac{CR_1 - CR_2}{CR_1} \times 100\ \% \qquad (1)$$

where CR_1 is corrosion rate in the absence of inhibitor and CR_2 is the corrosion rate in the presence of inhibitor.

The corrosion rate, in mmd, was calculating using the formula,

Corrosion rate (mpy) = 5.34 × W / a × d × t

where,

W = weight loss in gram,

a = the area of the specimen in cm^2

d = 7.8 and

t = time exposure in hour.

2.1.4. Electrochemical study

In the present work corrosion inhibition of carbon steel immersed in various test solutions were measured by polarization study. Electrochemical measurements were performed in a CHI-electrochemical work station with impedance model 660A.

2.1.5. Polarization study

Polarization studies were carried out in a three - electrode cell assembly. A SCE was the reference electrode. Platinum was the counter electrode. Carbon steel was the working electrode. From polarization study, corrosion parameters such as corrosion potential (E_{corr}), corrosion current (I_{corr}), Tafel slopes anodic = b_a, and cathodic = b_c ,and LPR (linear polarisation resistance) values were measured [23,24]

2.1.6. AC Impedance spectra

The same instrument and set-up used for polarization study was used to record AC impedance spectra also. A time interval of 5 to 10 min was given for the system to attain a steady state open circuit model. The real part (Z') and imaginary part (-Z") of the cell impedance were measured in ohms at various frequencies. AC impedance spectra were recorded with initial E(V) = 0, high frequency (1-10^5 Hz), low frequency (1 Hz), amplitude (V) = 0.005 and quiet time (s) = 2. From Nyquist plot the values of charge transfer resistance (R_t) and the double layer capacitance (C_{dl}) values were calculated [25,26].

2.1.7. Surface Examinations

The mild steel specimens were immersed in various concentrations of inhibitor and blank for 2 hours. After 2 hours the specimens were taken out and dried. The nature of the film formed on the surface of mild steel specimens was analyzed by surface analytical technique SEM, EDAX and AFM.

2.1.8.SEM analysis

The mild steel specimens immersed in various test solutions for two hours were taken out, rinsed with double distilled water, dried and subjected to the surface examination [27]. The surface morphology measurements of the mild steel surface were carried out by scanning electron microscopy (SEM) using SEM instrument, JEOL MODEL JSM 6390.

2.1.9. EDAX analysis

The element is present on the mild steel surface is examined by energy dispersive analysis of X – rays (EDAX) the mild steel specimen with and without inhibitor solutions for 2 hours. Then they were removed, rinsed quickly and dried. The analysis was performed on Quantex 200 with X Flash - 6130 EDAX [28].

2.2. AFM analysis

The mild steel specimens immersed in various test solutions for one day were taken out, rinsed with double distilled water, dried and subjected to the surface examination [29]. The surface morphology measurements of the mild steel surface were carried out by atomic force microscopy (AFM) using SPM Veeco di Innova connected with the software version V7.00 and the scan rate of 0.7Hz.

3. RESULTS AND DISCUSSION

3.1. Weight loss measurements

The corrosion rate and corrosion inhibition efficiency were determined by weight loss method before and after immersion of mild steel in 1M HCl acid medium (Table 1). The corrosion parameters of mild steel, including inhibition efficiency and corrosion rates, were measured after ten days of expiry date using the weight loss method. It is observed that 0.001 M concentration of ERN gives 92.85% of inhibition efficiency. As the concentration of ERN increases, the corrosion protection properties increases. It is because of an increase of surface coverage at higher concentration of the inhibitor additives which hold back destruction of mild steel. The chance of interface between the hetero atoms present in the ERN and metal ion from the mild steel surface can be attributed for higher inhibition efficiencies. The occurrence of active constituents in the ERN is accountable for the inhibition of mild steel corrosion. It may be the reasons for the anti-corrosive character of expired drugs of Ropinirole and the same hypothesis has been already reported. This investigation is in good agreement with the results reported by many researchers [30-34].

Table 1. The mild steel immersed in a 1M HCl in the absence and presence of inhibitor (ERN) at different concentrations and the inhibition efficiency (IE %) obtained weight loss method

Tabela 1. Meki čelik potopljen u 1M HCl u odsustvu i prisustvu inhibitora (ERN) u različitim koncentracijama i efikasnosti inhibicije (IE %) dobijene metodom gubitka težine

Temperature: 303 K *Time: 2 hours*

Concentration of ERN inhibitor (M)	Corrosion rate (mpy)	Inhibition Efficiency (%)	Surface Coverage (θ)
blank	0.8386	-	-
0.0000001	0.3594	57.14	0.5714
0.000001	0.2738	67.35	0.6735
0.00001	0.2053	75.51	0.7551
0.0001	0.1198	85.71	0.8571
0.001	0.0599	92.85	0.9285

3.1.1. Effect of concentration of ERN inhibitor on corrosion inhibitive process

The corrosion rate decreases and corrosion inhibition efficiency increases with increase in concentration of ERN inhibitor and the concentration range is 0.0000001 M to 0.001 M for two hours immersion of the mild steel specimens in corroding solution at room temperature (303 K) [35-38].

The inhibition efficiency increases owing to the adsorption of inhibitor molecules present in ERN inhibitor on the mild steel surface. The maximum inhibition efficiency and the lower corrosion rate is obtained at high concentration 0.001 M for ERN additive. Further increase in inhibitor concentration above 0.001 M, the inhibition efficiency and corrosion rate almost remained constant. So the 0.001 M concentration is fixed as the concentration for maximum inhibition for the ERN as corrosion inhibitor. This concentration corresponds to the attainment of a saturation value in surface coverage of mild steel [39].

3.1.2. Effect of temperature on corrosion rate and inhibition studies

Generally, the corrosion reaction occurs rapidly at high temperatures. Increase the temperature, the rate of corrosion of mild steel increases and the same time the corrosion inhibition efficiency decreases. At high temperature, the dissolution of mild steel increases and undergoes corrosion vigorously. In electrochemical studies, the influence of temperatures indicates a main role to get an idea about the adsorption mechanism of inhibitor molecules on surface of mild steel. In fact, the corrosion inhibition efficiency and corrosion rate is investigated for ERN inhibitor system from 0.0000001 M to 0.001 M with temperatures varying from 303-333 K [38]. The values of inhibition efficiency and the corrosion rate of ERN are given in Table 2.

Table 2. The corrosion parameters of ERN on the corrosion of mild steel in 1M HCl at different temperatures

Tabela 2. Parametri korozije ERN na koroziju mekog čelika u 1M HCl na različitim temperaturama

Temperature (K)	Corrosion rate (mpy)	I.E. (%)	Surface coverage (θ)
303	0.0599	92.85	0.9285
308	0.0770	90.81	0.9081
313	0.1112	86.73	0.8673
318	0.2053	75.51	0.7551
323	0.3337	60.20	0.602
328	0.4364	47.96	0.4796
333	0.5476	34.70	0.347

The inhibition efficiency is decreases from 92.85 % to 34.70 % and the corrosion rate is increases from 0.0599 to 0.5476 as the rise in temperature from 303 to 333 K in 1M HCl at the maximum concentration (0.001 M) for ERN. The influence of temperature increased with increasing inhibitor concentration on the dissolution of mild steel and the partial desorption of inhibitor molecule from the surface of the mild steel [40].

3.2. Analysis of electrochemical methods

The electrochemical techniques comprise a method for determining the rate of corrosion of a mild steel. It allows fast assessment of the performance of inhibitor, durability of surface layer and also the inhibition efficiency of corrosion inhibitors.

The following techniques were used to know whether they act as cathodic or anodic or mixed type inhibitor for mild steel immersed in 1M HCl without and with the presence of the ERN inhibitor system. The mechanism of corrosion protection for expired Ropinirole inhibitor drugs depends on inhibitor nature, corrosive medium, and experimental conditions. Further studies are needed to determine suitable mechanisms for mild steel contact

3.2.1. Potentiodynamic polarization study

Potentiodynamic polarization technique has been applied to observe the development of defensive layer on the surface of mild steel [41-44]. If a protective film is developed on the surface of mild steel, the linear polarization resistance values (LPR) increases and the corrosion current value (I_{corr}) decreases. The potentiodynamic polarization arcs of mild steel submerged in 1M HCl without and with presence of ERN inhibitor is shown in Figure 2.

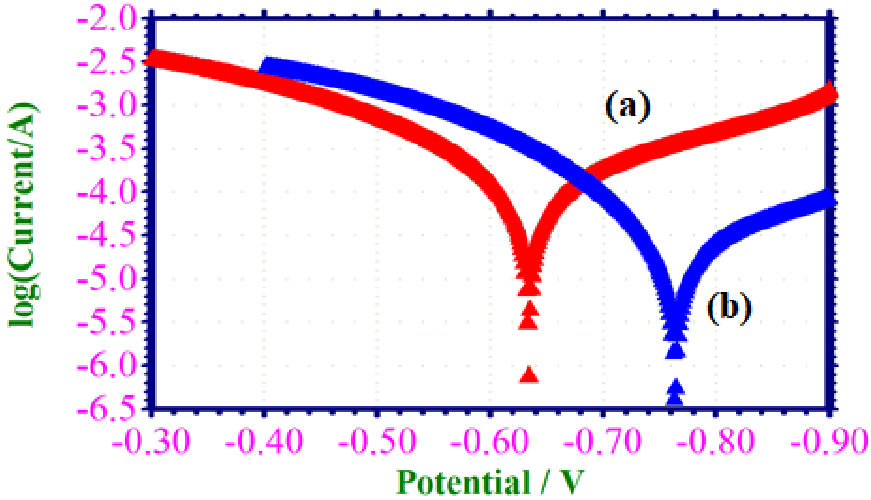

Figure 2. Potentiodynamic polarization arcs for corrosion of mild steel in 1M HCl in absence and presence of ERN inhibitor: (a) Mild steel in 1M HCl (blank); (b) Mild steel in 1M HCl with 0.001 M of ERN inhibitor

Slika 2. Potenciodinamički polarizacioni lukovi za koroziju mekog čelika u 1M HCl u odsustvu i prisustvu ERN inhibitora: (a) Meki čelik u 1M HCl (prazno); (b) Meki čelik u 1M HCl sa 0,001 M inhibitora ERN

The corrosion parameters namely corrosion potential (E_{corr}) Tafel slopes, b_c and b_a, linear polarization resistance (LPR) and corrosion current (I_{corr}) are given in Table 3. It is noted in Figure 4. that when mild steel is submerged in 1M HCl, the corrosion potential is – 632 mV Vs SCE (Saturated Calomel Electrode). The LPR value is 291 Ohm/cm^2. The corrosion current is 1.2730 × 10^{-4} A/cm^2. The corrosion potential is shifted to the cathodic side - 761 mV SCE when 0.001 M of ERN is added to the above corrosive environment.

Table 3. Potentiodynamic Polarization parameters for the corrosion of mild steel in 1M HCl without and with presence of ERN inhibitor system

Tabela 3. Potenciodinamički parametri polarizacije za koroziju mekog čelika u 1M HCl bez i sa prisustvom ERN inhibitorskog sistema

Concentration of the ERN inhibitor (M)	E_{corr}, mV/SCE	Tafel slope		I_{corr} A / cm^2	LPR **Ω**/cm^2
		Ba, mV/dec	bc mV/dec		
blank	- 632	1.2730 × 10^{-4}	0.152	0.208	291
0.001	- 761	2.3180 × 10^{-5}	0.113	0.224	1158

This specifies that the corrosion potential is shifted to the cathodic side due to the formation of defensive layer on the mild steel surface. This film controls the cathodic reaction of mild steel dissolution by forming Fe^{2+}-ERN complex on the cathodic sites of the mild steel surface [45,46]. This inhibitor act as cathodic type inhibitor because the corrosion potential shift is more negative side when compare to blank value. Increase in LPR and decrease in I_{corr} values are indications of more corrosion resistant nature of inhibitor system.

3.2.2. Alternating current impedance spectra

Electrochemical impedance spectra have been used to validate the development of defensive layer on the surface of mild steel [47,48]. If a defensive layer is formed on the mild steel surface, charge transfer resistance (R_t) increases; double layer capacitance value (C_{dl}) decreases and the impedance log (z/ohm) value increases. AC impedance spectra of mild steel dipped in 1M HCl in the absence and presence of ERN inhibitor system are shown in Figure 3 (Nyquist plots) and Figures-4(a, b) (Bode plots).

The alternating current impedance spectra of mild steel dipped in various test solutions were recorded. The AC impedance parameters, namely, charge transfer resistance (R_t) and double layer capacitance (C_{dl}) are given in Table -4. When mild steel is engrossed in 1M HCl, R_t value is 23.62 ohm cm^2 and C_{dl} value is 42.3779 × 10^{-6} F cm^{-2}. R_t value increases from 23.62 to 41.30 ohm cm^2 when 0.001M of ERN is added to 1M HCl blank system. The C_{dl} value is also decreases from 42. 3779 × 10^{-6} to 67.1092 × 10^{-6} F cm^{-2}. The impedance value [log (z/ohm)] increases from 0.502 to 0.574. Furthermore, the phase angle of inhibitor system increases from 25.9° to 29.9° when compare to the blank system. This suggests that a defensive layer is formed on the surface of the mild steel surface.

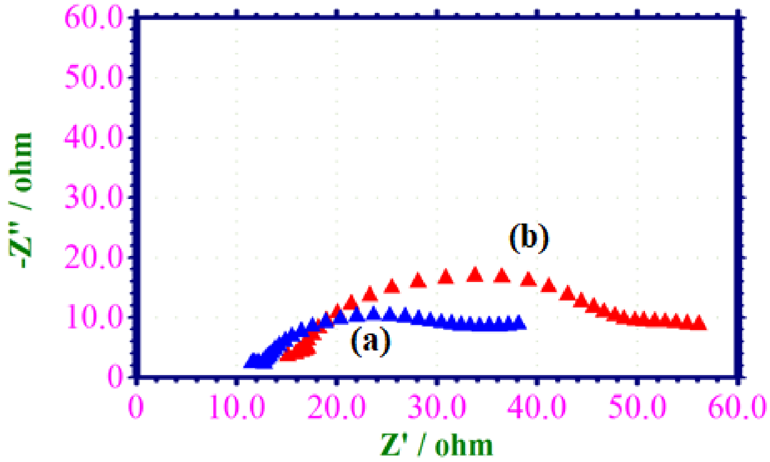

Figure 3. AC impedance spectra of mild steel submerged in 1M HCl in the absence and presence of ERN inhibitor (Nyquist plots): (a) Mild steel in 1M HCl without inhibitor (b) Mild steel in 1M HCl with 0.001 M of ERN inhibitor

Slika 3. Spektri impedanse naizmenične struje mekog čelika potopljenog u 1M HCl u odsustvu i prisustvu ERN inhibitora (Nyquist-ove krive): (a) Meki čelik u 1M HCl bez inhibitora (b) Meki čelik u 1M HCl sa 0,001 M inhibitora ERN

Table 4. Electrochemical impedance parameters from Nyquist plots for the corrosion of mild steel submerged in 1M HCl in the absence and presence of ERN inhibitor

Tabela 4. Parametri elektrohemijske impedanse iz Nyquist-ovih dijagrama za koroziju mekog čelika potopljenog u 1M HCl u odsustvu i prisustvu ERN inhibitora

Concentration of the ERN inhibitor (M)	Nyquist plot		Impedance Log (z/ohm)	Phase angle (degree)
	R_t, Ω/cm^2	C_{dl} , F/cm^2		
blank	23.69	42. 3779 × 10^{-6}	0.502	25.9
0.001	41.30	67.1092 × 10^{-6}	0.574	29.9

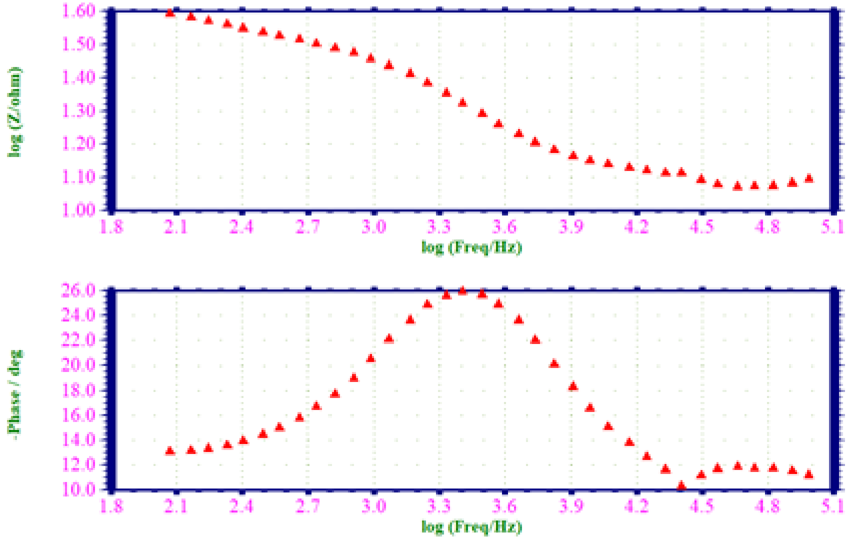

Figure 4a. AC impedance spectra of mild steel dipped in 1M HCl (Bode Plot)

Slika 4a. Spektri impedanse naizmenične struje mekog čelika umočenog u 1M HCl (Bode-ov dijagram)

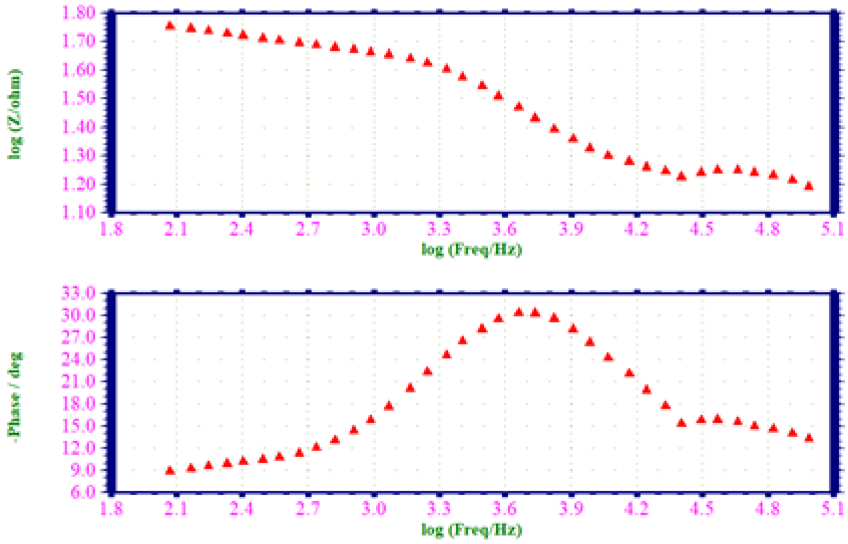

Figure 4b. AC impedance spectra of mild steel dipped in 1M HCl with 0.001 M of ERN inhibitor (Bode Plot)

Slika 4b. Spektri impedanse naizmenične struje mekog čelika umočenog u 1M HCl sa 0,001 M ERN inhibitor (Bode-ova kriva)

3.3. Surface analysis of mild steel by SEM

Scanning electron microscopy characterization provide a surface morphology consequence to realize the nature of the surface coating of mild steel in absence and presence of corrosion inhibitors and magnitude of corrosion. The SEM pictures of the mild steel surface are examined in absence and presence of inhibitor. To understand the nature of the coating developed in the absence and presence of ERN inhibitor on the mild steel surface and the extent of corrosion of mild steel [49,50]. The SEM images of mild steel specimen immersed in 1M HCl for two hours in the absence and presence of ERN inhibitor system are shown in figures 5 (a, b & c) respectively.

The mild steel specimen is immersed in the 1M HCl solution containing inhibitor for two hours. The specimen is taken out, dried and observed under the investigation of SEM. The images of polished mild steel is shown (control) figure-6a which show the smooth surface and also absence of corrosion inhibitor formed on the mild steel surface. The mild steel surface has been corroded due to metal dissolution in 1M HCl is shown (blank) figure 6b. It is a rough mild steel surface which specify highly corroded area. The mild steel surface immersed in 1M hydrochloric acid containing inhibitor is shown in figure 6c. However, in the presence of inhibitor (0.001 M of ERN) the rate of corrosion is suppressed, as can be seen from the decrease of corroded areas. The mild steel surface almost free from corrosion due to the formation of insoluble complex on the surface of the mild steel. The surface is covered by a thin layer of inhibitor which effectively controls the dissolution of mild steel immersed in 1M HCl with 0.001 M of ERN.

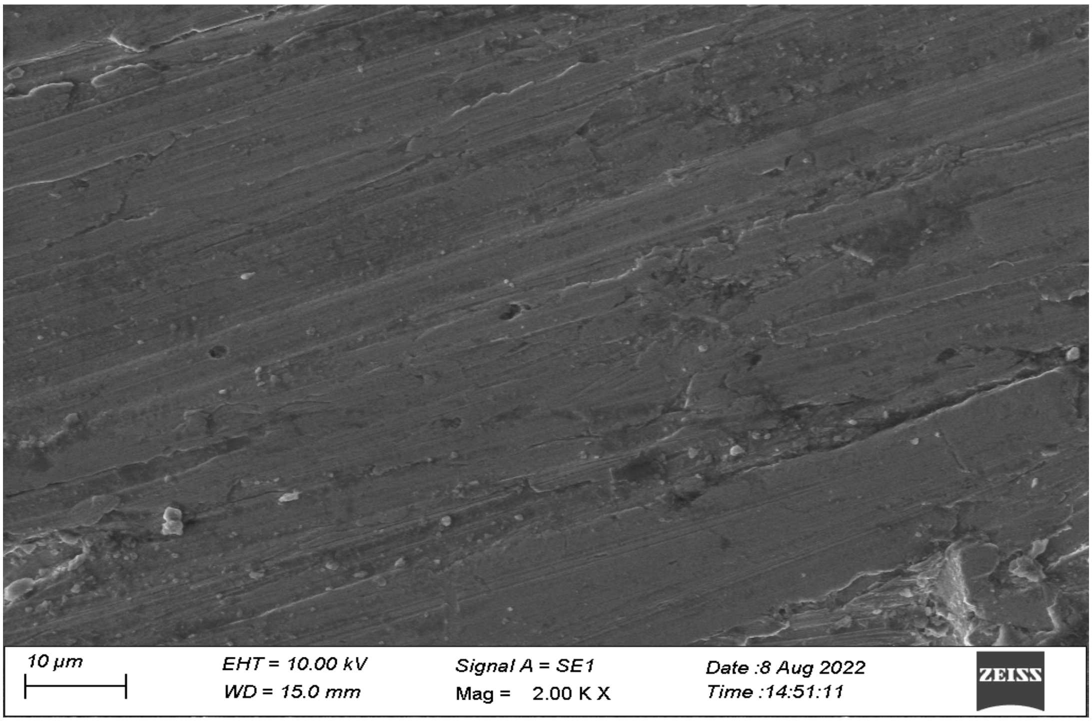

Figure 5a. SEM image of polished mild steel coupon before immersion in 1M HCl (control)

Slika 5a. SEM slika uzorka od poliranog mekog čelika pre potapanja u 1M HCl (kontrola)

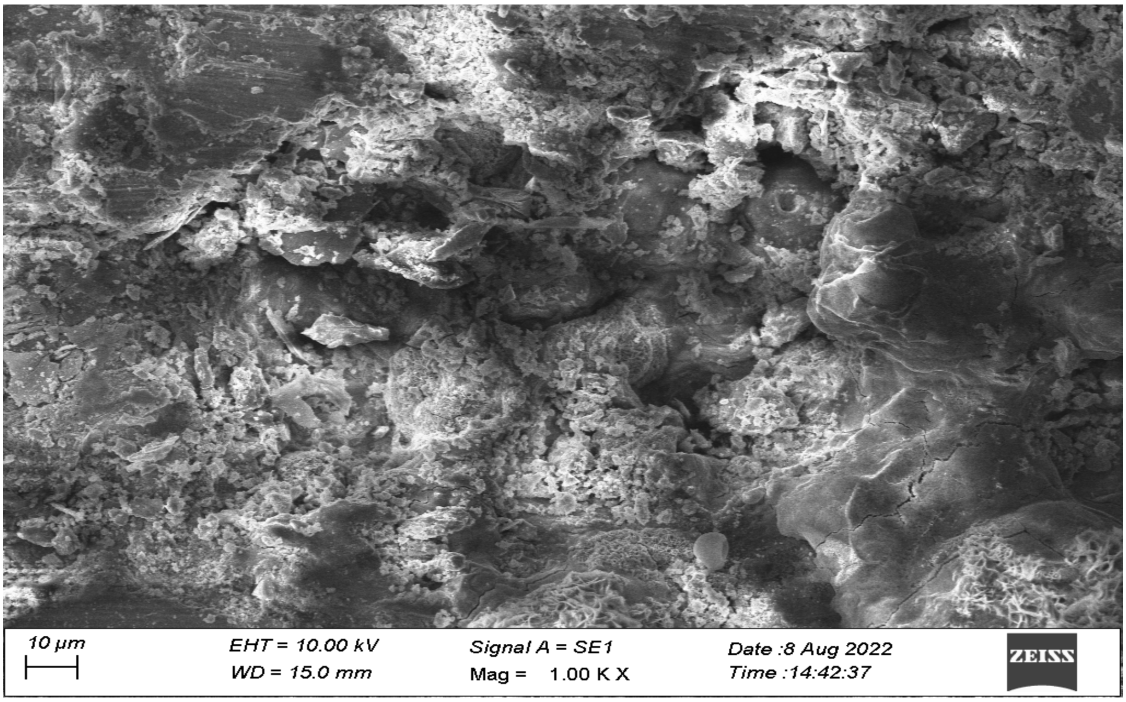

Figure 5b. SEM image of mild steel coupon after immersion in 1M HCl (blank)

Slika 5b. SEM slika uzorka od mekog čelika nakon potapanja u 1M HCl (prazno)

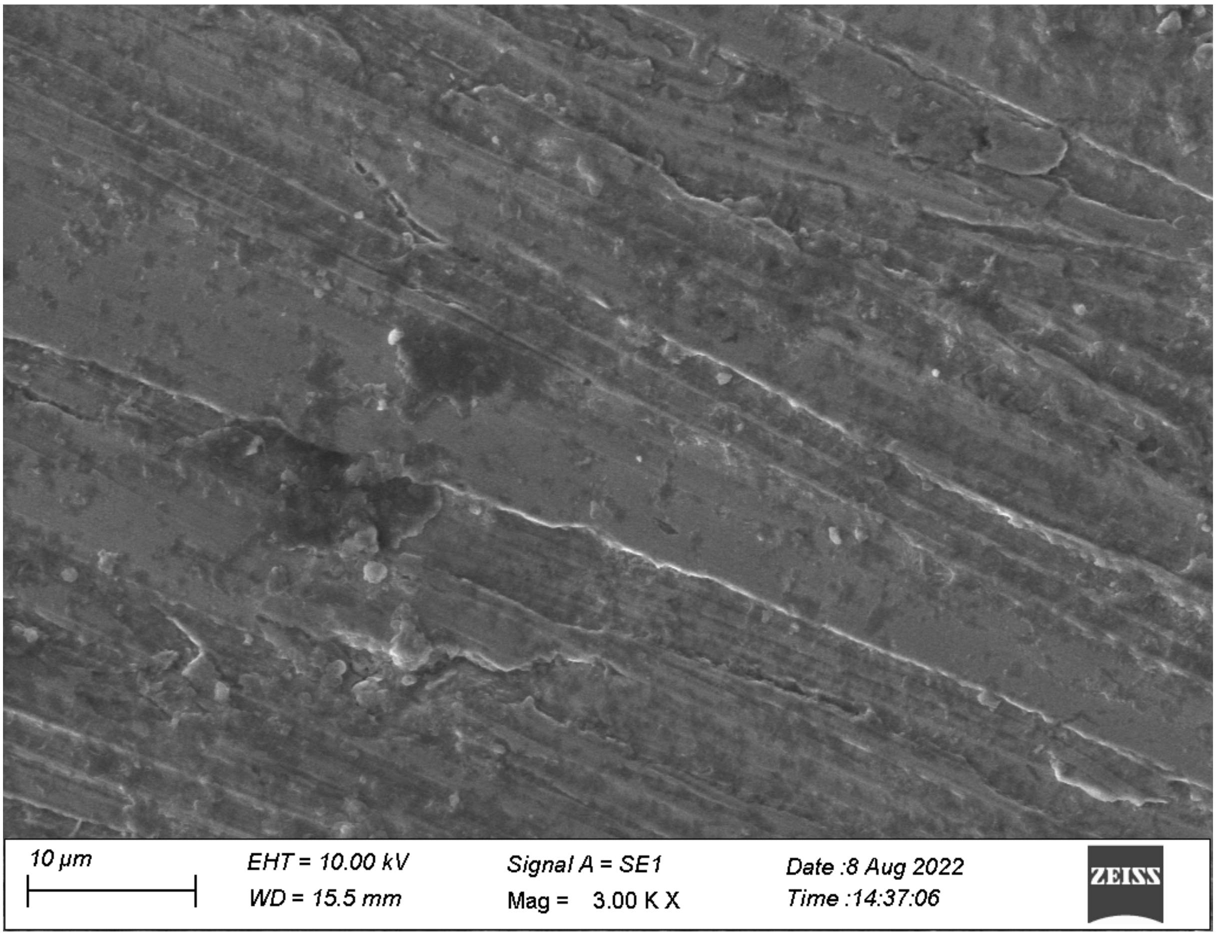

Figure 5c. SEM image of polished mild steel coupon after immersion in 1M HCl in the presence of 0.001 M of ERN.

Slika 5c. SEM slika uzorka od poliranog mekog čelika nakon potapanja u 1M HCl u prisustvu 0,001 M ERN

3.4. Surface characterization of mild steel by Energy Dispersive Analysis (EDAX)

EDAX examinations of the mild steel surface were performed in the absence and presence of inhibitors system. The EDAX spectra have been used to determine the elements present on the mild steel surface before and after exposure to the inhibitor solution [51].

The EDAX spectrum of mild steel is shown in figure-6a and it shows the characteristic peaks of some of the elements constituting the mild steel sample. The EDAX spectrum of mild steel immersed in 1M HCl is shown in figure-6b and it shows the decrease of constituting elements of mild steel. Moreover, the presence of Cl^- it indicates the mild steel damaged by attack of 1M HCl. The EDAX spectrum of mild steel immersed in 1M HCl and 0.001M of ERN is shown in figure-6c. It shows the additional line characteristic for the existence of the intensity of Cl signals is reduced and the intensity of constituting elements of mild steel surface signal is increased. The appearance of Fe signal and this enhancement of O signal are due to the presence of inhibitor. These data show that carbon steel surface is covered with the Fe, S, C, P, Ni, N and O atoms. This layer is undoubtedly due to the presence of inhibitor in corrosive system. These results suggest that O, N and C atoms of 0.001M of ERN may adsorbed on mild steel surface, resulting in the formation of Fe^{2+}-ERN complex on the mild steel surface [52].

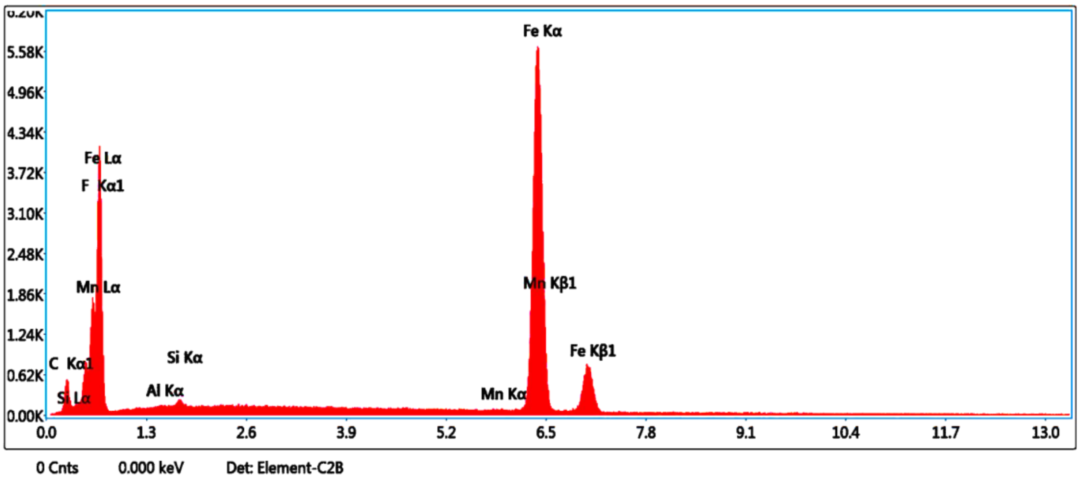

Figure 6a. EDAX spectrum of mild steel specimen (control)

Slika 6a. EDAX spektar uzorka od mekog čelika (kontrola)

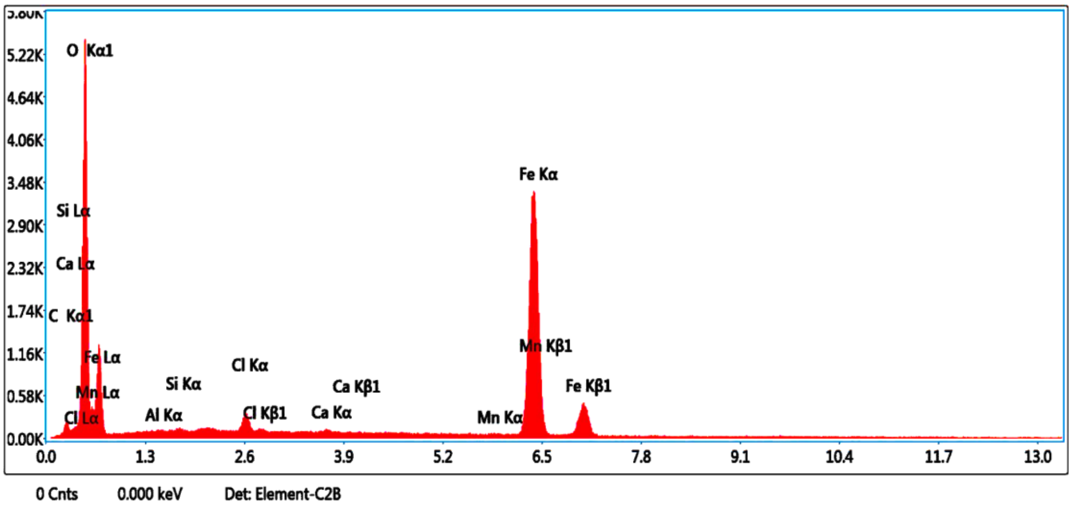

Figure 6b. EDAX spectrum of mild steel specimen immersed in 1M HCl (blank)

Slika 6b. EDAX spektar uzorka od mekog čelika uronjenog u 1M HCl (prazno)

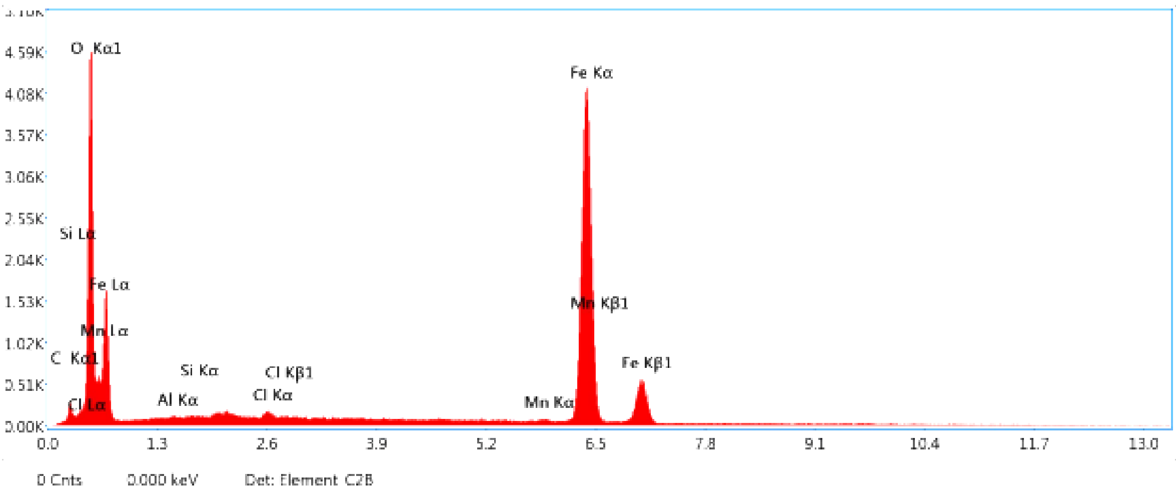

Figure 6c. EDAX spectrum of mild steel specimen immersed in 1M HCl with 0.001 M of ERN.

Slika 6c. EDAX spektar uzorka od mekog čelika uronjenog u 1M HCl sa 0,001 M ERN.

3.5. Surface characterization of mild steel by Atomic force microscopy

The surface morphology contain coated defensive layers on mild steels are studied with AFM. Roughness in any surface is easily investigate by AFM studies. Atomic force microscopy provides direct insight view into the changes in the surface morphology that takes place at several hundred nanometers. In the present investigation the effect of corrosion inhibitors on the surface of mild steel in acid medium with the help of AFM [53,54]. This characterization contains three dimensional (3D) AFM morphologies and AFM cross-sectional profile for polished mild steel surface (control sample), mild steel in 1M HCl (blank sample), mild steel surface with corrosion inhibitor (0.001 M of ERN) immersed in 1M HCl are shown in figures-7 a, b and c.

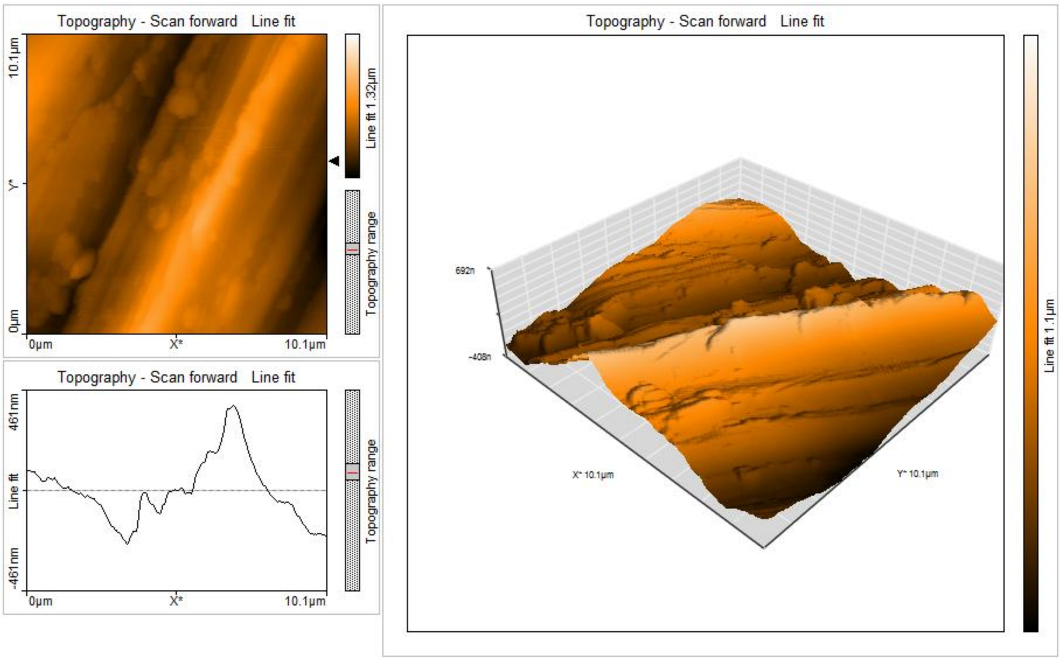

Figure 7a. AFM cross sectional image of the polished mild steel surface (control)

Slika 7a. Slika poprečnog preseka AFM površine poliranog mekog čelika (kontrola)

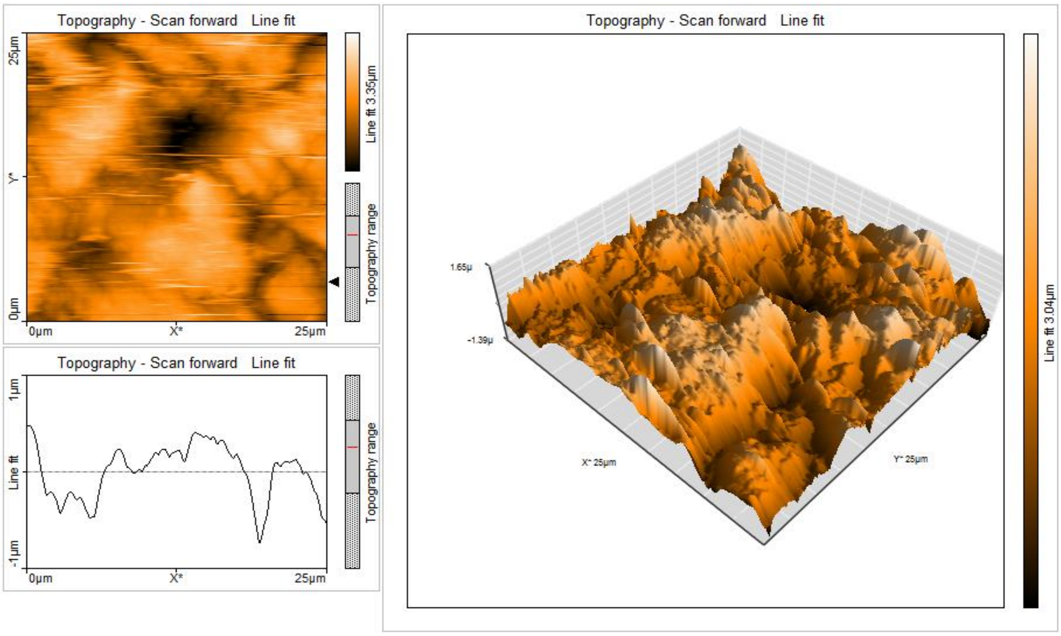

Figure 7b. AFM cross sectional image of the mild steel surface after immersion in 1M HCl (blank)

Slika 7b. Slika poprečnog preseka AFM površine mekog čelika nakon potapanja u 1M HCl (prazno)

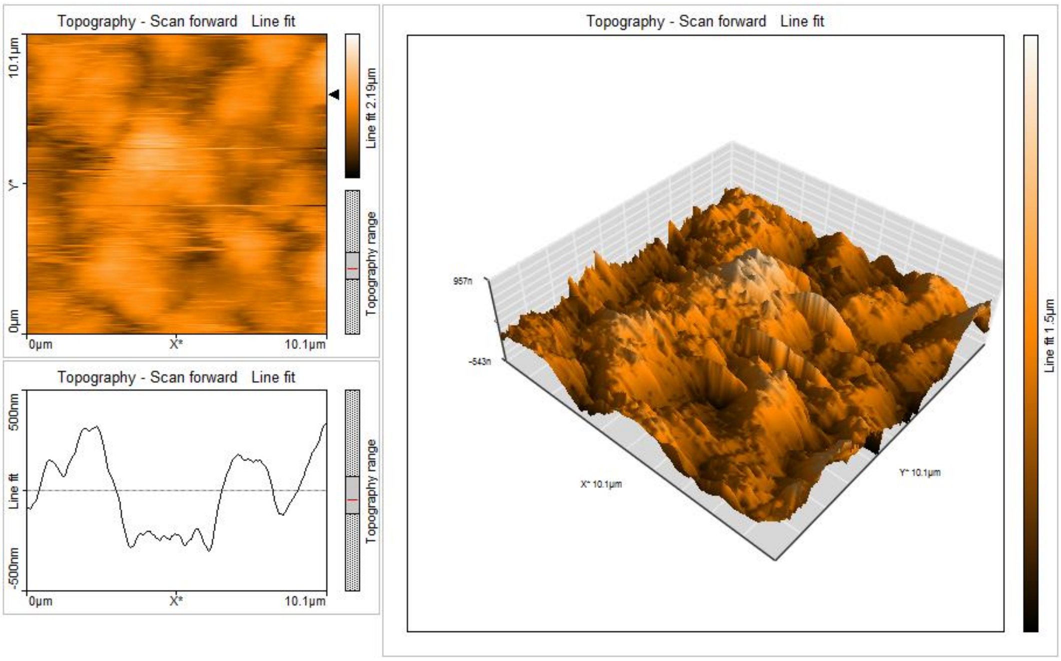

Figure 7c. AFM cross sectional image for the mild steel surface after immersion in 1M HCl with 0.001 M of ERN inhibitor.

Slika 7c. Slika poprečnog preseka AFM za površinu od mekog čelika nakon potapanja u 1M HCl sa 0,001 M inhibitora ERN.

AFM images analysis was performed to obtain the area roughness of average surface roughness, S_a (the average deviation of all points roughness profile from a mean line over the evaluation length), root-mean-square surface roughness, S_q (the average of the measured height deviations taken within the evaluation length and measured from the mean line), S_y the maximum peak-to-valley (largest single peak-to-valley height in five adjoining sampling heights) and S_p maximum peak height (Maximum profile peak height indicates the point along the sampling length at which the curve is highest). The AFM parameters are given in Table 5.

Table 5. AFM data for mild steel immersed in the absence and presence of inhibitor systems (Area roughness)

Tabela 5. AFM podaci za meki čelik uronjen u odsustvo i prisustvo inhibitornih sistema (hrapavost površine)

Samples	S_a nm	S_q nm	S_y nm	S_p nm
Mild steel surface	136.47	168.68	892.96	476.88
Mild steel surface immersed in 1M HCl	379.59	476.21	3295.40	1530.6
Mild steel surface immersed in 1M HCl + 0.001 M of ERN	162.29	202.90	1637.80	757.12

AFM images analysis was performed to obtain the line roughness average surface roughness, R_a (the average deviation of all points roughness profile from a mean line over the evaluation length), root-mean-square surface roughness, R_q (the average of the measured height deviations taken within the evaluation length and measured from the mean line), R_y the maximum peak-to-valley (largest single peak-to-valley height in five adjoining sampling heights) and R_p maximum peak height (Maximum profile peak height indicates the point along the sampling length at which the curve is highest). The AFM parameters are given in Table 6.

Table 6. AFM data for mild steel immersed in the absence and presence of inhibitor systems (Line roughness)

Tabela 6. AFM podaci za meki čelik uronjen u odsustvo i prisustvo inhibitornih sistema (hrapavost linije)

Samples	R_a nm	R_q nm	R_y nm	R_p nm
Mild steel surface	119.44	161.1	684.87	406.66
Mild steel surface immersed in 1M HCl	344.72	393.18	1359.9	726.51
Mild steel surface immersed in 1M HCl + 0.001 M of ERN	189.81	222.98	927.43	510.20

It is observed that average surface roughness for carbon steel in corrosive medium (blank) is very high. In presence of 0.001 M of ERN inhibitor, this value decreases. This value is lower than that of the corrosive medium (blank) but higher than that of the polished mild steel surface. This is due to the fact that, in presence of 0.001 M of ERN inhibitor, a defensive layer is covered on the mild steel surface. This film is found to be smooth. Similar is the case with, other three parameters namely root mean square roughness, maximum peak to valley height and maximum peak height [55-57].

4. CONCLUSIONS

- In this current study the erosion opposition properties of ERN has been tried against the mild steel in 1M HCl (destructive medium).
- Expansion in hindrance productivity and reduction in consumption pace of mild steel in 1M HCl medium was seen with the expansion in centralization of ERN. The greatest hindrance effectiveness of 92.85% was accomplished for 0.001 M of ERN.
- The potentiodynamic polarization studies presume that ERN proceeded as a cathodic kind of inhibitor.
- Electrochemical impedance spectroscopy revealed an expansion in polarization resistance and a decrease in double layer capacitance due to the formation of a thick defensive layer on the metal/electrolyte surface.
- The development of defensive film on the outer layer of mild steel has been described by SEM.
- EDAX analysis reveals a smooth surface on inhibited mild steel samples, indicating the protective effect of expired Ropinirole inhibitor drugs.
- Atomic force microscopy (AFM) results show that adding ERN inhibitor reduces roughness and pitting of mild steel surfaces, resulting in a lower harshness value compared to blank steel.
- The ERN inhibitor system effectively inhibited corrosion on mild steel when exposed to a 1M hydrochloric acid solution, potentially benefiting the pickling industry.

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IZVOD

ANTIKOROZIVNA SVOJSTVA LEKA ROPINIROL (ERN SISTEM) SA ISTEKLIM ROKOM TRAJANJA KAO INHIBITORA ZA MEKI ČELIK U 1M HCL

Ropinirol se koristi za prevenciju bolesti i za hemoterapiju i lečenje zračenjem. Deluje tako što ometa serotonin, karakterističnu supstancu u telu koja izaziva mučninu i povraćanje. Nakon isteka, mogu se koristiti kao inhibitori korozije. Aktivnost opstrukcije potrošnje prekinutog leka Ropinirol (ERN) na eroziju mekog čelika u 1M HCl medijumu je procenjena strategijom smanjenja težine. Procene smanjenja težine su pokazale da se efikasnost ograničavanja erozije povećava sa povećanjem konvergencije inhibitora, sa najvećom bezbednosnom produktivnošću na 0,001 M. Temperatura utiče na tempo erozije; na visokim temperaturama smanjuje se efikasnost ograničavanja potrošnje i primećuje se erozija. Robotski delovi opstrukcije potrošnje koncentrisani su metodom potenciodinamičke polarizacije i spektroskopijom elektrohemijske impedanse (EIS). Potenciodinamička strategija polarizacije otkriva da je okvir inhibitora sposoban kao katodna vrsta inhibitora, koji kontroliše katodne odgovore. Inhibitor može smanjiti struju korozije zbog inhibirane brzine reakcije i povećati otpor linearne polarizacije zbog formiranja barijere na površini elektrode. Površinska morfologija potisnutog mekog čelika je skenirana pomoću filterske elektronske mikroskopije (SEM). Prirodni sastojci na čeličnoj površini prikazani su spektroskopijom X-zraka sa disperzijom energije (EDAKS). Oštrina čelične površine u očišćenom MS, bistrom MS i inhibitorskim okvirima opisana je pomoću AFM. Rezultati su očigledno pokazali da ERN ima represivnu granicu u pogledu smanjenja erozije mekog čelika potopljenog u hlorovodoničnu korozivnu sredinu.

Ključne reči: *kiseli rastvori, ropinirol, blagi čelik, EIS, izoterma, SEM-EDAX i AFM.*

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