KUI 03/2004
Received January 27, 2003
Accepted April 11, 2003

Corrosion Inhibition of Mild Steel in 1 mol dm^{-3} HCl by Oxalic *N*-Phenylhydrazide *N′*-Phenylthiosemicarbazide

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Oxalic *N*-phenylhydrazide *N′*-phenylthiosemicarbazide (OPHPT), synthesized in our laboratory, was tested as inhibitor for the corrosion of mild steel in molar HCl by mass loss, potentiodynamic and polarization resistance measurements. It was found that OPHPT is a good inhibitor for the corrosion of mild steel in 1 mol dm^{-3} HCl and its inhibition efficiency (η) increases with its concentration and attains approximately 93 % at 5×10^{-4} mol dm^{-3}. Polarization curves indicate that OPHPT acts as a mixed type inhibitor. The inhibitor was adsorbed on the mild steel surface according to the Langmuir adsorption isotherm model. Results show that the rate of corrosion of mild steel increased with increasing temperature over the range 25 – 55 °C, both, in the presence of inhibitor and in its absence. It was also found that, on the one hand, the inhibiting effect grows with the increase of the temperature of the corrosion medium and, in the other hand, the presence of inhibitor in the solution induces an increase of the activation energy of the corrosion process. The synergistic action of iodide ions on the inhibition of mild steel in 1 mol dm^{-3} HCl by OPHPT was also investigated. The corresponding results suggest that the presence of iodide ions in the solution stabilized the adsorption of OPHPT molecules on the metal surface and, therefore, improved the inhibition efficiency of OPHPT.

Keywords: *Thiosemicarbazide, mild steel, inhibition corrosion, hydrochloric acid*

Introduction

Acid inhibitors are usually used in several industrial processes to control the corrosion of metals. They find wide applications as components in pretreatment composition, in cleaning solutions for industrial equipments, and in acidification of oil wells. Most of the well-known acid inhibitors are organic compounds containing nitrogen, sulphur and oxygen. The influence of organic compounds containing nitrogen, such as amines and heterocyclic compounds, on the corrosion of steel in acidic solutions has been investigated by several works.[1–6] Usually, sulphur-containing inhibitors, such as sulphides,[7] sulphoxides[8] and thioureas[9] are primarily useful in sulphuric acid. The existing data show, that most organic inhibitors used, act by adsorption on the metal surface. The selection of a suitable inhibitor depends on its chemical, its concentration , its composition, the nature of metal and on the type of acid. It is of interested to note that thiosemicarbazide-type organic compounds have been used as good corrosion inhibitors.[10–15]

The aim of this work is to investigate the role played by a newly synthesized thiosemicarbazide-type organic compound, oxalic *N*-phenylhydrazide *N′*-phenylthiosemicarbazide (OPHPT), on the corrosion inhibition of mild steel in 1 mol dm^{-3} HCl. The choice of this inhibitor is based on the fact that it can be conveniently synthesized. The effect of the temperature and the synergistic influence of iodide ions on the performance of OPHPT, as a corrosion inhibitor of mild steel, have been also studied.

Experimental

Synthesis of inhibitor

Preparation of N-phenyl oxalic dihydrazide (PODH)

The PODH compound was prepared according to procedures previously published in the literature[16] according to reaction (1). Depending on the experimental conditions, the half-unit phenylhydrazine reacts with diethyl oxalate to give either an oxamato derivative (2) or a symmetrical oxamido compound (1). The oxamato derivative reacts further with hydrazine to yield unsymmetrical oxamido compound PODH.

Preparation of inhibitor OPHPT

A solution of phenylisothiocyanate (13.52 g, 0.1 mol) (Merck) in 50 cm^3 of absolute ethanol was slowly added to a solution of PODH (19.42 g, 0.1 mol) in 150 cm^3 of absolute ethanol. The mixture was refluxed for 2 h with stirring.

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The yellow product was filtered off, recristallized from ethanol and finally dried in a vacuum desiccator. The purity of the solid was checked and confirmed by elemental analyses, ^{1}H-NMR and IR spectroscopy. Yield, 92 %; m.p. 204 °C. *Anal.* Found: C, 54.9; H, 05.1; N, 20.8. Calc. for $C_{15}H_{15}N_5O_2S$: C, 54.7; H, 04.6; N, 21.2 %. IR spectrum (cm^{-1}): 3305, 3202, 3046, 3023, ν(N–H); 1679, ν(C=O); 1656, ν(C=O + N–H); 1250, 745, ν(C=S). ^{1}H-NMR data, δ (ppm): in DMSO-d_6 6.69–7.45 (10H, m), 7.85 (1H, s), 9.72 (1H, s), 9.82 (1H, s), 10.68 (1H, s), 10.77 (1H, s).The molecular structure of OPHPT is shown on Fig.1.

Gravimetric measurements

The experiments were carried out in solution of 1 mol dm^{-3} hydrochloric acid (uninhibited and inhibited) on mild steel containing 0.14 % C, 0.21 % Si, 0.01 % Al, 0.012 % S, 0.09 % Mn, 0.006 % Cu. Specimens in the form of discs with a diameter of 30 mm and a thickness of 2 mm were used for mass loss measurements studies. They were polished with emery paper (from 380 to 1200 grade). Each run was carried out in a glass vessel containing 40 cm^3 test solution. A clean weighed mild steel specimen was completely immersed at an inclined position in the vessel. After 2 hours of immersion in 1 mol dm^{-3} HCl, with and without addition of OPHPT at different concentrations, the specimen was withdrawn, rinsed with bidistilled water, washed with acetone, dried and weighed. The mass loss was used to calculate the corrosion rate in milligrams per square centimeter per hour.

Polarization measurements

Disc electrode (0.95 cm^2 area) was prepared from the investigated mild steel. The electrode was polished with emery papers (from No 380 to 1200), rinsed with bidistilled water, degreased by acetone, washed thoroughly with bidistilled water and dried at room temperature. The concentration range of inhibitor employed was 10^{-7} to 5 × 10^{-4} mol dm^{-3}. The studies were carried out potentiodynamically in a thermostated electrolytic cell. Platinum disc was used as a counter-electrode (CE) and a saturated calomel electrode as a reference electrode (SCE). The latter was connected through a Luggin's capillary to the cell. The working electrode (WE) was immersed in a test solution for 1 h until a steady state open-circuit potential (E_{ocp}) was obtained. The potentiodynamic current-potential curves were recorded by changing the electrode potential automatically from –700 to –300 mV with scanning rate of 0.5 mV s^{-1} using the PGP201 potentiostat-galvanostat (VoltaLab21-Radiometer). The polarization resistance measurement was performed by applying a controlled potential scan over a small range typically ±15 mV with respect to E_{corr}. The resulting current is linearly plotted versus potential, the slope of this plot at E_{corr} being the polarisation resistance (R_p). All experiments were carried out in freshly prepared solution at constant temperatures, 25 °C, 35 °C, 45 °C and 55 °C ± 0.1 °C using a thermostat.

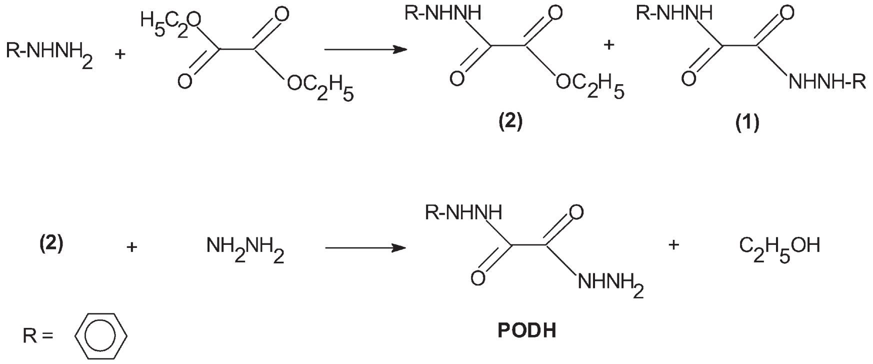
Results and discussion

Mass loss measurements

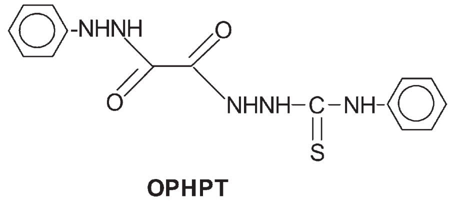
Table 1 collects the values of inhibitor efficiency and corrosion rate obtained from mass loss measurements for different concentrations of the inhibitor in 1 mol dm^{-3} HCl at 25 ± 0.1 °C. From the calculated mass loss values, the inhibition efficiency η was calculated using the equation:

$$\eta = \left(1 - \frac{v}{v_0}\right) \qquad (2)$$

Where v and v_0 are rates of corrosion (mg cm^{-2} h^{-1}) with and without inhibitor, respectively.



Reaction (1)



OPHPT

Fig. 1 – *Molecular structure of OPHPT*

Slika 1 – *Molekularna struktura OPHPT*

Table 1 – *Inhibition efficiency for different concentrations of OPHPT for the corrosion of mild steel in 1 mol dm^{-3} HCl obtained from mass loss measurements*

Tablica 1 – *Inhibitorska djelotvornost različitih koncentracija OPHPT na koroziju mekog čelika u 1 mol dm^{-3} HCl dobivena mjerenjem gubitka mase*

c / mol dm^{-3}	Corrosion rate (Brzina korozije) v / mg cm^{-3} h^{-1}	η / %
0	3.20	–
10^{-7}	1.75	45.3
10^{-6}	1.20	62.5
10^{-5}	0.70	78.1
$5 \cdot 10^{-5}$	0.50	84.3
10^{-4}	0.25	92.1
$5 \cdot 10^{-4}$	0.20	93.7

Table 1 shows that inhibitor efficiency increases with increase in inhibitor concentration. At this purpose, one observes that the optimum concentration of inhibitor required to achieve the efficiency is found to be 5 × 10^{-4} mol dm^{-3} (η = 93%).

Electrochemical measurements

Potentiodynamic anodic and cathodic polarization scans were carried out at 25 ± 0.1 °C in 1 mol dm^{-3} HCl with different concentrations of OPHPT. Anodic and cathodic polarization curves in the absence and in the presence of inhibitor at different concentrations after 1 h of immersion and at 25 °C, are shown in Figure 2. It can be seen from Fig. 2 that, in the presence of the inhibitor, the curves are shifted to lower current regions, showing the inhibition tendency of OPHPT. The values of various electrochemical parameters are summarized in Table 2.

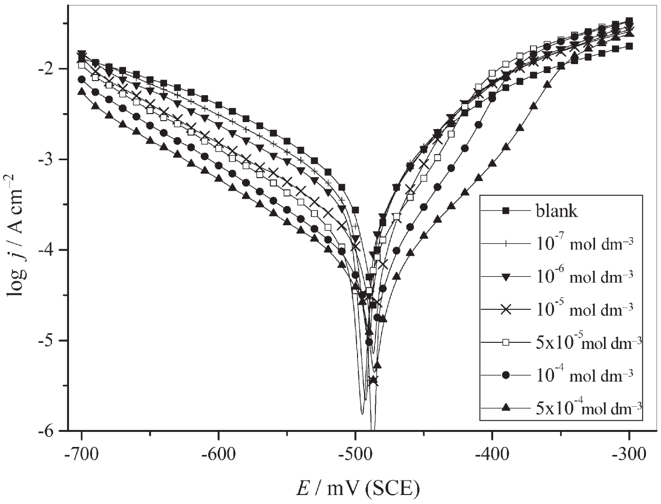


Fig. 2 – *Potentiodynamic polarization curves for mild steel in 1 mol dm^{-3} HCl containing different concentrations of OPHPT at 25 °C*

Slika 2 – *Krivulje potenciodinamičke polarizacije mekog čelika u 1 mol dm^{-3} HCl uz dodatak različitih koncentracija OPHPT pri 25 °C.*

Table 2 – *Electrochemical quantities of mild steel in 1 mol dm^{-3} HCl containing OPHPT at 25 °C.*

Tablica 2 – *Elektrokemijski parametri mekog čelika u 1 mol dm^{-3} HCl uz dodatak OPHPT kod 25 °C*

c mol dm^{-3}	$E_{corr.}$ mV/SCE	b_c mVdec^{-1}	j_{corr} μAcm^{-2}	η_1 %	R_p Ω cm^2	η_2 %
0	-488	129	717	–	40	–
10^{-7}	-490	126	426	40.5	64	37.5
10^{-6}	-492	120	316	57.9	76	47.3
10^{-5}	-487	116	171	76.0	106	62.3
$5 \cdot 10^{-5}$	-491	114	154	78.5	144	72.2
10^{-4}	-488	113	78	89.0	224	82.1
$5 \cdot 10^{-4}$	-487	114	57	92.0	341	88.3

The E_{corr} values were only slightly shifted in the presence of the inhibitor. These observations show clearly that the inhibition of corrosion is under mixed control.

The cathodic Tafel slopes were found to vary over a range of 113–126 mV dec^{-1}. Therefore, the cathodic slopes values are almost same with and without the presence of inhibitor in 1 mol dm^{-3} HCl. It indicates that the inhibitor adsorbs by simple blocking the active sites of the metal surface. Behavior of this type has been observed for mild steel in hydrochloric acid and sulphuric acid solutions containing 2,5-disubstituted 1,3,4-oxadiazoles.[17]

The corrosion current densities were estimated by Tafel extrapolation of the cathodic curves to the open circuit corrosion potentials.

An inhibition efficiency was then calculated using the expression:

$$\eta = \frac{j_u - j_i}{j_u} \qquad (3)$$

where j_u is the corrosion current density in uninhibited acid and j_i is the corrosion current density in inhibited acid.

Table 2 shows that an increase in inhibitor concentration is resulted in increased inhibition efficiency. It is evident from the results that the j_{corr} values decrease considerably in the presence of inhibitor and that the maximum decrease in j_{corr} coincides with the optimum concentration of inhibitor. The compound studied performed excellently (92 % inhibition efficiency at 5 × 10^{-4} mol dm^{-3}) as inhibitor of the corrosion of mild steel in 1 mol dm^{-3} HCl. Linear polarization technique was performed in 1 mol dm^{-3} HCl with various concentrations of OPHPT. The corresponding polarization resistance (R_p) values of mild steel in the absence and in the presence of different inhibitor concentrations are also given in Table 2. It is apparent that R_p increases with increasing inhibitor concentration. The inhibition efficiency (η) calculated from R_p values are also presented in Table 2. We remark that η increases with increasing concentration of inhibitor and attains 88 % at 5×10^{-4} mol dm^{-3}.

The inhibition efficiencies of OPHPT obtained by potentiodynamic polarization and by polarization resistance methods are in good agreement, particularly, at high concentrations.

For anodic polarization, it can be seen from Fig. 2 that, in the presence of OPHPT at high concentrations, two linear portions were observed. When the anodic potentials increases, the anodic current increases at a slope of b_{a1} in the low polarization potential region. After passing a certain potential E_u, the anodic current increases rapidly and dissolves at a slope of b_{a2} in the high polarization region. This behavior was already documented for iron in HCl solutions.[18–21] The rapid increase of anodic current after E_u may be due to desorption of OPHPT molecules adsorbed on the electrode. This means that the inhibition mode of OPHPT depends on electrode potential. In this case, the observed inhibition phenomenon is generally described as corrosion inhibition of the interface associated with the formation of a bidimensional layer of adsorbed inhibitor species at the electrode surface.[22] Note that the potential E_u is also denoted E_1 in *Bartos* and *Hackerman*'s paper.[18]

Fig. 2 shows also that, at potentials higher than E_{corr}, OPHPT affects the anodic reaction. This result indicates that OPHPT exhibits, both, anodic and cathodic inhibition effect.

Adsorption isotherms

It was shown that the inhibitor acts via a simple adsorption mode. Thus, the apparent corrosion rate of the inhibited mild steel electrode is proportional to the ratio of the surface covered θ and that not covered $(1 - \theta)$ by the inhibitor. Surface coverage θ values have been evaluated for different concentrations of the compound under study from corrosion rates in uninhibited and inhibited solutions by means of the equation:

$$\theta = 1 - \frac{j_i}{j_u} \tag{4}$$

θ is also calculated from mass loss and resistance polarization measurements using the following equations:

$$\theta = 1 - \frac{v_i}{v_0} \tag{5}$$

and

$$\theta = 1 - \frac{R_{pu}}{R_{pi}} \tag{6}$$

were v and v_0 are rates of corrosion (mg cm^{-2} h^{-1}) with and without inhibitor, respectively and R_{pu} and R_{pi} are the polarization resistance values without and with inhibitor, respectively.

The Langmuir adsorption isotherm may be expressed as:

$$\theta = \frac{Kc}{Kc + 1} \tag{7}$$

where K is the equilibrium constant for the adsorption process, c is the concentration of the inhibitor and θ is the surface coverage, 1 when inhibition efficiency is 100 %. Rearrangement of equation (7) yields to:

$$\frac{c}{\theta} = \frac{1}{K} \cdot c \tag{8}$$

It was found that Fig. 3 (plot of c/θ versus c using different methods) gives straight lines with slope, practically equal to unity, indicating that the adsorption of compound under consideration on mild steel/acidic solution interface obeys Langmuir's adsorption isotherm. The deviation of the slope from unity is attributed to the difference in the rate of interaction between the adsorbed species on the metal surface. The interaction between the adsorbed species is not taken into account during derivation of the Langmuir isotherm equation, while the interaction between adsorbed organic molecules, with polar atoms or groups on the anodic and cathodic sites of the metal surface plays a crucial role. This interaction may be either mutual repulsion or attraction.

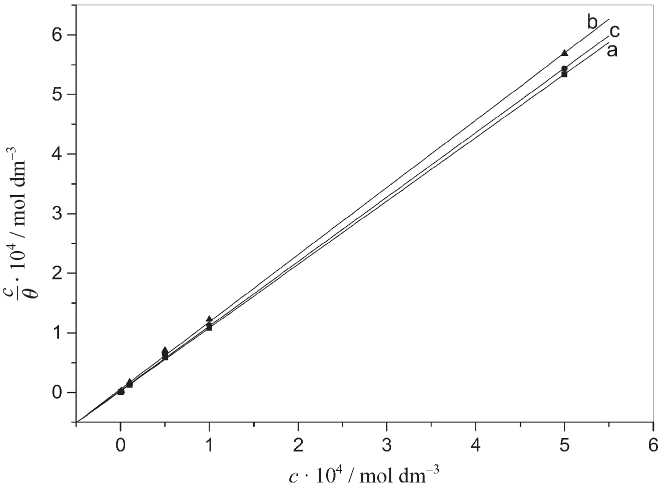


Fig. 3 – *Curves fitting of the corrosion data of mild steel in the presence of inhibitor to Langmuir isotherm, (a) mass loss measurement, (b) polarization resistance and (c) polarization curves*

Slika 3 – *Krivulje korozijskih podataka mekog čelika u prisustvu inhibitora prilagođenih Langmuirovoj izotermi a) mjerenjem gubitka mase b) polarizacijskog otpora i c) polarizacijskih krivulja*

From the intercept of the straight line on the c/θ axis, it is possible to deduce the value of K. For example, the value obtained from mass loss measurements is: $K = 4.6 \times 10^5$.

On the other hand, plot of θ versus log c gives straight lines (Fig. 4) showing that the adsorption of the compound on the mild steel surface from 1 mol dm^{-3} HCl obeys also Temkin's adsorption isotherm. This observation supports the assumption of a chemi- sorptive bond between the metal and the inhibitor molecules. The adsorption behavior of the inhibitor investigated is determined by the presence of a double bond with the S-atom which is an

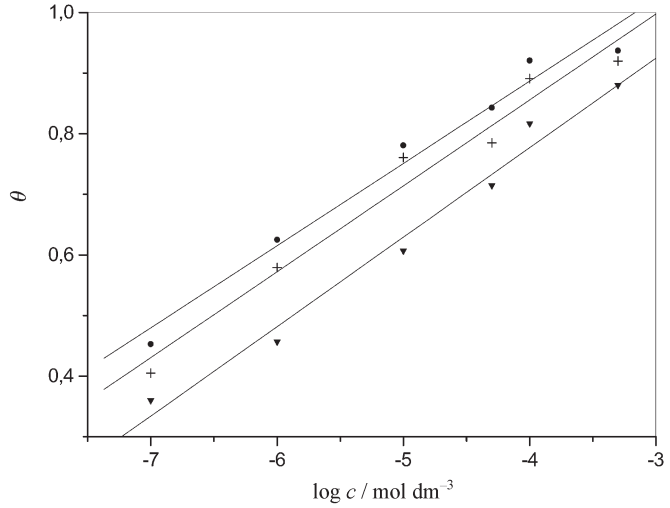


Fig. 4 – *Curves fitting of the corrosion data of mild steel in the presence of inhibitor to Temkin isotherm, (a) mass loss measurement, (b) polarization resistance and (c) polarization curves*

Slika 4 – *Krivulje korozijskih podataka mekog čelika u prisustvu inhibitora prilagođenih Temkinovoj izotermi a) mjerenjem gubitka mase b) polarizacijskog otpora i c) polarizacijskih krivulja*

adsorption centre[23] and that of π-electrons. The S-atom possesses vacant d–orbitals which are compatible with those of the metal atom. The π-electrons present can overlap with the d-orbitals and form dπ–dπ bonds. Therefore, they decrease the residual positive charge of the S-atom and the negative charge of the Fe-atom stabilizing thus the initial electron bond.[23]

In summary, we can note that a plausible mechanism of corrosion inhibition of mild steel in 1 mol dm^{-3} HCl may be deduced on the basis of adsorption. In acidic solutions, the inhibitor under investigation can exist as cationic species which may be adsorbed on the cathodic sites of the mild steel and reduce the evolution of hydrogen. The protonated inhibitor can also be adsorbed on the metal surface on specifically adsorbed chloride ions[24, 25] which act as a bridge between the metal surface and the electrolyte.

The adsorption of this compound on anodic sites through lone pairs of electrons of nitrogen and sulphuric atoms and through π-electrons of C=S group will then reduce the anodic dissolution of mild steel.

Effects of temperature on the inhibition characteristics of compound used

To elucidate the mechanism of inhibition and to determine the activation energies of the corrosion process, mass loss measurements were performed at various temperatures in the absence and in the presence of the compound used. It has been reported that, for ion and steel in acid, the logarithm of the corrosion rate of steel, ν, can be represented as a straight-line function of $1/T$ (Arrhenius equation),

$$\ln \nu = -\frac{E^*_\mathrm{A}}{RT} + B \qquad (9)$$

where E^*_A is the activation energy, R is the universal gas constant and B is a constant.

The variation in the logarithm of the corrosion rate of mild steel in 1 mol dm^{-3} HCl in the absence and in the presence of inhibitor at concentration of 10^{-5} mol dm^{-3} with reciprocal of the absolute temperature, is given in Fig. 5. The calculated value of the E^*_A shows that the addition of the inhibitor to the acid provokes an increase in E^*_A, from 54.1 to 69 kJ mol^{-1} indicating its higher protective efficiency.

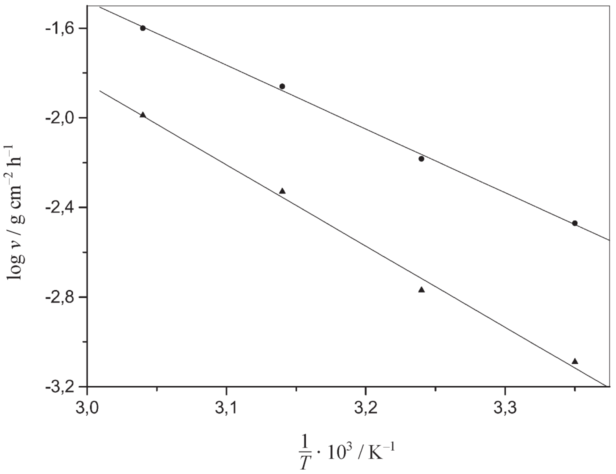


Fig. 5 – *log v vs. 1/T for mild steel dissolution in 1 mol dm^{-3} HCl in the presence and in the absence of. 10^{-5} mol dm^{-3} OPHPT. a) 1 mol dm^{-3} HCl and b) 1 mol dm^{-3} HCl + 10^{-5} mol dm^{-3} OPHPT*

Slika 5 – *Dijagram log v vs. 1/T za otapanje mekog čelika sa i bez dodatka 10^{-5} mol dm^{-3} OPHPT. a) 1 mol dm^{-3} HCl i b) 1 mol dm^{-3} HCl + 10^{-5} mol dm^{-3} OPHPT*

Table 3 shows that the inhibition efficiency (η) increases both with the increase of inhibitor concentration and the temperature of corrosion medium (between 25 °C and 45 °C). This result can be explained by the characteristics of the cathodic process of hydrogen evolution in acidic solutions. The hydrogen evolution overvoltage decreases with increasing temperature, that leads to increase in the cathodic reaction rate. On the other hand, temperature increase accelerates the chemisorption of the inhibitor of the metal surface. When the latter effect is predominant, the final result is an increase of the inhibiting effect which is observed in this work. Similar results were found by *Stoyanova* et al.[26]

Table 3 – *Inhibition efficiency at different temperatures and for different concentrations of OPHPT for the corrosion of mild steel in 1 mol dm^{-3} HCl obtained from potentiodynamic polarization (η_1%) and resistance polarization (η_2%).*

Tablica 3 – *Inhibitorska djelotvornost OPHPT na koroziju mekog čelika u 1 mol dm^{-3} HCl pri različitim temperaturama i različitim koncentracijama inhibitora dobivena iz potenciostatske polarizacije (η_1%) i polarizacijskog otpora (η_2%)*

T/K	298		308		318		328	
c/mol dm^{-3}	η_1/%	η_2/%	η_1/%	η_2/%	η_1/%	η_2/%	η_1/%	η_2/%
5 · 10^{-5}	78.5	72.3	88.4	80.6	88.5	87.0	87.4	83.0
10^{-4}	89.0	82.0	91.0	84.5	94.5	86.4	94.5	93.0
5 · 10^{-4}	92.0	88.3	95.0	91.7	96.0	92.0	95.0	94.0

Influence of KI concentration

Fig. 6 shows the variation of polarization resistance R_p with the concentration of KI when the OPHPT concentration remained at 5×10^{-5} mol dm^{-3}. The maximum of R_p value was obtained for a KI mass fraction of 0.10 %. Excessive amounts of KI may result in the occupancy of the limited active sites available for the adsorption of OPHPT molecules.

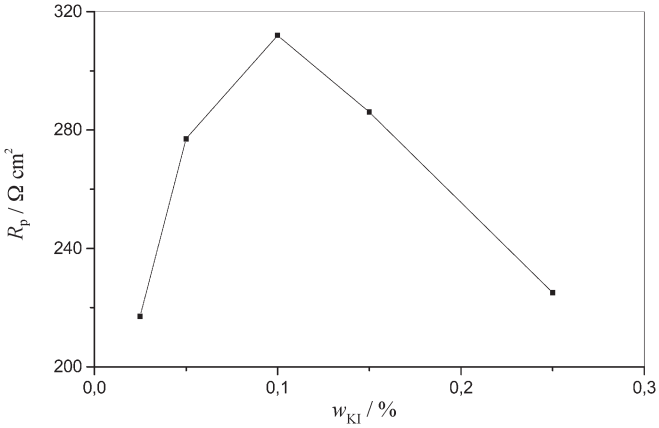


Fig. 6 – *The variation of polarization resistance (R_p) with concentration of KI in the presence of $5 \cdot 10^{-5}$ mol dm^{-3} OPHPT*

Slika 6 – *Promjena polarizacijskog otpora (R_p) s koncentracijom KI uz dodatak $5 \cdot 10^{-5}$ mol dm^{-3} OPHPT*

Figure 7 depicts the polarization curves for mild steel in 1 mol dm^{-3} HCl in the presence of 5×10^{-5} mol dm^{-3} OPHPT and different concentrations of KI after 1h of immersion.

The values of the inhibition efficiency are given in Table 4.

Table 4 – *Inhibition efficiency for different concentrations of KI for the corrosion of mild steel in 1 mol dm^{-3} HCl in the presence of 5x10^{-5} mol dm^{-3} OPHPT at 25°C*

Tablica 4 – *Inhibitorska djelotvornost različitih koncentracija KI na koroziju mekog čelika u 1 mol dm^{-3} HCl u prisustvu 5x10^{-5} mol dm^{-3} OPHPT pri 25 °C*

Mass fraction Maseni udjel w_{KI} / %	Inhibition efficiency Inhibitorska djelotvornost η / %
0.000	78.50
0.025	90.41
0.050	92.80
0.100	94.10
0.150	90.13
0.250	87.63

It can be seen from Table 4 that the maximum synergistic effect is observed for a KI mass fraction of 0.10 %. Mass fractions of KI either higher or lower than this value give a smaller synergistic effect. The synergistic effect between OPHPT and KI can be explained by the fact that iodide ions are strongly chemisorbed on the metal surface and OPHPT$^+$ ions are then adsorbed by coulombic attraction on the metal surface where iodide ions are already chemisorbed.

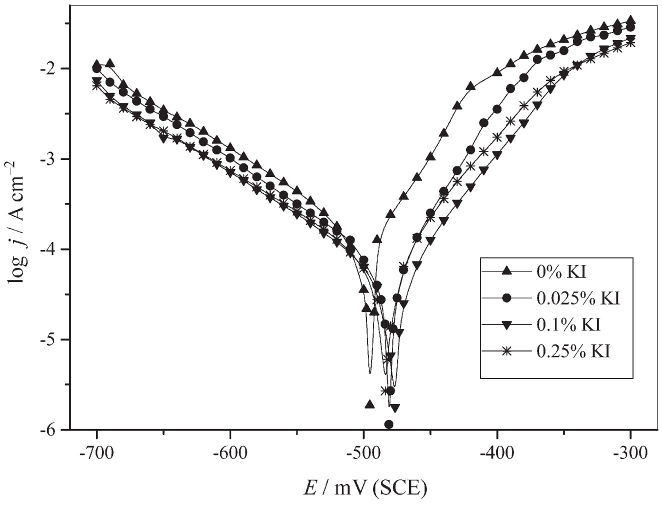


Fig. 7 – *Potentiodynamic polarization curves for mild steel in 1 mol dm^{-3} HCl in the presence of $5 \cdot 10^{-5}$ mol dm^{-3} OPHPT and different concentrations of KI*

Slika 7 – *Krivulje potenciodinamičke polarizacije mekog čelika u 1 mol dm^{-3} HCl uz dodatak $5 \cdot 10^{-5}$ mol dm^{-3} OPHPT i KI u različitim koncentracijama*

The stabilization of the adsorption of inhibitor on the mild steel surface caused by the interaction between OPHPT$^+$ and I$^-$ leads to more surface coverage and thereby greater corrosion inhibition.

On the other hand, analysis of Figure 7 shows that the E_u values shift toward positive potential with addition of KI. This result suggests that the iodine ions have played an important role in stabilizing the adsorbed OPHPT molecules and the two species (I$^-$ and OPHPT) seemed to compete for active sites for adsorption.

Conclusions

The main conclusions drawn from this study are:

1. The inhibiting effect of OPHPT increases with increase of inhibitor concentration and temperature of the corrosion medium.

2. The inhibition is due to adsorption of the inhibitor molecules on the steel surface and blocking its active sites.

3. The adsorption of OPHPT is described by Langmuir and Temkin adsorption isotherms.

4. The substance is adsorbed through the S-atom which is the adsorption center.

5. Synergistic effect between OPHPT and KI was observed. The adsorption of OPHPT was stabilized by the presence of iodine ions in the solution.

ACKNOWLEDGEMENTS

The authors are very indebted to the A.N.D.R.U "Agence Nationale du Développement de la Recherche Universitaire" (Algérie) for financial support.

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SAŽETAK

Inhibicija korozije mekog čelika u 1 mol dm^{-3} HCl pomoću *N*-fenilhidrazid-*N*'-fenilsemikarbazida oksalne kiseline

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N-fenilhidrazid-*N*-fenilsemikarbazid oksalne kiseline (OPHPT), sintetiziran u našem laboratoriju, ispitivan je kao inhibitor korozije mekog čelika u 1 mol dm^{-3} HCl mjerenjem gubitka mase, potenciodinamičkom polarizacijom i određivanjem polarizacijskog otpora. Ustanovljeno je da je OPHPT dobar inhibitor korozije mekog čelika u 1 mol dm^{-3} HCl i da njegova djelotvornost raste s njegovom koncentracijom i postiže vrijednost od oko 93 % kod koncentracije od 5 x 10^{-4} mol dm^{-3}. Polarizacijske krivulje ukazuju da OPHPT djeluje kao mješoviti tip inhibitora. Inhibitor je adsorbiran na površini mekog čelika prema modelu Langmuirove adsorpcijske izoterme. Rezultati pokazuju da se brzina korozije mekog čelika povećava s povišenjem temperature u području između 25 – 55 °C, uz inihibitor kao i bez njega. Također je ustanovljeno da se, s jedne strane, inhibitorska djelotvornost povećava s povišenjem temperature korozijske sredine i, s druge strane, prisutnost inhibitora u otopini prouzrokuje povećanje energije aktivacije korozijskog procesa. Također je ispitivano sinergističko djelovanje iona jodida na inhibiciju korozije mekog čelika u 1 mol dm^{-3} HCl pomoću OPHPT. Dobiveni rezultati navode na zaključak da ioni jodida u otopini stabiliziraju adsorpciju molekula OPHPT na površini metala i, prema tome, poboljšavaju inhibicijsku djelotvornost OPHPT.

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Prispjelo 27. siječnja 2003.
Prihvaćeno 11. travnja 2003.