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Study of steel corrosion inhibition with the use of secondary waste

Abstract. *The article investigates the inhibition of steel corrosion by phosphorus-containing oligomeric inhibitors. In the experiment, samples of carbon steel of the following chemical composition (mass %) were tested: 0.19 carbon, 0.075 manganese, 0.055 phosphorus, 0.625 iron, 0.047 sulfur, and 0.008 others. Tafel graphs were compiled to provide a deeper understanding of the kinetics of cathodic and anodic corrosion reactions. It was found that the polarization data at 500 mg/l of the phosphorus-containing oligomer PSK-1 in 1M HCl have a significantly higher inhibition efficiency of 97.76%, respectively.*

Keywords: *corrosion inhibitors, metal corrosion, phosphorus (V)-chloride, cyanuric acid.*

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Introduction

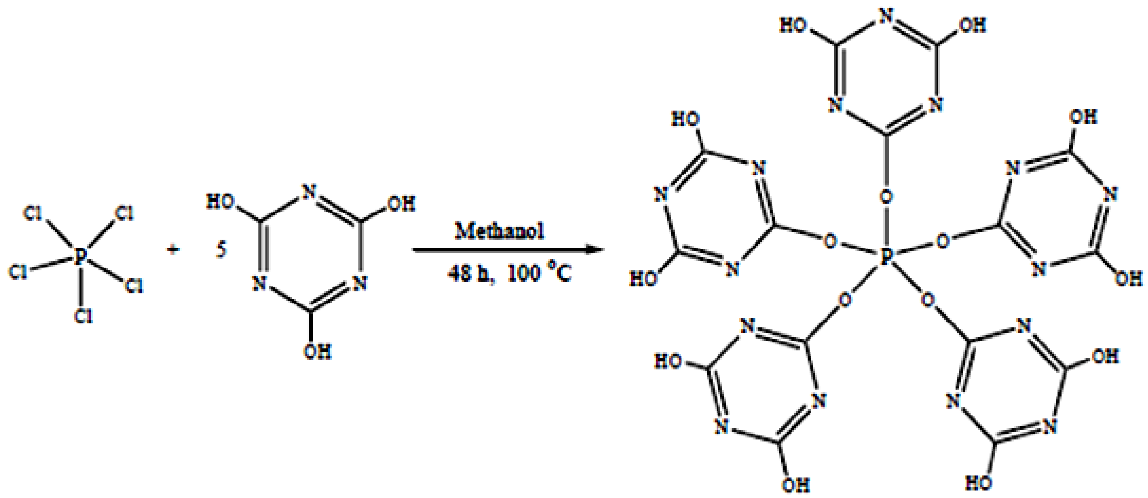
Carbon steel is one of the most widely used materials in the industry due to its high availability, physical and chemical characteristics, and relatively low cost [1]. These characteristics guarantee the widespread use of carbon steel in several areas such as chemical processing, spatial construction, metal processing, seawater, and oil refining [2] or minimize it by introducing compounds of phosphorus-containing polymers and oligomers into a corrosive environment [3].

The addition of polymeric chemical compounds to a corrosion solution to reduce corrosion (HCI, H_2SO_4, H_3PO_4, and HNO_3) is referred to as a corrosion inhibitor by forming a protective layer on the surface of the steel, and this form of corrosion protection is called inhibition [4]. In addition, phosphorus-containing polymers are adsorbed on the steel surface due to physical, chemisorption, and/or physicochemical adsorption [5]. Chemical adsorption distributes or transfers the load from the phosphorus-containing polymer to the surface of the metal, which leads to the development of a covalent bond of a coordinated type. However, physical adsorption is a van der Waals and electrostatic interaction between loaded phosphorus-containing polymers and the metal surface of the contaminated metal. Phosphorus-containing polymers having active sites (especially heteroatoms such as O, N, and S), aromatic rings, epoxy groups, phosphorus atoms, and π-electrons can be used as steel corrosion inhibitors [6].

The purpose of this article is to study a phosphorus-containing oligomer as a carbon steel corrosion inhibitor in an aggressive solution (1M HC1). The influence of a phosphorus-containing oligomer based on phosphorus (V)-chloride with cyanuric acid (PSK-1) at various concentrations was evaluated using potentiodynamic polarization.

Experimental part

In the experiment, samples of carbon steel of the following chemical composition (mass %) were tested: 0.19 carbon, 0.075 manganese, 0.055 phosphorus, 0.625 iron, 0.047 sulfur, and 0.008 others. The used solution (1M HC1) was analyzed based on 37% HCI using a dilution with bidi stilled water. The concentration range from 100mg/l to 500mg/l is realized, and the surface of carbon steel used is 1 cm^2. The structure of the studied phosphorus-containing oligomeric PSK-1 inhibitor is shown in scheme-1.



Synthesis of a phosphorus-containing oligomer PSK-1

The device for electrochemical measurements consists of three-electrode cells, namely the counter electrode (platinum), the reference electrode (Ag/AgCI), and the working electrode (carbon steel), respectively. The electrochemical measurement is connected to the SP-200 with a signal amplitude (10 mV) [6].

The obtained results and their discussion. Tafel graphs were compiled to provide a deeper understanding of the kinetics of cathodic and anodic corrosion reactions. Graphs of potentiodynamic polarization of the carbon steel sample in an aggressive solution (1M HCl) without inhibitor and with different concentrations of phosphorus-containing oligomer after30 minutes of immersion at 298 K are shown in Fig. 1. Corresponding electrochemical corrosion variables, such as corrosion current density (i_{corr}), corrosion potential (E_{corr}), inhibition efficiency (η_{Taffel} (%)), cathode (βs) and anode30 minutes of immersion at 298 K are shown in Fig. 1. Corresponding electrochemical corrosion variables, such as corrosion current density (i_{corr}), corrosion potential (E_{corr}), inhibition efficiency (η_{Taffel}(%)), cathode (βs), and anode(βa) The Tafel constants are determined by the Tafel slope and are shown in Table 1.

It is known that the electrochemical reaction of carbon steel in 1M HCl solution without an inhibitor is a cathodic reaction associated with proton reduction (reduction) 1 reduction (1 reduction). The corrosion inhibition efficiency (η_{tafel} (%)) was calculated by formula 3.

$$2H + + 2e- \leftrightarrow H2 \qquad (1)$$

$$Fe \leftrightarrow Fe2 + + 2e- \qquad (2)$$

$$\eta_{tafel}\,(\%) = (1 - iinh / i0) \times 100 \qquad (3)$$

where i0 and iinh are the corrosion current density not inhibited and the corrosion current density suppressed by different PSK-1 concentrations, respectively.

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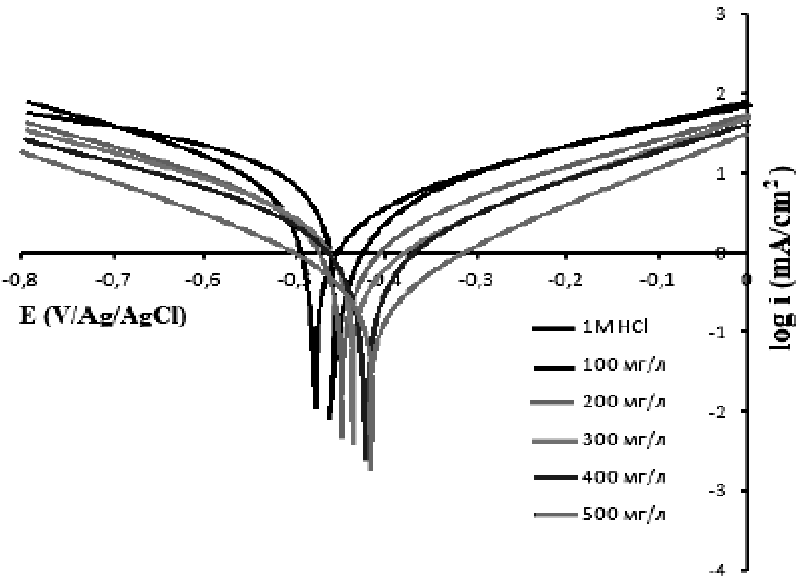
Table 1

Different polarization parameters for carbon steel are not inhibited and are not inhibited by different concentrations of PSK-1 at 298 K.

Inhibitor	Concentration, mg / l	$-E_{corr}$ (mB)	i_{corr} (A/cm^{-2})	TiltSlopes (mB дес$^{-1}$)		η(%)
				-βs	βa	
Noinhibitor (1M HCI)	0	439,7	397,3	193,1	94	-
PSK-1	100	451.7	83.1	68.7	59.2	79.08
	200	412.1	41.5	57.9	41.1	89.55
	300	423.3	31.7	60.3	44.9	92.02
	400	416.2	23.1	69	41.3	94.18
	500	421.4	22.3	69.4	42.6	97.76



Picture 1. Polarization curves of carbon steel in 1M HCI, uninhibited and inhibited by various concentrations of PSK-1 at 298 K

Electrochemical parameters can be calculated based on Tafel plots [3]. The current densities of cathodic and anodic corrosion decreased significantly with increasing concentration of PSK-1 in 1M HCI, indicating that the phosphorus-containing oligomeric inhibitor may also affect cathodic and anodic reactions (equations 1 and 2). As shown in Table 1, corrosion current densities indicate a significant decrease with increasing PSK-1 concentration. As a result, it is assumed that the increase in PSK-1 minimizes the dissolution of iron. Corrosion potential shift (E_{corr}) was evaluated according to formula 4, values (E_{corr}) are negligible or equal to zero. In addition, the likelihood of corrosion is caused by a geometrical obstacle on the surface of carbon steel when using a phosphorus-containing oligomer. If E_{corr} values are below 85 mV, the inhibitor can be considered a mixed type of inhibitor [4].

In the case where the E_{corr} value was negative below -85 mV, the phosphorus-containing oligomer can be attributed to the cathodic inhibitor type, while a positive value above +85 mV could be assumed to be the anodic inhibitor type [4]. In this article, the E_{corr} value of the polymer was -451.7mV, so it is classified as a mixed-type inhibitor. The addition of PSK-1 phosphorus-containing oligomer to the 1M HCI solution significantly affected the slope of the cathode leg, the decrease in the corrosion current density of the cathode leg, the decrease in the corrosion current density of the cathode leg may indicate that the mechanism of hydrogen generation was changed due to the adsorption of PSK-1 on the metal surface.

$$\Delta E_{corr} = E_{corr} - E0 \quad (4)$$

where E0 and Einh mean that the corrosion potential is not inhibited and the corrosion potential is inhibited by different concentrations of PSK-1, respectively.

Conclusion

Thus, the corrosion inhibition efficiency of a phosphorus-containing oligomer (PSK-1) on carbon steel was investigated in an aggressive solution using potentiodynamic polarization. The polarization parameters at 500mg/l of PSK-1 phosphorus oligomer in 1M HC1 have a significantly higher inhibition efficiency of 97.76%, respectively, and the inhibition efficiency of PSK-1 phosphorus oligomer increases with inhibitor concentration.

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Болаттың коррозиясын тежеуді қосалқы қалдықтарды пайдалана отырып зерттеу

Аңдатпа. Мақалада фосфоры бар олигомерлі ингибиторлар болатының коррозиясын тежелуі зерттеледі. Экспериментте келесі химиялық құрамдағы көміртекті болаттың үлгілері сыналды (мас. %): 0,19 көміртегі, 0,075 марганец, 0,055 фосфор, 0,625 темір, 0,047 күкірт және 0,008 т.б. Катодты және анодты коррозия реакцияларының кинетикасын тереңірек түсіну үшін Тафель графикасы жасалды. 500 мг/л фосфоры бар PSK-1 олигомерінің 1 м HCL-де поляризация деректері сәйкесінше 97,76% ингибирлеу тиімділігіне ие екендігі анықталды.

Түйін сөздер: коррозия ингибиторлары, металл коррозиясы, фосфор (V) - хлорид, цианур қышқылы.

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Исследование ингибирования коррозии стали с использованием вторичных отходов

Аннотация. В статье исследовано ингибирование коррозии стали фосфорсодержащими олигомерными ингибиторами. В эксперименте были испытаны образцы углеродистой стали следующего химического состава (мас. %): 0,19 углерода, 0,075 марганца, 0,055 фосфора, 0,625 железа, 0,047 серы и 0,008 прочих. Для более глубокого понимания кинетики катодной и анодной реакций коррозии были построены графики Тафеля. Было установлено, что данные поляризации при 500 мг/л фосфорсодержащего олигомера PSK-1 в 1М HCl имеют значительно более высокую эффективность ингибирования - 97,76% соответственно.

Ключевые слова: ингибиторы коррозии, коррозия металлов, фосфор (V)-хлорид, циануровая кислота.

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