CORROSION INHIBITION PROCESS OF CARBON STEEL IN HYDROCHLORIC ACID BY CRONOX

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Abstract
The aim of this investigation is to examine the inhibitory effect of CRONOX toward the corrosion of carbon steel corrosion in 1M hydrochloric acid solution. Weight loss and potentiodynamic polarization techniques were used in this work to evaluate the inhibition efficiency of the tested inhibitor. Also, Tafel method for determining of the kinetic parameters, scanning electron microscopy, all of them providing complete information about the mode of action of the inhibitors; simultaneously, has been studied, the CRONOX inhibiting efficiency with increasing temperature.

Introduction
Carbon steel corrosion process in hydrochloric acid solution is extensively studied because the industrial applications of acid solutions especially in pickling rescaling and cleaning process of steel surface [1,2]. Inhibitors are generally used to reduce the corrosive attack on metallic materials acting on metal dissolution [3]. They are single or mixtures organic compounds, which have nitrogen, oxygen and sulfur atoms in their molecular structure [4]. Inhibitory effect consist in formation of a physical and/or chemical adsorption film barrier on the metal surface [1,5].
CRONOX is a commercial corrosion inhibitor which has composition presented in Table 1. CRONOX corrosion inhibitor supplied are used in the subsea oil and gas industry. CRONOX is a water soluble, oil insoluble corrosion inhibitor concentrate designed for application in water based drilling mud systems and as a packer fluid inhibitor [6,7].

Table 1. Inhibitor composition [6,7]:

Ingredients	Wt%
Methanol	30 - 60
Fatty acids	10 - 30
Polyoxyalkylenes	10 - 30
Modified thiourea polymer	10 - 30
Propargyl alcohol	5 - 10
Olefin	1 - 5

Experimental
The working electrode was a cylindrical disc cut from a carbon steel sample. HCl reagent was used for the preparation of aggressive solutions. To determine the inhibitor effect of CRONOX on the corrosion rate of carbon steel in 1M HCl solution, in preliminary studies presented in this paper, 0.1% inhibitor was used.
The cyclic voltammetry, linear polarization (Tafel polarization method) and weight loss methods were used in order to notice the inhibitive properties of CRONOX on the carbon steel corrosion process. The electrochemical studies were recorded using a SP150 BioLogic potentiostat/galvanostat.

Results and discussion

The electrochemical behavior of CRONOX in 1 M HCl electrolyte was studied by cyclic voltammetry on platinum electrode. In figures 1 and 2 are presented CVs recorded in test solution without and with 0.1% inhibitor at different scan rate.

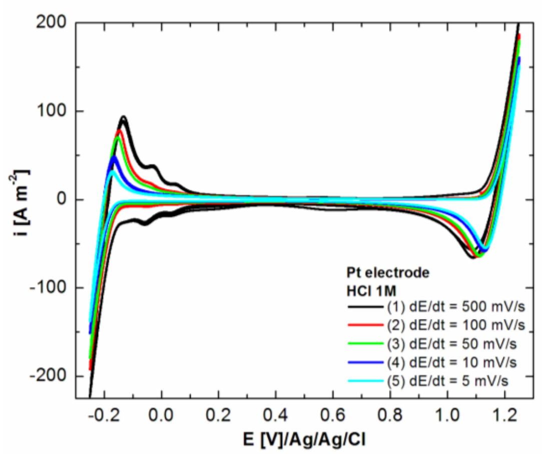

Figure 1. CVsrecorded on Pt electrode in 1 M HCl solution, at different scan rate.

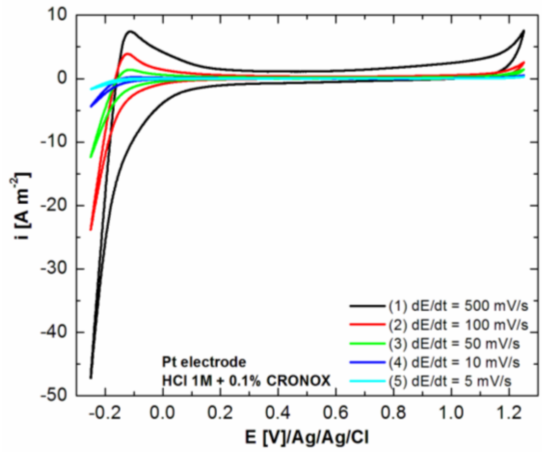

Figure 2. CVsrecorded on Pt electrode in 1 M HCl + 0.1% CRONOX solution, at different scan rate.

The manner in which CRONOX can be a corrosion inhibitor for carbon steel in 1 M HCl solution and its effect on corrosion rate can be estimated by Tafel method from linear polarization curves recorded without and with 0.1% inhibitor at temperatures range between 298 and 338 K, as shown in figures 3 and 4.

Numerical values of the corrosion current density (i_{corr}) variation, corrosion potential (E_{corr}), anodic Tafel slope (b_a), cathodic Tafel slope (b_c) and polarization resistance (R_p) were obtained from polarization profiles by extrapolating potentiodynamic curves from figures 3 and 4 using BioLogics software.The inhibition efficiency (*IE*) has been calculated using equation (1). All obtained values are presented in Table 2.

$$IE(\%) = \left(\frac{i^{o}_{corr} - i^{inh}_{corr}}{i^{o}_{corr}}\right) \times 100 \qquad (1)$$

where $i^{0}_{corr}$and i^{inh}_{corr} are the uninhibited and inhibited corrosion current densities, respectively.

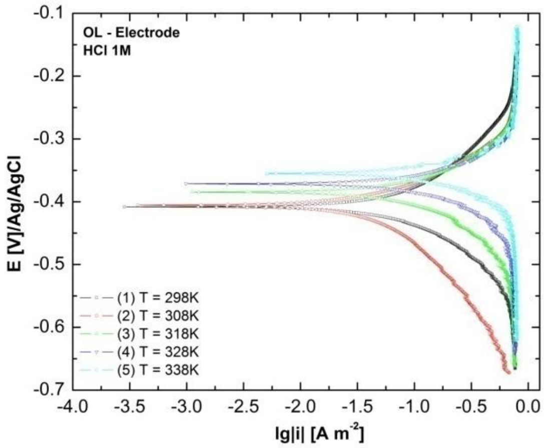

Figure 3. LVs recorded on carbon steel electrodes in 1 M HCl solution, scan rate: 1 mV s^{-1}.

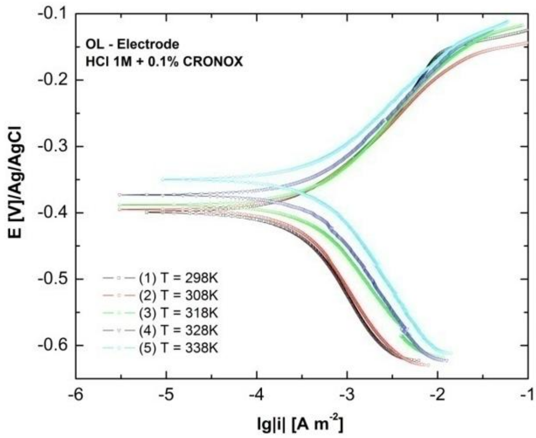

Figure 4. LVs recorded on carbon steel electrodes in 1 M HCl + 0.1% CRONOX solution, scan rate: 1 mV s^{-1}.

Table 2. Polarization parameters for test electrodes corrosion process in 1 M HCl solution in the absence/presence of CRONOX at different temperatures:

Electrolyte	T [K]	i_{corr}, [μA cm^{-2}]	E_{corr}, [mV]	$-b_c$, [mV dec^{-1}]	b_a, [mV dec^{-1}]	R_p, [Ω]	v_{corr}, [mm an^{-1}]	IE, %
SB (HCl 1M)	298	**5.314**	-406	175	165	1.338	**109**	-
	308	**9.861**	-394	162	158	1.708	**569**	-
	318	**13.51**	-385	154	149	0.846	**158**	-
	328	**22.13**	-372	141	137	0.733	**259**	-
	338	**23.4**	-366	134	124	0.398	**273**	-
SB + 0.1% Cronox	298	**0.044**	-421	163	156	214	**0.452**	**99.17**
	308	**0.067**	-415	156	154	194	**0.647**	**99.32**
	318	**0.079**	-411	148	153	179	**0.834**	**99.42**
	328	**0.088**	-401	142	148	164	**0.933**	**99.60**
	338	**0.102**	-391	140	145	147	**1.026**	**99.56**

The gravimetric measurements of carbon steel discs samples immersed in 1 M HCl, in the absence and presence of 0.1% CRONOX inhibitor, were investigated and determined after

240 hours of immersion, at 298 K. The corrosion rate of carbon steel (W_L) and the inhibition efficiency (*IE*) obtained are shown in Table 3.

Table 3. The inhibition efficiency obtained by weight loss method:

CRONOX conc. [%]	W_{corr} [mg cm^{-2} h^{-1}]	*IE* [%]
0	1.192	-
0.1	0.035	**98.28**

Conclusion

CRONOX inhibition efficiency has been studied by two different methods: weight loss and linear polarization, both giving comparable values. This compound exhibited excellent inhibition performance as carbon steel inhibitor in 1 M HCl.

Acknowledgements

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