

Effect of N-Furfuryl-Aniline and N-Furyl-C-Phenyl-Nitrone on Corrosion Inhibition of Low Carbon Steel in 3% NaCl

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ABSTRACT

Carbon steel is one of the most commonly used metals in the oil, gas, and hydrocarbons transport industry, given its mechanical properties and low production cost; however, its low corrosion resistance to different aggressive environments has been considerably reported. Worldwide, there is an interest in mitigating corrosion and minimizing the associated cost. Inhibitors have become one of the best practical methods to avoid internal corrosion damage, especially in hydrocarbons transport lines. This investigation aims to develop and evaluate the molecules n-furfuryl-aniline (NFA) and n-furyl-c-phenyl-nitrone (NFCPN) in 3% NaCl on low carbon steel using Tafel polarization and impedance spectroscopy measurement techniques. Concentrations of the molecule of 5, 10, 25, 50, and 100 ppm were used in this study. The results show that the inhibition efficiencies increased in the presence of the molecules. The inhibitors presented efficiencies up to 80% showing that the inhibitors are effective in helping to reduce and slowing down the corrosion process that occurs to the carbon steel samples evaluated.

Keywords: organic inhibitor, inhibitive efficiency, electrochemical test

INTRODUCTION

In the hydrocarbon industry, internal corrosion is one of the most worrisome threats because it can cause catastrophic failures in the pipelines and cause harm to people and the environment. Some authors mention that internal corrosion damage is due to components such as H₂S, CO₂, mercaptans, sulfate-reducing bacteria, and suspended solids. These variables lead to thickness losses in the ducts, which contributes to the increase in the rate of deterioration.^{1 2 3} study reported by Askari et al, shows that the internal corrosion rate can be so high that it can consume the 3-6mm allowed for the pipeline in a year, which leads to irreparable economic losses.⁴ One of the most used methods to control internal corrosion is corrosion inhibitors, thanks to their low cost, availability, and efficiency. A corrosion inhibitor is a chemical substance used in quantities of the order of ppm, and its primary function is to adsorb on the metal surface to prevent the interaction of the corrosive species in the fluid and the metal structure. Even though there are many corrosion inhibitors, there is always room for more efficient and cost-effective corrosion inhibitors that will help the economics of operators. Thus, the search for new efficient and cost-effective organic corrosion inhibitors has been going on for the last years, and it is a very competitive business.⁵ Aouniti et al, highlights the behavior of 2-acetyl thiophene, which can be easily protonated due to its thiophene derivative. These molecules contain planar aromatic benzene and thiophene rings and also contain S and N atoms and π electrons.⁶ Also, Hamadi et al, report that glutaminic acid can be an effective corrosion inhibitor due to stabilizing its adsorption on the metal surface by the oxygen atoms that exist in its structure.⁷

In the same way, Macedo et al, report that the carboxymethyl chitosan showed efficiencies of 60% and 80% in media containing Cl⁻ by the chemisorption mechanisms.⁸ Baux et al, also studied octadecylamine as an inhibitor in carbon steels, achieving efficiencies of up to 90% by optimizing the layer adsorption with a thickness of approximately 0.16nm.⁷ Sadeghi et al, report that Carboxamide derivatives are also effective corrosion inhibitors on the metallic surface due to the interaction between the heteroatoms unshared electron pairs and the vacant d-orbitals of the iron atoms.⁹

According to the above, this study presents the synthesis of the molecules NFA and NFCPN by reductive amination and its electrochemical evaluation using carbon steel in 3% wt. NaCl by Electrochemical Impedance Spectroscopy (EIS).

EXPERIMENTAL PROCEDURE

Materials

A steel sample was machined to obtain a cylindrical specimen with an exposure area of 1.2 cm². The steel surface was wet grounded with silicon carbide papers down to grade 2000, ultrasonically cleaned with ethanol, rinsed with deionized water, and dried. The electrolyte solution was prepared using deionized water and 3wt—% NaCl (analytical grade).

Synthesis characterization of NFA

The compound was obtained by direct reduction of furfural with aniline. Schiff's base was prepared and then reduced with NaBH₄ in methanol

Synthesis characterization of NFNP

NFCPN was obtained by mixing NFA, sodium tungstate (Na₂WO₄), hydrogen peroxide (H₂O₂) in proportions (1: 0.05: 3), respectively, using methanol as solvent. This mixture was left stirring for ten days; then, the solvent was rotary evaporated with ethyl acetate to form an emulsion. Then, sodium carbonate (Na₂CO₃) was added to separate the emulsion and obtain the product used as a corrosion inhibitor.

Electrochemical measurements

The inhibitory activity of the investigated compound on carbon steel corroding was examined through Potentiodynamic Polarization (PP) and Electrochemical impedance spectroscopy (EIS) in 3 wt.% NaCl in the absence and presence of NFA and NFCPN concentrations going of 5-10-25-50 and 100ppm, respectively. The electrochemical experiments were performed using a potentiostat/galvanostat⁽¹⁾. A classical cell with a three electrodes configuration was used in the present study. The working electrode consisted of carbon steel, whereas a platinum rod and a silver chloride electrode (Ag/AgCl) were employed as counter and reference electrodes. Before electrochemical tests, the working electrode was immersed in 3 wt.% NaCl solution without and with different inhibitors concentrations for 30 min at open circuit potential (OCP). The PP plots were drawn with a scan rate of 0.5 mV s⁻¹ at the standard potential range found by adding ± 200 mV. EIS spectra were recorded between 10⁻¹ – 10⁴ Hz with an amplitude of 10 mV. The value of inhibition efficiency (η) can be obtained using equation 1.

$$\eta\% = \frac{(1/R_{ct})_{\text{blank}} - (1/R_{ct})_{\text{inhibitor}}}{(1/R_{ct})_{\text{inhibitor}}} \quad (1)$$

RESULTS

NFA was synthesized through indirect reductive amination. Schiff's base was prepared by condensation between furfural and aniline in ethanol as solvent. Then its reduction was carried out with NaBH₄ in methanol at room temperature, as shown in Figure 1.

⁽¹⁾ Gamry model G 750