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Study of a quaternary imidazoline-based corrosion inhibitor for oil and gas industry under high temperature and pressure conditions

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Abstract

Corrosion is recognized as an important factor for the oil pipelines, well casing and drilling equipment failure, especially in the development of deep and ultra-deep wells. Organic nitrogen-based surfactants, such as imidazolines, have been used successfully in the oil and gas industry as one of the most practical and economical corrosion inhibitors. The objective of this work is to study and evaluate the performance of quaternary imidazoline as a corrosion inhibitor for carbon steel in acidified brine using gravimetric and electrochemical techniques. The experimental work was carried out at elevated temperatures of 250 °C and 4.1 MPa pressure using imidazoline-based inhibitor at different concentrations in 3 wt % NaCl solution acidified with hydrochloric acid until reaching pH 3 with the objective of simulating the environment of deep water oil extraction. Carbon steel 1020 was used in the experiments as substrate in the hypothesis of simulating the petroleum duct materials and their corrosion inhibition by imidazoline-based inhibitor in acidified NaCl solution. Potentiodynamic polarization, electrochemical impedance spectroscopy and the gravimetric tests results showed that a quaternary imidazoline can efficiently inhibit the corrosion of carbon steel at high temperature and pressure.

Keywords: petroleum, oil production, corrosion inhibitor, imidazoline, autoclave, high temperature

Introduction

Corrosion is one the mains causes in the failure of pipelines, production columns and drilling equipment, especially in the development of deep and ultra-deep wells, which results in losses of millions of dollars per year. Nitrogen-based organic surfactants, such as imidazolines or their salts, have been used successfully in the oil and gas industry as corrosion inhibitors [1], and their inhibition effectiveness is attributed mainly to the adsorption of the inhibitor in an active center on the metal surface forming a protective film in the metal-corrosive interface, whose efficiency depends on the quality of the film formed on the metallic surface, because, in doing this, the inhibitor is able to suppress electrochemical reactions during corrosion process [2]. Usually, corrosion of carbon steel above 150 °C is rare, but there are already oil wells operating

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above this temperature and with high partial pressures of CO_2 and H_2S, which requires the development of materials and corrosion inhibitors for these severe conditions [3].
The present work investigates the corrosion process and evaluates the performance of a quaternary imidazoline based inhibitor for carbon steel in acidified saline solution at pH 3 at high temperature and pressure (250° C and 4.1 MPa (600 psig)), using gravimetric techniques, electrochemical impedance spectroscopy and potentiodynamic polarization, in order to evaluate this corrosion inhibitor for pre-salt exploration.

Methodology

The weight loss tests were performed in an Hasteloy C-276 Autoclave 2 L, at 250 ºC and 4.1 MPa (600 psig) with AISI 1020 steel specimens immersed in a non-deaerated solution 3% NaCl, pH 3, in the absence and presence of quaternary imidazoline from Evonik in different concentrations (100, 200, 400, 600, 1000 and 2000 mg/L) for 26 hours, the procedure being based on the ASTM G31 standard. In order to avoid the samples come into contact with any metallic part of the autoclave or with other samples, a Teflon support was made. After the immersion, the samples were chemical pickled with Clarke's solution. Each sample was weighed before and after the test procedure on a Mettler Toledo AX analytical balance with a sensitivity of 10^{-5} g. The measured mass was compared with that of a standard 304 stainless steel specimen to minimize weighing error.
The Gamry Reference 600^{TM} potentiostat was used for electrochemical tests. Impedance spectroscopy were made in the frequency range from 40 kHz to 10 mHz with a potential disturbance of 10 mV_{rms} around the corrosion potential and ten measurements per decade of frequency. The results obtained are represented by the Nyquist diagrams. The polarization resistance was determined by the inverse of the slope of the line limited to disturbances of ± 10 mV around the open circuit potential (Eoc), which is proportional to the inverse of the corrosion rate following Stern-Geary equation.
After the impedance tests, the polarization curves were obtained with a scan rate of 1 mV/s in the potential range of -250 mV at 250 mV in relation to the open circuit potential. For data treatment, a 50 mV overvoltage criterion was established in relation to the open circuit potential for the cathodic lines, being these linear sections extrapolated to the Eoc, to determine the corrosion current (icorr).

Results and discussion

Figure 1a shows immersion corrosion test results as the corrosion rates as a function of the concentration of the quaternary imidazoline inhibitor in an autoclave, at a temperature of 250 °C and a pressure of 4.1 MPa (600 psig). It is verified that with the addition of inhibitor, the corrosion rate decreases significantly, being possible to observe that the inhibitor protects the metal from the aggressive medium, since the inhibition efficiency increases with the concentration, reaching a maximum of approximately 79 % at 1000 mg/L inhibitor concentration. It is observed that the corrosion rate stabilizes at concentrations higher than 1000 mg/L, which shows that in this concentration the maximum efficiency of inhibition of imidazoline is obtained for the studied conditions. Considering that the corrosion process increases with temperature, it is necessary to have a higher concentration of inhibitor, otherwise, the surface is not fully protected by the adsorbed film leading to low inhibition efficiency or localized corrosion [4].

In the Nyquist diagram (Figure 1b) is possible observe that the addition of imidazoline results in an increase in the capacitive arc diameter when compared with the sample without imidazoline, indicating a protective character due to the formation of adsorbed film. The impedance values for the test in the autoclave are much lower than those found at room temperature. This can result from the more aggressive conditions inside the autoclave. Noisy data can be noted at low frequencies range.

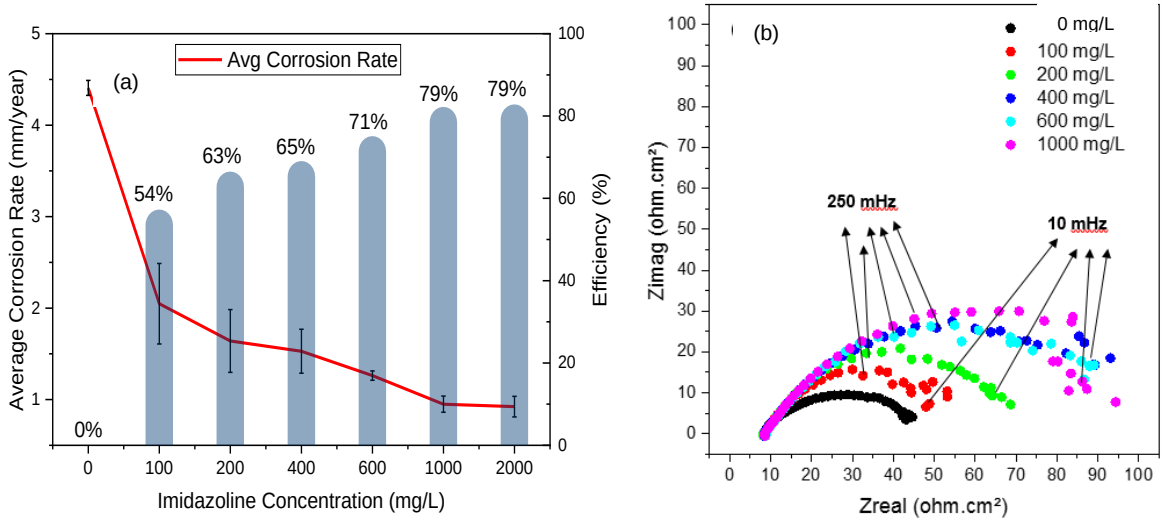

Figure 1 – Results of corrosion rate (mm / year) and inhibition efficiency (%) and Diagram of (a) Nyquist for carbon steel in 3.0% NaCl medium, pH 3, 250 ° C and 4.1MPa (600 psig) for different concentrations of quaternary imidazoline.

Conclusions

Mass loss tests indicate that corrosion inhibitor based on quaternary imidazoline is efficient in inhibiting corrosion of carbon steel in 3% NaCl solution, pH 3 at 250ºC of temperature and 4.1MPa (600 psig) of pressure, observing that the inhibition efficiency increases with the inhibitor concentration.

Electrochemical tests show that high temperature and pressure influence the action of quaternary imidazoline, as there was a reduction in the maximum efficiency obtained and a higher concentration of the inhibitor was required for adsorption of protective film, when compared to room temperature.

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