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REVIEW

Nontoxic corrosion inhibitors for N80 steel in hydrochloric acid

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Abstract The purpose of this paper is to evaluate the protective ability of 1-(2-aminoethyl)-2-oleylimidazoline (AEOI) and 1-(2-oleylamidoethyl)-2-oleylimidazoline (OAEOI) as corrosion inhibitors for N80 steel in 15% hydrochloric acid, which may find application as eco-friendly corrosion inhibitors in acidizing processes in petroleum industry. Different concentrations of synthesized inhibitors AEOI and OAEOI were added to the test solution (15% HCl) and the corrosion inhibition of N80 steel in hydrochloric acid medium containing inhibitors was tested by weight loss, potentiodynamic polarization and AC impedance measurements. Influence of temperature (298–323 K) on the inhibition behavior was studied. Surface studies were performed by using FTIR spectra and SEM. Both the inhibitors, AEOI and OAEOI at 150 ppm concentration show maximum efficiency 90.26% and 96.23%, respectively at 298 K in 15% HCl solution. Both the inhibitors act as mixed corrosion inhibitors. The adsorption of the corrosion inhibitors at the surface of N80 steel is the root cause of corrosion inhibition.

Contents

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1. Introduction

The N80 carbon steel has been generally used as the main construction material for down hole tubular, flow lines and transmission pipelines in petroleum industry. Acidization of a petroleum oil well is one of the important stimulation techniques for enhancing oil production. It is commonly brought about by forcing a solution of 15–28% hydrochloric acid into the well to remove plugging in the bore well and stimulate production in petroleum industry. To reduce the aggressive attack of the acid on tubing and casing materials (N80 steel), inhibitors are added to the acid solution during the acidifying process (Allen and Roberts, 1982). In the previous work various organic inhibitors have been tested for the corrosion inhibition of N80 steel in hydrochloric medium (Vishwanatham and Sinha, 2009; Emranuzaman et al., 2004; Quraishi et al., 2002; Neemla et al., 1989). Corrosion protection of N80 steel in HCl by condensation products of aniline and phenol, (Vishwanatham and Sinha, 2009) was studied. Corrosion inhibition of N80 steel in hot hydrochloric acid medium by disalicylidene acetone, dicinnamylidene acetone and divanilidene acetone was reported (Quraishi et al., 2002). Despite the vast number of corrosion inhibition investigations, there remains relatively few works directed toward the study of non-toxic organic compounds as corrosion inhibitors for steel in hydrochloric acid (Yadav and Sharma, 2011; Khaled, 2008; Hluchan et al., 1998; Ashassi-Sorkhabi et al., 2004; Ghareba and Omanoic, 2010). The effective acidizing inhibitors that are usually found in commercial formulations, suffer from drawbacks, they are effective only at high concentrations and they are harmful to the environment due to their toxicity, so it is important to search for new non-toxic and effective organic corrosion inhibitors for N80 steel – 15% hydrochloric acid system.

Thus, it was considered interesting to prepare nontoxic imidazoline compounds like 1-(2-aminoethyl)-2-oleylimidazoline (AEOI) and 1-(2-oleylamidoethyl)-2-oleylimidazoline (OAE-OI) and to assess their inhibitive properties for oil-well tubular steel (N80) in 15% hydrochloric acid.

2. Experimental

Rectangular steel coupons in the size of $6.0 \times 2.0 \times 0.3$ cm were cut from the N80 steel casing (supplied by ONGC) with a small hole ≈2 mm diameter at the upper edge of specimen for weight loss studies. For electrochemical studies the size of the electrodes was $1 \times 1 \times 1$ cm with a 4 cm long tag for electrochemical contact. N80 steel sample used for the study was analyzed in MET-CHEM Laboratories, Baroda, India and found to have the composition, C(0.31%), S(0.008%), P(0.010%), Si(0.19%), Mn(0.92%), Cr(0.20%) and Fe the rest. The corrosive solution was 15% HCl, obtained by dilution of hydrochloric acid (Emerk, sp gravity ≈1.18) with distilled water. The inhibitor concentration in weight loss and electrochemical study was in the range of 10–150 ppm. The volume of test solution for weight loss and for electrochemical measurement was 300 and 150 ml, respectively. The test coupons were mechanically polished with different grades of emery papers and cleaned with acetone and washed with distilled water and finally dried in dry air before every experiment. After weighing accurately, the specimens were immersed in 300 ml of 15% HCl with and without the addition of different concentrations of inhibitors. After 6 h the coupons were taken out, washed, dried and weighed accurately. The temperature (30–50 °C) experiments were also carried out for a period of 6 h using water circulated Ultra thermostat (model NBE, Germany) with an accuracy of ± 0.5 °C. Duplicate experiments were performed in each and the mean value of weight loss was reported. The corrosion inhibition ability of an inhibitor is expressed in terms of inhibitor efficiency and is determined by the percentage decrease in corrosion rate after inhibition test.

$$\%\mathrm{IE} = \left(\frac{CR^{\circ} - CR}{CR^{\circ}}\right) \times 100 \tag{1}$$

where, $CR°$ = corrosion rate in the absence of inhibitor, CR = corrosion rate in the presence of inhibitor.

Corrosion rate (CR) for the specimen can be calculated in millimeter penetration per years (mmpy) with the help of the following equation:

$$\text{Corrosion rate} = \frac{87.6 \times \Delta W}{\mathrm{DAT}} \tag{2}$$

where, T = exposure time in hours, ΔW = weight loss of metal coupons in mg, A = area of the test coupons in square inches, D = density of the steel.

The potentiodynamic polarization curves were recorded in the absence and presence of the inhibitors at different concentrations with N80 steel (area 1 cm^2) as working electrode using Potentiostat (VoltaLab 10) at 25 °C. Experiments were performed with saturated calomel electrode as reference electrode and platinum as counter electrode. The potentiodynamic polarization study has been carried out at a steady state and at a scan rate of 10 mV/s and potential range from −400 to −550 mV. From the anodic and cathodic polarization curves, Tafel slopes (βa and βc) and corrosion current (I_{corr}) were

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