Corrosion inhibition of mild steel in hydrochloric acid by cetyl compounds

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Inhibiting effect of cetyl trimethyl ammonium chloride (CTMAC) and cetyl trimethyl ammonium bromide (CTMAB) on the corrosion of mild steel in 1 M HCl solution have been studied using three different techniques (weight loss, electrochemical polarization studies and surface study by SEM). Weight loss studies were conducted in 1 M HCl at different temperatures (25°, 35° & 45°C) using various concentrations (50-250 ppm) of inhibitor for 24 h immersion time. Inhibitor efficiency (IE) increases with increase in inhibitor concentrations (50-250 ppm) at a given temperature and time. IE was found to vary with concentration, temperature and immersion time. Electrochemical polarization result revealed that CTMAC and CTMAB were mixed type inhibitors.

Keywords: Cetyl compounds, Corrosion inhibition, Electrochemical polarization, Mild steel

Introduction

Acid solutions are extensively used for different purposes in various types of industries to clean heat exchanging apparatus, to remove deposits, in pickling operations for scale removal and for improvement of heat transfer efficiency of equipment. Corrosion due to hydrochloric acid (HCl) in crude and vacuum units represents a significant portion of refining cost as a result of loss of production, inefficient operation and high maintenance and cost of corrosion control. Organic compounds containing nitrogen (N), sulphur (S) and/or oxygen (O) atoms are used as inhibitors of acid corrosion. Those containing N and S provide better inhibition efficiency (IE) than those containing N or S alone. IE of sodium n, n-diethyl dithiocarbamate (SDEDTC) for mild steel (MS) in HCl solution has been studied. SDEDTC as a corrosion inhibitor has been studied for the alloy CuNiFe in natural seawater. Bereket & Yurt studied corrosion inhibition of low carbon steel in acidic solution by selected quaternary ammonium compounds. Maximum IE of cationic surfactant was observed around and above critical micelle concentration (CMC), IE of quaternary ammonium salts was found to increase with the increase in their concentration. Corrosion inhibition of carbon steel in HCl by organic compounds containing heteroatom indicated that IE of undecenoic acid hydrazine (UAH), 2-mercaptobenzothiazole (MBT) and 2-hydrazinebenzothiazole (HTB) increases with increased temperature (30-60°C) and with increase in concentration (25-500 ppm). Corrosion behavior of iron and MS in inorganic acid solutions has attracted attention of several investigators. Corrosion studies on metals in organic acid solutions are scarce in comparison with similar studies in mineral acids. Lebrini et al. studied corrosion inhibition of MS by 2,5-bis(4-pyridyl)-1,3,4-thiadiazole. Effective corrosion inhibition of MS using anionic surfactant (p-myristyloxy carbonyl methoxy-p-sodium carboxylate azobenzene) has also been studied. Quraishi et al. studied heterocyclic anils as corrosion inhibitor for MS in formic and acetic acid solutions. This study presents inhibiting effect of cetyl trimethyl ammonium chloride (CTMAC) and cetyl trimethyl ammonium bromide (CTMAB) on MS exposed to aggressive solutions of 1 M HCl solutions.

Experimental Procedure

Preparation of Specimen

MS specimen (C, 0.14; Si, 0.03; Mn, 0.32; S, 0.05; P, 0.20; Ni, 0.01; Cu, 0.01; Cr, 0.01; and Fe, 98.78 wt. %) was used. For weight loss measurements, carbon
steel specimen (3.0 cm x 1.5 cm x 0.25 cm) was used and for electrochemical polarization investigation, specimen (5.0 cm x 1.5 cm x 0.25 cm) was used. All specimens were mechanically polished with a sequence of emery papers of various grades (150, 320, and 600) and then thoroughly washed with double distilled water and then acetone. Dried and cleaned specimens were kept in a desiccator over silica gel.

Inhibitor and Electrolyte
Two inhibitor compounds (Fig. 1) used were CTMAC (mol mass, 320) and CTMAB (mol mass, 364). The aggressive solutions were made of AR grade HCl. Appropriate concentrations of acids were prepared using double distilled water. Inhibitor concentrations (50-250 ppm) in 1 M HCl were prepared.

Weight Loss Studies
MS samples (3.0 cm x 1.5 cm x 0.025 cm) were used for weight loss measurement studies at various temperatures (25-45°C) for 24 h exposure time. IE (%) of all inhibitors was calculated as

\[
IE(\%) = \frac{(C_{R0} - C_{RI}) \times 100}{C_{R0}}
\]

where \(C_{R0}\) = corrosion rate without inhibitor (blank), \(C_{RI}\) = corrosion rate with inhibitor.

Electrochemical Polarization Measurement
Electrochemical polarization experiments were carried out using a potentiostate /galvanostate PGS 20IT (Radio meter analytical SA, France). MS strips of same composition coated with commercially available lacquer (exposed area, 1.0 cm\(^2\)) were used. Experiments were carried out for various concentrations at 35±1°C. Electrochemical polarization were also carried out at 45±1°C for inhibitor concentration of 150 ppm. A platinum foil was used as auxiliary electrode and saturated calomel electrode (SCE) was used as reference electrode before recording the polarization curve, the working electrode was maintained at its corrosion potential for 30 min until steady state conditions were obtained. Corrosion rate (CR) was calculated as

\[
C_R = \frac{0.13 \times I_{corr} \times EW}{D}
\]

where, \(I_{corr}\) = corrosion current density, \(\frac{1}{4}A/cm^2\); \(EW\) = equivalent weight of metal/alloy; and \(D\) = density of metal, g/cm\(^3\).

Surface Study by Scanning Electron Microscopy (SEM)
Immersion corrosion analysis of MS sample in acidic solution with and without optimal concentrations of inhibitor was performed. Immediately after the corrosion test, samples were observed by scanning electron microscope (JSM 840JEOL) taken at a magnification of X400.

Results and Discussion
IEs of CTMAC and CTMAB vs concentration were plotted (Fig. 2). IE increases with the increase in temperature (Fig. 3) in the presence of optimal concentration (250 ppm). Electrochemical parameter at 35°C corrosion potential (\(E_{corr}\)), corrosion current density (\(I_{corr}\)), anodic and cathodic tafel slopes \(\beta_a\) and \(\beta_c\) respectively, corrosion rate and %age inhibition efficiency are presented in Table 1. Corrosion potential is found to shift more towards +ve potentials with the
Fig. 2—Inhibition efficiencies vs concentration at different temperatures of: a) CTMAC; b) CTMAB
increase in concentration of inhibitor (Fig. 4). So, the inhibition of corrosion of MS in 1 M HCl solution is under mixed control. IE is found to reach a maximum value at 250 ppm inhibitor concentration for CTMAC (95.73%) and CTMAB (95.66%). At higher concentration (>250ppm), no appreciable change in performance of inhibitor was observed.

Surface roughness of MS appears very much lower with the addition of inhibitor than that without addition (Fig. 5). Also, roughness is more uniform after treatment with HCl solution, which contains inhibitor. Inhibitor increases surface coverage due to adsorption of the inhibitor on MS surface in HCl solution and restricts the corrosion rate.

**Conclusions**

CTMAC and CTMAB inhibit corrosion of MS in aggressive 1 M HCl solutions. CTMAC is more efficient than CTMAB in corrosion inhibition. Inhibition efficiency in both cases (CTMAC and CTMAB) increases at higher temperatures. Inhibition of corrosion of MS surface in acid solution is by a mechanism of adsorption of these compounds on metal surface. For both inhibitors, inhibition efficiency was found to increase with increase in concentrations. Inhibition effects of both the inhibitors are mixed type.

**References**

1   Achouri M El, Infante M R, Lzquierdo F, Kertit S, Gouttoya H M & Nciri B, Synthesis of some cationic gemini surfactants


