

# Influence of surfactants on the corrosion inhibition behaviour of 2-aminophenyl-5-mercapto-1-oxa-3,4-diazole (AMOD) on mild steel

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## Abstract

The corrosion inhibition characteristics of 2-aminophenyl-5-mercapto-1-oxa-3,4-diazole (AMOD) on mild steel in HCl solution have been studied by weight loss studies and potentiodynamic polarization. AMOD is a good corrosion inhibitor in HCl solution and its inhibition efficiency is increased markedly in presence of surfactants (SDS, CTAB, TX-100). TX-100 is found to be most effective among the tested surfactants. Weight loss measurements showed that the inhibition efficiency increased with the increasing surfactant concentration and attained a maximum value around  $0.2 \text{ mol dm}^{-3}$ . In presence of surfactant, the adsorption of AMOD on the mild steel surface obeyed Langmuir's adsorption isotherm. The influence of inhibitor concentration, solution temperature, and acid concentration on the corrosion rate of mild steel has also been investigated. The deduced thermodynamic parameters for adsorption reveal a strong interaction between the inhibitor and mild steel surface. The negative values of  $G_{\text{ads}}$  indicate the spontaneous adsorption of inhibitors on the mild steel surface. Potentiodynamic polarization studies show that these surfactants are mixed-type inhibitors.

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## 1. Introduction

Surfactants [1,2] also called detergents are amphiphile that contain polar or ionic head group and apolar residues. In the water or similarly strongly hydrogen-bonded solvents, they self-associate at concentrations above the critical micellar concentration (cmc) to form association colloids called micelles. Micelles have interfacial regions containing ionic or polar headgroups. This polar or ionic headgroups plays an important role in the adsorption [3,4] of surfactants onto the solid surfaces and thereby inhibit corrosion by blocking the surface of metal. Surfactant adsorption may occur due to electrostatic interaction, van der Waals interaction, hydrogen bonding and/or solvation and desolvation of adsorbate and adsorbent species [5]. Studies in surfactant media have demonstrated a marked inhibiting effect on corrosion [6–8]. The best efficiency appears to be at concentrations in the region of cmc. Depending upon the concentration of the surfactant, the adsorption may occur as

an individual molecule or as surfactant aggregates of various types.

Surfactant adsorption to the metallic surface is below monolayer level at concentrations below cmc. At concentrations above cmc, adsorption of surfactant can consist of multiple layers of physically adsorbed surfactant molecules. In the present study we have investigated the effect of anionic sodium dodecylsulfate (SDS), cationic cetyltrimethylammonium bromide (CTAB), and non-ionic Triton-X-100 (TX-100) surfactants on the corrosion efficiency of 2-aminophenyl-5-mercapto-1-oxa-3,4-diazole (AMOD) by weight loss measurements and potentiodynamic measurement studies.

## 2. Experimental

### 2.1. Material preparation

The inhibitor (2-aminophenyl-5-mercapto-1-oxa-3,4-diazole, AMOD) was synthesized in the laboratory following the procedure described earlier [9]. The mild steel samples having composition (wt%): 0.14% C, 0.35% Mn, 0.17% Si, 0.025% S, 0.03% P and balance Fe have been used for the experiment. CTAB (CDH, India), SDS (BDH, India) and TX-100 (Himedia, India) were used as

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received. All the other chemicals used were of reagent grade. The stock solutions of HCl and surfactants were prepared using double distilled water.

## 2.2. Weight loss measurements

Weight loss measurements were conducted on the mild steel of size (surface area  $2\text{ cm} \times 2\text{ cm}$  and thickness  $2.5\text{ mm}$ ) in  $1\text{ mol dm}^{-3}$  HCl in varying concentration ranges of surfactants in the absence and presence of inhibitor. Mild steel samples were polished with Emery Polishing paper III Grade 1/0 Plus and then degreased using acetone and was finally dried. The cleaned specimens were weighed before and after the experiments. The experiments were performed as per ASTM method described previously [10]. The inhibition efficiency (IE) was calculated by using the following equation:

$$IE = \frac{CR_{o,wl} - CR_{i,wl}}{CR_{o,wl}} \times 100 \quad (1)$$

where  $CR_{o,wl}$  is the corrosion rate in blank hydrochloric acid determined by weight loss method;  $CR_{i,wl}$  is the corrosion rate in presence of surfactant with and without inhibitor determined by weight loss method.

## 2.3. Potentiodynamic polarization studies

Potentiodynamic polarization studies were carried out using an EG&G Princeton Applied research (PAR) potentiostat/galvanostat (model 173), a universal programmer (model 175) and a X-Y recorder (model RE0089). A platinum foil was used as auxiliary electrode. A saturated calomel electrode (SCE) and mild steel were used as reference and working electrodes, respectively. All the studies were carried out at temperature  $(30 \pm 1\text{ }^\circ\text{C})$ . Equilibrium time leading to steady state of the specimens was 30 min. Sweep rate in potentiodynamic experiment was  $1\text{ mV s}^{-1}$ . The inhibition efficiency (IE) was calculated by using the following relationship [11]:

$$CR_{\text{corr}} = \frac{0.13 I_{\text{corr}} EW}{D} \quad (2)$$

Table 1

Variation of corrosion parameters on [CTAB] for mild steel in  $1\text{ mol dm}^{-3}$  HCl in the absence and presence of AMOD at  $30\text{ }^\circ\text{C}$  for 3 h

[CTAB] ( $\text{mol dm}^{-3}$ )	In absence of AMOD			In presence of AMOD		
	Weight loss (mg)	IE (%)	CR (mmpy)	Weight loss (mg)	IE (%)	CR (mmpy)
0.0	62.4	–	23.20	11.3	81.85	4.21
0.01	31.0	50.09	11.62	9.1	85.43	3.38
0.05	28.8	54.17	10.69	8.6	86.12	3.20
0.075	29.7	54.89	11.03	7.4	88.14	2.74
0.10	24.7	60.16	9.20	5.2	91.66	1.93
0.20	23.9	61.57	8.91	4.1	93.43	1.52
0.30	24.7	60.31	9.20	6.2	90.05	2.30
0.50	26.0	58.24	9.68	10.9	82.49	4.06

Table 2

Variation of corrosion parameters on [SDS] for mild steel in  $1\text{ mol dm}^{-3}$  HCl in the absence and presence of AMOD at  $30\text{ }^\circ\text{C}$  for 3 h

[SDS] ( $\text{mol dm}^{-3}$ )	In absence of AMOD			In presence of AMOD		
	Weight loss (mg)	IE (%)	CR (mmpy)	Weight loss (mg)	IE (%)	CR (mmpy)
0.0	62.4	–	23.20	11.3	81.85	4.21
0.01	29.8	52.07	11.08	8.8	85.87	3.27
0.05	27.9	55.14	10.37	7.1	88.66	2.63
0.075	26.3	57.64	9.79	6.8	89.11	2.52
0.10	23.8	61.62	8.87	4.3	91.03	2.08
0.20	22.2	64.31	8.25	2.5	95.99	0.92
0.30	23.3	62.47	8.67	4.5	92.74	1.67
0.50	24.6	60.49	9.13	9.6	84.61	3.57

$$IE = \frac{CR_{o,\text{corr}} - CR_{i,\text{corr}}}{CR_{o,\text{corr}}} \times 100 \quad (3)$$

where  $CR_{\text{corr}}$  is the corrosion rate determined by measuring  $I_{\text{corr}}$ ;  $CR_{o,\text{corr}}$  the corrosion rate in blank hydrochloric acid;  $CR_{i,\text{corr}}$  the corrosion rate in presence of surfactant with and without inhibitor; EW the equivalent weight of iron;  $D$  the density of iron;  $I_{\text{corr}}$  is the corrosion current density.

## 3. Results

### 3.1. Weight loss measurements

Tables 1–3 show the dependence of inhibition efficiency (IE) on varying concentrations of surfactants of cationic CTAB, anionic SDS and non-ionic TX-100, respectively, in the range from  $1 \times 10^{-2}\text{ mol dm}^{-3}$  to  $5 \times 10^{-1}\text{ mol dm}^{-3}$  in the absence and presence of 500 ppm AMOD. These surfactants alone displayed good IE and the presence of AMOD has further enhanced the IE appreciably as shown in Fig. 1. The IE first increased with increase in [surfactant], giving a maxima at concentration  $0.2\text{ mol dm}^{-3}$  and, thereafter, a decrease in IE was observed on further increasing the [surfactant].

The dependence of IE on variation in concentration of acid ( $0.01\text{--}5.0\text{ mol dm}^{-3}$ ) at fixed concentrations of surfactant ( $0.2\text{ mol dm}^{-3}$ ) and AMOD (500 ppm) at  $30\text{ }^\circ\text{C}$  are depicted in Fig. 2. The IE decreased with the increase in acid concentration. It may be due to the greater aggressiveness of acid solutions at higher concentration.

A very small change in IE was observed (Fig. 3) on varying the temperature from  $30\text{ }^\circ\text{C}$  to  $60\text{ }^\circ\text{C}$ . The concentration of surfactant was kept constant at  $0.2\text{ mol dm}^{-3}$  in presence of 500 ppm AMOD and  $1.0\text{ mol dm}^{-3}$  HCl. These studies demon-

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