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Corrosion Inhibition of Mild Steel in Hydrochloric Acid by Sodium Lauryl Sulfate (SLS)

ATUL KUMAR

Department of Applied Sciences and Humanities,
N.C. College of Engineering, Israna-132107 (Panipat)
atul_verma1234@rediffmail.com; Phone +919416311565

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Abstract: Effect of Sodium Lauryl Sulfate (SLS), a surfactant on corrosion of mild steel in 1 M hydrochloric acid was studied using three techniques namely: weight loss, electrochemical polarization and metallurgical research microscopy. Results obtained reveal that SLS is good inhibitor and shows very good corrosion inhibition efficiency (IE). The IE was found to vary with concentration of inhibitor and temperature. The electrochemical polarization result revealed that SLS is anodic in nature.

Keywords: Corrosion Inhibition, Mild steel , Electrochemical polarization.

Introduction

Corrosion of metals generally occurs in the presence of oxygen and moisture and involves two electrochemical reactions. Oxidation occurs at anodic site and reduction occurs at cathodic site. In acidic medium hydrogen evolution reaction predominates. Inhibitors are generally used to protect materials against deterioration from corrosion. Most of the well-known acid inhibitors used in industry are organic compounds having multiple bonds in their molecules that mainly contain nitrogen, sulphur, oxygen atoms through which they get adsorbed on the metal surface¹⁻⁵. The effect of temperature on the inhibiting process is of great importance in industry. Effective inhibitors are expected to perform under a wide range of conditions. M.A. Quaraishi *et al*⁶ reported the use of four triazoles namely, 4-amino- 3 methyl -5 mercapto -1, 2, 4 triazole (AMMT), 4-amino- 3 ethyl -5 mercapto -1, 2, 4 triazole (AEMT), 4-amino- 3 propyl -5 mercapto -1, 2, 4 triazole (APMT) and 4-amino- 3 butyl -5 mercapto -1, 2, 4 triazole (ABMT) as inhibitors for the corrosion of mild steel in aqueous solution containing 20% formic acid and 20% acetic acid. The use of surfactants has been studied and it was shown that the inhibition efficiency increases with the no. of carbon atoms in the molecule. These compounds show very good inhibition efficiency near their critical micelle concentration⁷⁻¹⁰. The inhibitor adsorption mode was strictly dependent on the inhibitor structure^{7,11}. Z. Ait Chikh and coworkers¹² studied the effect of 1,12- bis (1,2,4-triazolyl) dodecane on carbon steel in 1M HCl solution by using electrochemical and analytical techniques. In the present paper, study of the inhibiting effect of SLS on mild steel surface in aggressive 1M HCl solution is presented.

Experimental

Electrolyte

For the preparation of aggressive HCl solution AR grade (Aldrich) HCl was used. Approximate concentrations of acid were prepared using double distilled water. Inhibitor concentrations ranging from 50 to 250 ppm in 1 M HCl solution were prepared.

Specimens

Mild Steel specimens of chemical composition C-0.14, Si-0.03, Mn-0.32, S-0.05, P-0.2, Ni-0.01, Cu-0.01, Cr-0.01 and Fe-Balance (wt %) were used. The specimens were mechanically polished with emery papers of 150, 320 and 600 grade, degreased with acetone, washed in double distilled water and finally dried. The cleaned specimens were weighed before and after immersion in 1M HCl for 24h in the absence and presence of various concentrations of SLS at different temperatures in the range of 25-45 °C.

Weight loss measurements

The mild steel strips of size (3.0 x 1.5 x 0.0025) cm were used for weight loss measurements. Weight loss measurements were carried out at different temperatures in the range 25-45 °C for 24h in 1M HCl solutions. The specimens were weighed before and after immersion and the percentage inhibition efficiency (IE) was calculated using the following equation.

$$IE = \frac{(W_0 - W)}{W} \times 100$$

Where w_0 and w are the weight loss in absence and presence of the inhibitor respectively.

Electrochemical polarization measurements

For electrochemical polarization studies mild steel strips of same composition and coated with commercially available lacquer with exposed area of 1.0 cm² were used and experiments were carried out at temperature 35±1 °C. The electrochemical measurements were carried out in a conventional three-electrode cell. The working electrode was a mild steel specimen of 1cm² area. A saturated calomel electrode (SCE) and a platinum foil were used as the reference and auxiliary electrodes respectively. The temperature was controlled thermostatically at 35±1 °C. Equilibrium time leading to steady state of the specimens was 30 min. Electro chemical polarization studies were carried out using a potentiostat / galvanostat PGS 20IT (Radiometer Analytical SA).

Corrosion rate (CR) was calculated using the following formula.

$$CR = \frac{0.13 \times I_{\text{corr}} \times EW}{D}$$

where I_{corr} = Corrosion current density in mA/cm².

EW = Equivalent weight of the metal in g/eq.

D = Density of metal in g/cm³.

Metallurgical research microscopy technique

To study the morphology of corroded surface of the specimen after exposing it to 1M HCl in the absence and presence of various concentrations of SLS at various temperatures range (25 °C to 45 °C) micrographs were taken through Metallurgical research microscope (JSM-840 JEOL). All micrographs were taken at magnification of x 400.

Results and Discussions

Weight loss studies

The corrosion inhibition efficiencies (IE) of SLS systems obtained from weight loss data are given in Table 1. It is seen that SLS inhibit corrosion of mild steel in 1M HCl acid at all

concentrations under study. It has been observed that IE for SLS increases with the increase in Concentration as shown in Figure 1. The influence of temperature on IE of SLS at various concentrations is shown in Figure 2. The IE increases with temperature up to 35 °C and after that it decreases at higher temperature due to desorption of inhibitor.

Table 1. Inhibition efficiencies (IE) obtained from weight loss data in 1 M HCl solution in presence and absence of Sodium Lauryl Sulfate (SLS) at different temperatures.

Temperature, °C	Concentration of SLS, ppm	Corrosion rate, mpy	IE, %
25	ZERO	206.65	Blank
25	50	146.54	29.08
25	100	142.08	31.24
25	150	138.85	32.81
25	200	132.37	35.94
25	250	100.80	51.22
35	ZERO	606.80	Blank
35	50	275.26	54.64
35	100	242.88	59.97
35	150	210.90	65.24
35	200	171.63	71.71
35	250	160.30	73.58
45	ZERO	1755.82	Blank
45	50	1668.59	4.97
45	100	1664.13	5.22
45	150	1605.44	8.56
45	200	1022.12	41.78
45	250	948.45	45.98

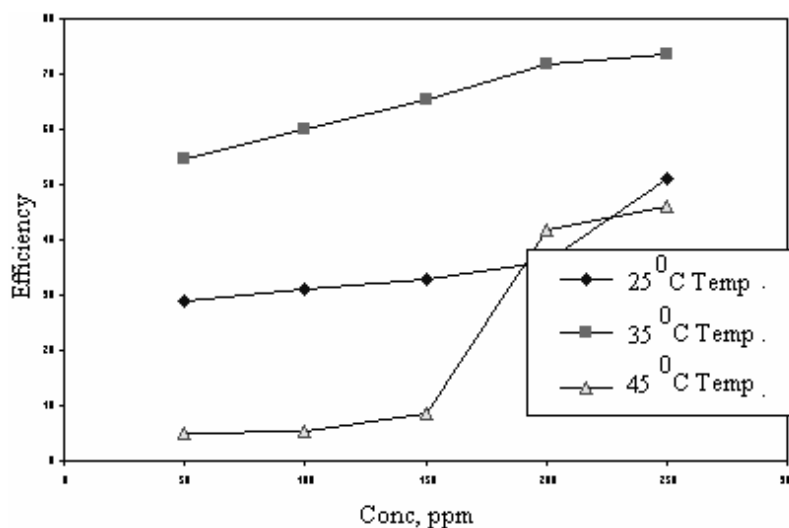


Figure 1. Variation of percentage inhibition efficiency with SLS concentration.

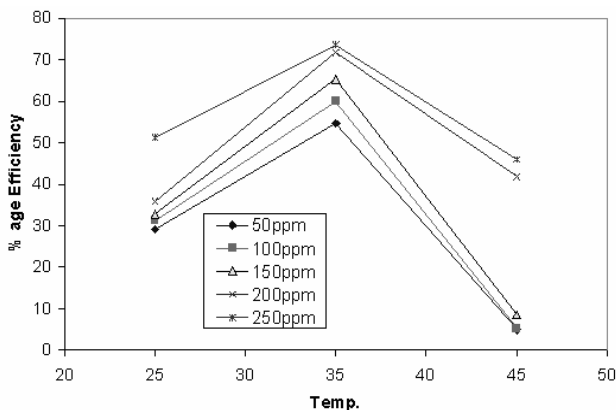


Figure 2. Variation of percentage inhibition efficiency of SLS with solution temperature.

Electrochemical polarization measurements

Figure 3 shows the polarization curves in 1M HCl solutions with and without addition of SLS at different concentrations. The corrosion current density decreases with increasing inhibitor concentrations and the corrosion potential shifts depending on the inhibitor concentration. The values of the electrochemical parameters obtained from the polarization curves, namely: corrosion potential (E_{corr}), cathodic Tafel slope (β_c), anodic Tafel slope (β_a), corrosion current density (I_{corr}), resistance polarization (R_p) and %age inhibition efficiency (% I.E.) for the different concentrations of CPC and SLS are given in Table 2. The inhibition efficiency in each case was calculated according to the following equation.

$$IE (\%) = (1 - I_{corr} / I'_{corr}) \times 100$$

Where I_{corr} and I'_{corr} are the corrosion current density in the absence and in the presence of inhibitor respectively.

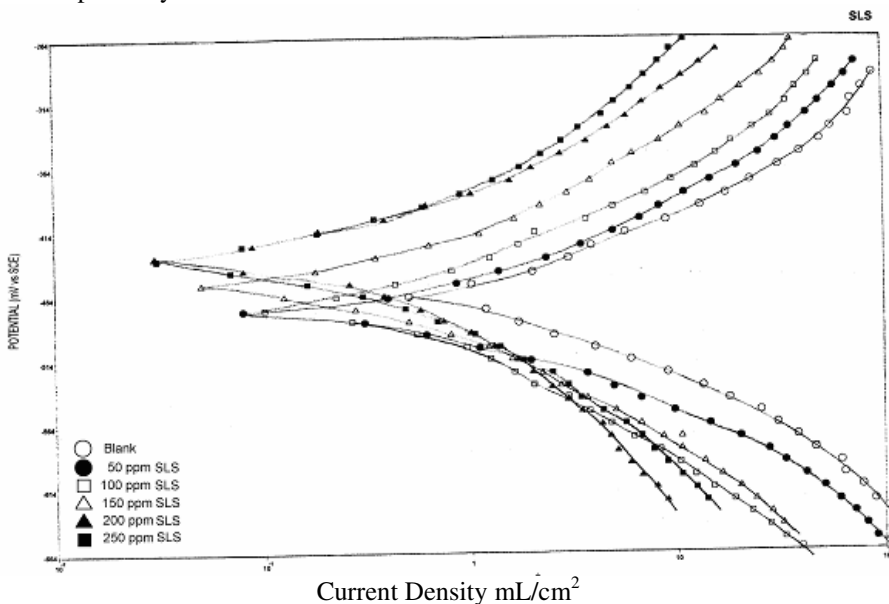


Figure 3 Polarization curves of mild steel in 1M HCl in absence and presence of various concentrations of SLS.

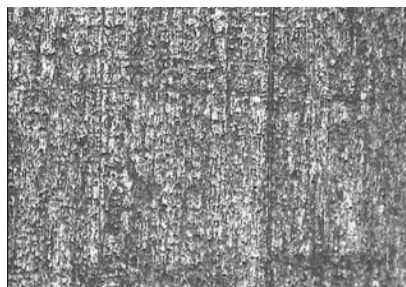
Table 2. Electrochemical parameters of mild steel corrosion in 1 M HCl solution contain various concentrations of Sodium Lauryl Sulfate (SLS) at 35 °C.

Concentration ppm	E corr mV	$\beta_{amv}/$ decades	$\beta_{cmv}/$ decades	I.corr. $\mu A/cm^2$	Corrosion Rate, mpy	IE, %
Blank	-464	1.95	2.48	1300	600.51	Blank
50	-475	11.11	2.89	0.560	258.68	56.92
100	-475	4.75	7.84	0.500	235.58	60.77
150	-455	11.76	5.56	0.140	189.39	68.46
200	-439	9.52	20.00	0.350	161.68	73.08
250	-436	19.05	11.63	0.340	157.06	73.85

The results depicted in Table 2 shows a decrease of the corrosion current density with the increasing SLS concentrations. The addition of SLS also leads to change in cathodic and anodic Tafel slopes. The corrosion potential is found to shift to more positive potential with increase in inhibitor concentration in presence of both the inhibitors. Thus the corrosion inhibition of mild steel in 1M HCl solutions is predominantly under anodic control. The inhibition efficiency is found to reach to a maximum value at 250 ppm inhibitor concentrations. The maximum values attained is 74 % in 1M HCl solutions in presence of 250 ppm concentrations of SLS at 35 °C.

Metallurgical research microscopy

In order to evaluate the conditions of the mild steel surfaces in contact with 1M HCl solutions, a superficial analysis was carried out. The micrographs of the specimens in presence of 1M HCl solutions are shown in Fig.4 (a). The influence of the SLS addition (250ppm) separately on the mild steel in Figs 4(b). It can be calculated from the figures that pitting corrosion does not occur and solid particles do not appear on the surface. The surface roughness of the mild steel appears lower with addition of the inhibitor than that without addition. The roughness is found to be more uniform after treatment with acidic solution which contains inhibitor.

**Figure 4 (a):** -Mild steel sample blank kept in 1 M HCl for 24 hours at 35⁰ C.**Figure 4 (b)** Mild steel sample kept in 1 M HCl for 24 hours with 250 ppm SLS at 35⁰ C

Corrosion inhibition of mild steel in acidic solution by SLS can be explained on the basis of adsorption. SLS inhibit the corrosion by controlling both anodic and cathodic reactions but predominantly anodic reaction is controlled.


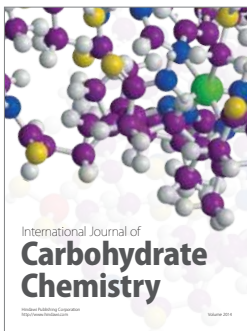
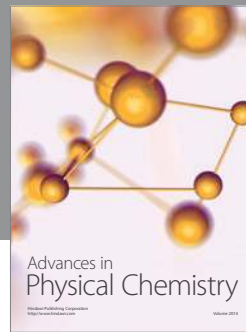
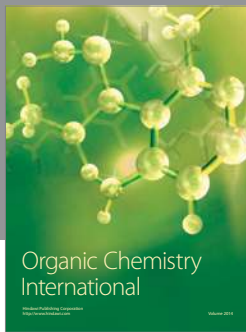
Conclusions

1. Sodium lauryl sulfate (SLS) inhibited mild steel corrosion in 1M HCl solutions.
2. Corrosion inhibition of mild steel in 1M HCl solutions by SLS is under anodic control.
3. Inhibition efficiency of SLS increases with increase in concentration.
4. The weight loss measurements are in good agreement with electrochemical method

5. The micrographs analysis has shown that inhibition of corrosion by SLS is due to formation of layer on the mild steel surface.

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