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Organic Corrosion Inhibitors for Aluminium in Sodium Hydroxide

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Inhibition of corrosion of aluminium in aqueous solutions of sodium hydroxide in the presence of sulfonic acid, sodium cumene sulfonate and sodium alkyl sulfate was studied in relation to the concentration of inhibitor and concentration of corrosive medium at various temperatures applying weight loss method. The additives tested were found to be good inhibitors for aluminium corrosion in aqueous solutions of sodium hydroxide in the studied concentration range. Due to the adsorption of the additive molecules on the metal surface the inhibition efficiency increases with increasing additive concentration, Sulfonic acid shows the best inhibition capability for aluminium corrosion in sodium hydroxide; probably, this is due to the planar orientation of the adsorbed additive molecules. Inhibition efficiency of the inhibitors tested increases with decreasing sodium hydroxide concentrations. The higher the temperature, the lower was the inhibition efficiency, which is due to the fact that the rate of corrosion of aluminium is higher than the rate of adsorption.

Key Words: **Aluminium, Sodium hydroxide, Corrosion, Inhibitors, Sulfonic acid, Sodium cumene sulfonate, Sodium alkyl sulfate, Weight loss.**

INTRODUCTION

Because of their lightweight and mechanical strength, aluminium and its alloys are very attractive materials for engineering applications. The interest of these materials arises from their importance in recent civilization. Inhibition of metal corrosion by organic compounds is a result of adsorption of organic molecules or ions at the metal surface forming a protective layer. This layer reduces or prevents corrosion of the metal. The extent of adsorption depends on the nature of the metal, the metal surface condition, the mode of adsorption, the chemical structure of the inhibitor and the type of corrosive media[1]. Heteroatoms in the structure of inhibitor molecules, such as oxygen, nitrogen, phosphorous, sulphur and the presence of aromatic rings or triple bonds enhance the adsorption process. It has been reported that the inhibition efficiency increases in the order: $O < N < S < P$[2–5]. Corrosion inhibition of aluminium and its alloys was the subject of numerous studies[6–13]. A literature survey showed only limited systematic work done to the corrosion inhibition of aluminium and its alloys in various corrosive media[14, 15].

The purpose of the present article is to study the application of sulfonic acid (SA), sodium cumene sulfonate (SCS) and sodium alkyl sulfate (SAS), as corrosion inhibitors for aluminium in aqueous solutions of sodium hydroxide. A literature survey revealed that the selected additives have never been tested as corrosion inhibitors for aluminium in sodium hydroxide.

EXPERIMENTAL

The inhibition efficiency of aluminium in aqueous solutions of sodium hydroxide by using sulfonic acid, sodium cumene sulfonate and sodium alkyl sulfate as inhibitors was determined by the weight loss method. The tests were performed with samples of aluminium in the form of rods measuring 30 by 3 mm diameter that were cut from commercial pure aluminium (Al 99.5%).

The aluminium samples were first abraded with emery paper 800, degreased with acetone, rinsed with distilled water, then dried. The organic inhibitors used were in pure form. AnalaR sodium hydroxide pills, dissolved in double distilled water to the selected concentrations, were taken as corrosive media. The tests were carried out at different concentrations of additives (25, 50, 100, 150 and 200 ppm) and concentrations of corrosive media (0.5, 1.0, 1.5 and 2.0 M) at temperatures (30, 40, 50 and 60°C). The volume of the test solution was 10 mL and the immersion time for each test was 30 min. A water thermostat controlled to ±0.5°C maintained the temperature.

The percentage inhibition (I%) of aluminium was determined from weight losses as follows:

$$I\% = \frac{W_0 - W_{in}}{W_0} \times 100\% \qquad (1)$$

where W_0 and W_{in} are the weight losses of aluminium specimens without and with inhibitor, respectively. The percentage inhibition was then plotted *vs.* concentration of additives and corrosive media at different temperatures.

The surface coverage (θ) was calculated from weight loss as follows:

$$\theta = \frac{W_0 - W_{in}}{W_0} \qquad (2)$$

RESULTS AND DISCUSSION

The curves in Fig. 1 represent the percentage inhibition (I%) of aluminium corrosion for various NaOH concentrations *vs.* the concentration of sulfonic acid in ppm at 30, 40, 50 and 60°C, respectively.

The corresponding curves for SCS and SAS showed similar behaviour as those of Fig. 1 but with less inhibition efficiency. For the three tested additives the percentage inhibitor (I%) increased with increasing inhibitor concentrations reaching a maximum value. This issue might be explained by the adsorption of inhibitor molecules forming mono-layer[16]. A very important criterion to characterize the efficiency of inhibitors is their efficiency to concentration ratio. High

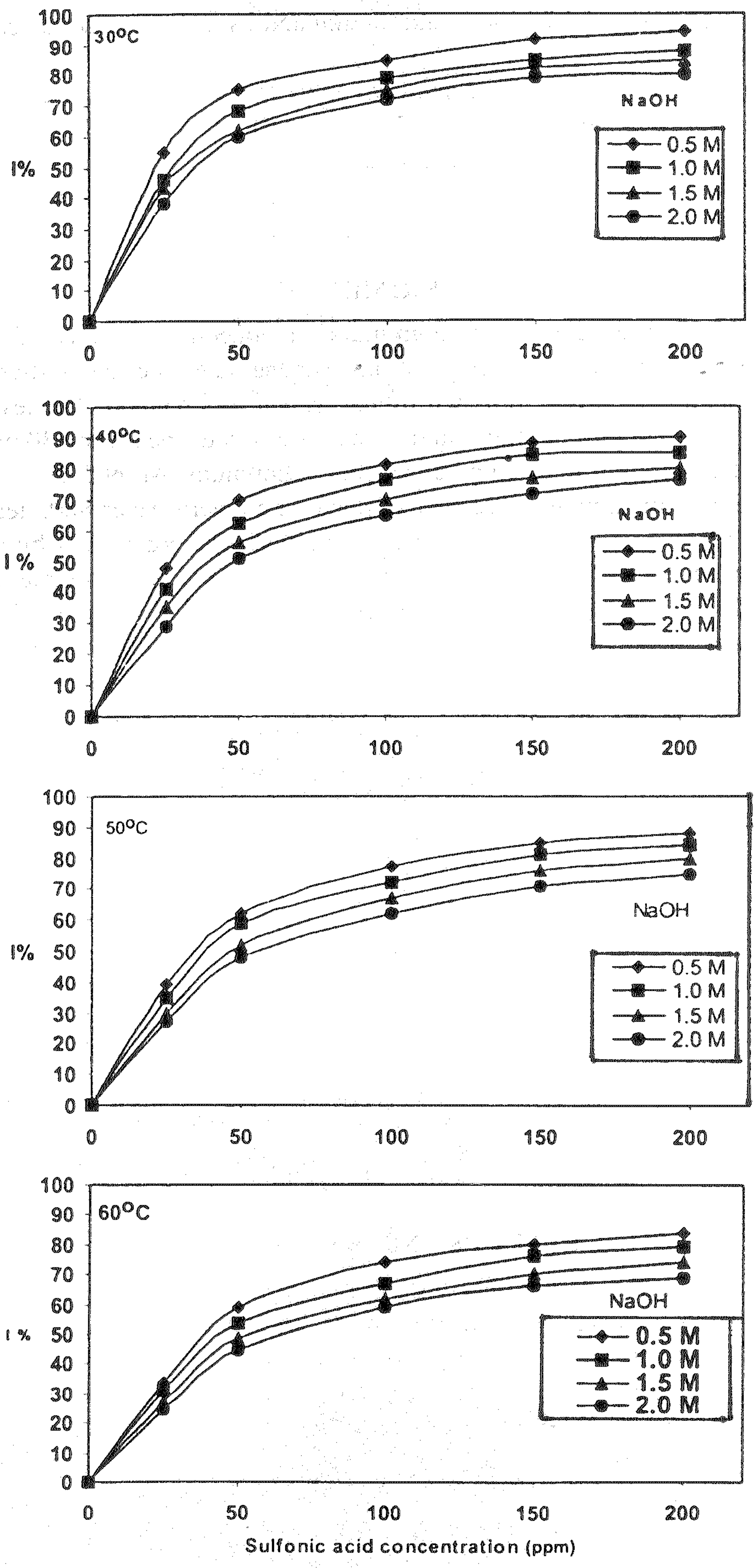

Fig. 1. Effect of SA concentration on inhibition efficiency of Al corrosion in NaOH

protection at low inhibitor concentrations is required, not only for economic reasons, but also to maintain appropriate inhibitor concentration and avoid insufficient inhibition[17]. The ratio for 200 ppm and 0.5 M NaOH at 30°C was calculated to 0.47, 0.42 and 0.33 for SA, SCS and SAS, respectively.

High rate of reaction relative to the rate of adsorption led to a slight decrease in the inhibition efficiency with increasing temperature, but the inhibitive effect still persists even at 60°C. This behaviour indicates that the adsorbed molecules formed a barrier film on the aluminium surface[18].

The effect of sodium hydroxide strength on the inhibition efficiency of the additives tested showed an increase in the efficiency with decreasing NaOH concentration, which was an evidence of applying NaOH as corrosive medium even at low concentrations.

Fig. 2 represents the variation of SA, SCS and SAS on aluminium corrosion in 0.5 M NaOH at 30°C with additive concentration. It is obvious that the efficiency decreases in the order: SA > SCS > SAS. To explain this trend one can say that both the benzene ring and the attached functional groups contribute to the inhibition action, which is also affected by the substituents on $(CH_2)_3$ benzene ring. Sulfonic acid molecules probably favour flat orientation on the metal surface to be adsorbed, while sodium cumene sulfonate molecules favour vertical orientation due to steric effect. Thus, sulfonic acid is better adsorbed and also has higher inhibition efficiency than SCS. Sodium alkyl sulfate was found to be a less efficient inhibitor than the others; this was due to its less adsorption on the metal surface.

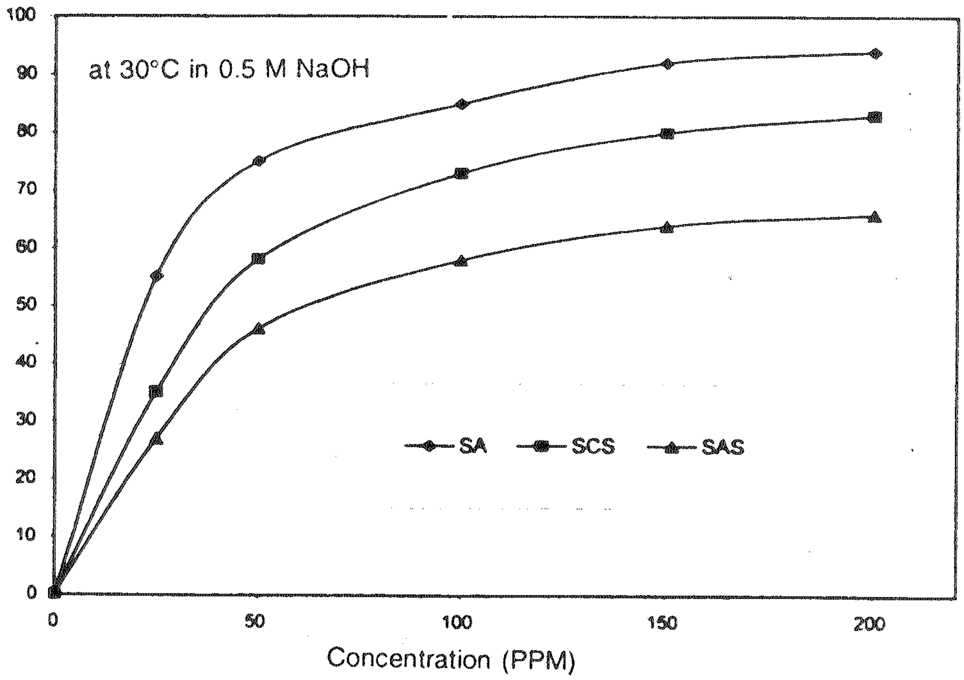

Fig. 2. Variation of inhibition efficiency of SA, SCS and SAS with inhibitor concentration in 0.5 M NaOH at 30°C

Fig. 3 shows the variation of the inhibition efficiency of SA, SCS and SAS with temperature in 0.5 M NaOH for 200 ppm inhibitor concentration. Higher efficiency was obtained for SA at lower temperature range. The limiting I% values, in Figs. 1 and 2, indicated the complete formation of the mono-layer film of additive molecules on the active sites of aluminium surface. Evidence for this conclusion was obtained by plotting Langmuir adsorption isotherms at 60°C.

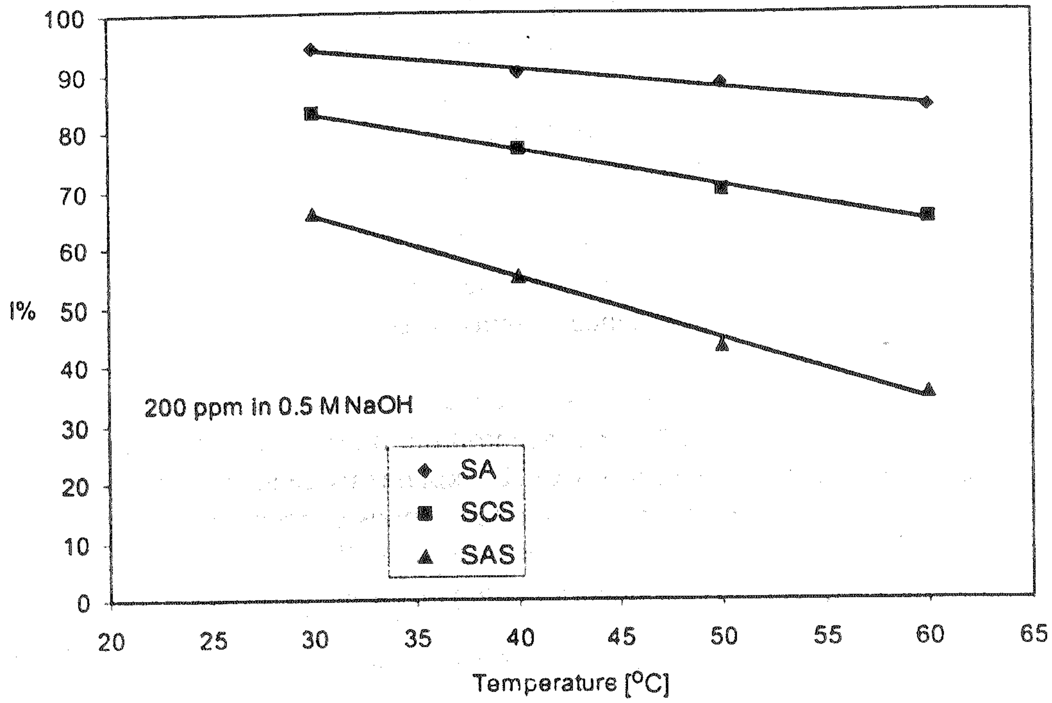

Fig. 3. Variation of inhibition efficiency of SA, SCS and SAS on Al corrosion with temperature for 200 ppm and 0.5 M NaOH

Fig. 4 represents the Langmuir isotherms for the effect of SA on the Al corrosion in various NaOH concentrations. The resulting parallel straight lines at different temperatures confirm that the inhibition was due to the adsorption of SA on the metal surface.

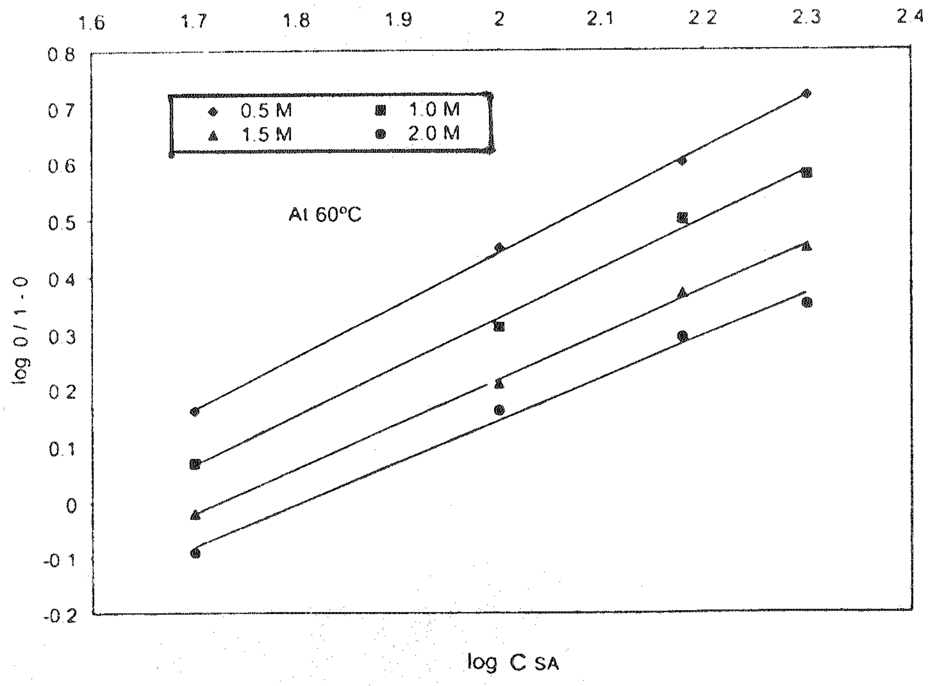

Fig. 4. Langmuir adsorption isotherms for SA in various NaOH concentrations at 60°C

The corresponding isotherms for SCS and SAS showed similar parallel straight lines. The degree of surface coverage (θ) varied linearly with the logarithm inhibitor concentration fitting Langmuir adsorption isotherm[19].

$$\log \theta/(1-\theta) = \log C + \log k \tag{3}$$

where k is the adsorption constant, C is the inhibitor concentration.

Fig. 5 shows Langmuir isotherms for SA, for aluminum corrosion in 0.5 M NaOH. The corresponding isotherms for SCS and SAS show similar shapes as those in Fig. 5.

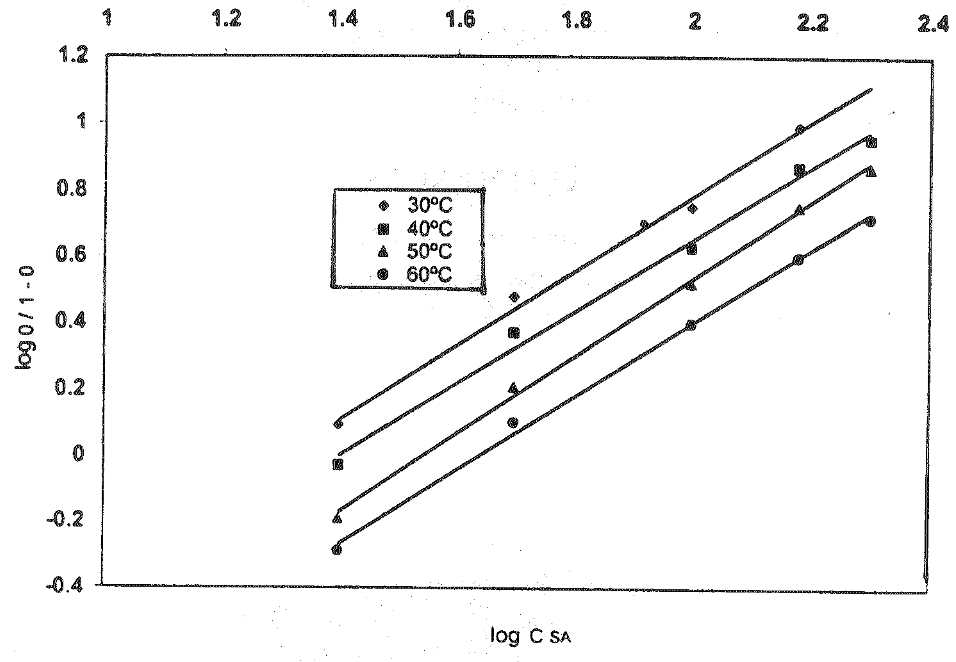

Fig. 5. Langmuir adsorption isotherms for SA in 0.5 M NaOH

Fig. 6 represents Langmuir isotherms for SA, SCS and SAS at 30°C and 0.5 M NaOH. This trend supports the obtained issue previously in Fig. 2.

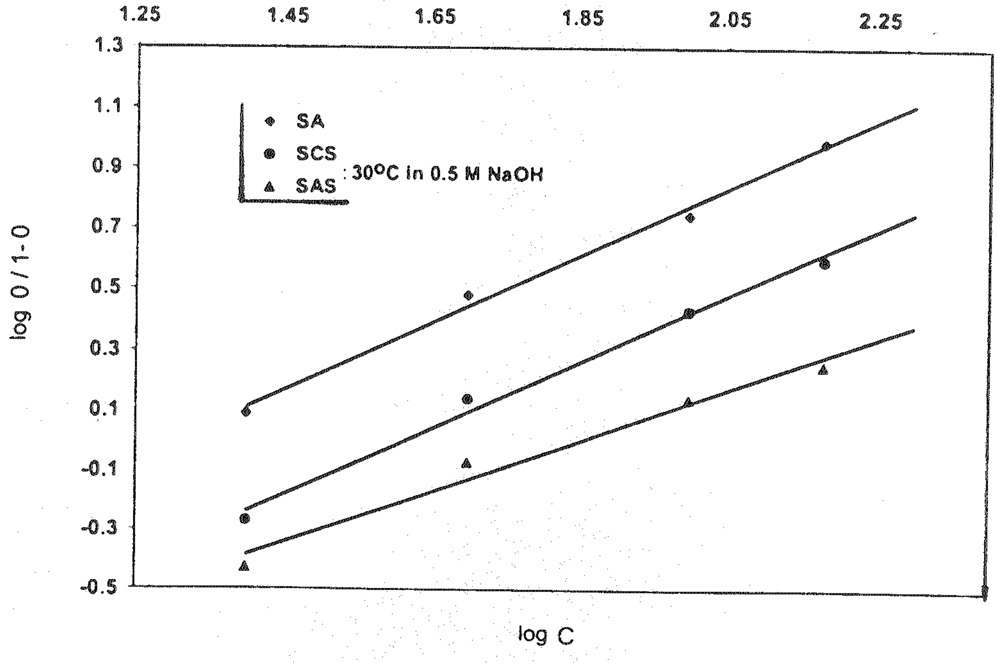

Fig. 6. Langmuir adsorption isotherms for SA, SCS and SAS at 30°C in 0.5 M NaOH

Conclusions

It can be concluded that:

1The organic compounds tested were beneficial inhibitors for aluminum corrosion in alkaline media and the inhibition efficiency varies in the order:

SA > SCS > SAS

2Inhibition efficiency increases with increasing inhibitor concentration and decreasing concentration of corrosive media.

3The higher the temperature the lower is the inhibition efficiency.

4Inhibition was attributed to adsorption of inhibitor molecules at the surface of aluminium, which fits the Langmuir adsorption isotherm.

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