GLUCOSE AS A CORROSION INHIBITOR FOR AN ALUMINUM ALLOY IN 0.1M SODIUM HYDROXIDE

By

Umoru L.E., Onike, A. & Ige O.O.
Department of Metallurgical and Materials Engineering
Obafemi Awolowo University

ABSTRACT

Inhibition of corrosion of an aluminum alloy in solution of sodium hydroxide has been studied with respect to the concentration of inhibitor, and temperature using gravimetric technique. The test specimens were exposed to 0.1M NaOH solutions containing controlled additions of glucose in the range 0 to 5.0%.

At constant alkali concentration the efficiency of inhibition increases with the increase in the concentration of the inhibitor. A rise in temperature increases the extent of corrosion and an inhibitive efficiency of 95-98% was achieved at the level of 5% of glucose in 0.1M NaOH in the temperature range 30 – 60^0C. The activation energies are rather slightly higher in inhibited than in the uninhibited alkali.

INTRODUCTION

Aluminum is one of the most abundant metal in the earth's crust and its supply is limited by the economics of mining, extracting and processing. Because of their light weights and mechanical strength, aluminium and its alloys are very attractive materials for engineering applications. The interest in them arises from their importance in the recent civilization.[1] Nearly all metals interact with the environments to which they are exposed in service. Aluminium like some metals when exposed to air forms an adherent surface oxide (Al_2O_3) that imparts on its surface good corrosion resistance. It is noteworthy however that the oxide is rather precipitated as aluminium hydroxide at pH values greater than 4.5 and less than 10[2]. As a result of the amphoteric nature of aluminium, the film fails to protect it in solutions that are strongly acidic or strongly alkaline.

Because of manufacturing stains from oils and greases, it is imperative to subject metals to cleaning processes after processing. Aluminium is often subjected to alkaline cleaning. The pickling of aluminum in caustic alkalis for degreasing prior to anodizing, painting, or to give an attractive material finish is common practice[3] The alkalinity of the medium often results in the corrosive attack of the metal. According to Tabrizi et al,[1] the corrosion of aluminium in sodium hydroxide solutions in the pH range 8-12 and at temperature between 30 and 60 deg is controlled by competitive processes involving film growth and dissolution. The film formed consisting of a compact inner barrier layer, adjacent to the aluminium substrate, and an outer crystalline layer of total thickness in the range 5-10 microns. To reduce corrosive attack during pickling the standard practice is to add an amount of inhibiting materials which forms on the surface a very thin film to prevent etching, pitting and tarnishing. Maayta has worked on the inhibition of aluminium corrosion in sodium hydroxide using sulfonic acid, sodium cumene sulfonate and sodium alkyl sulfate.[4] Corrosion inhibition of aluminium and zinc pigments by copolymers are also reported in the literature.[3]

Although several investigations have been carried out regarding inhibition in dilute sodium hydroxide,[3,5] the data produced are still inadequate. The purpose of this research is to investigate the ability and effectiveness of glucose as a corrosion inhibitor of an aluminum alloy in NaOH solution. Glucose, a non-toxic organic food compound and probably the most widely occurring sugar in nature is obtained by the hydrolysis of starch using either mineral acids or enzymes or a combination of both.

EXPERIMENTAL TECHNIQUE

Nigerian Aluminum Extrusion Company Limited, Lagos, supplied the aluminum alloy. The chemical composition of the alloy was found to be: 0.2071%Si; 0.0268%Mn; 0.0085%Cr; 0.2062%Fe; 0.528%Mg; 0.013%Ti; 0.0215%Cu; 0.0179%Zn; 0.0002%Ca and 98.97%Al. The specimens used for the determination of the corrosion rate were cut into rectangular sizes, each measuring about 3cm x 3cm with a small hole of about 4mm drilled near the edge of specimen for the purpose of suspension in the corrosion medium.

The test coupons had their surfaces ground on emery papers to 600 grit finish for the purpose of removing scratches during cutting and oxide layers on the specimen under a flux of water. The dimension of each coupon was measured carefully in order to determine the exposed areas. The polished coupons were first degreased with liquid soap followed by thorough rinsing in water and subsequent swabbing of sample surfaces with acetone. The dried specimens were weighed carefully on an analytical chemical balance in readiness for immersion test. After preparation them, the coupons were stored in desiccators in readiness for exposure.

The NaOH solution (0.1M) was prepared by measuring 4g of NaoH pellets, and distilled water was added to 1 dm^3. The test specimens were exposed to caustic soda solutions that have concentration of 0.1M and containing controlled additions (about 1 – 5%) of the glucose inhibitor. Specimens were weighed and subsequently suspended in the freshly prepared corrosion media by a thread to each specimen that was exposed to the atmospheric condition at $30^0C \pm 2^0C$ for 1 hour. The tests were repeated at 40^0C, 50^0C and 60^0C ($\pm 3^0C$).

After the tests, scrubbing with cotton wool under a tap water cleaned each of the specimens. Afterwards, the specimens were dried and reweighed to obtain the weight loss data.

RESULTS AND DISCUSSION

The results of this investigation are contained in the graphs of Figs. 1-4. The effectiveness of inhibition of the corrosion of the aluminium is given in terms of efficiency of inhibition,I defined as

$$I = 100\frac{W_u - W_i}{W_u}\% \qquad \text{-------------- (1)}$$

Where W_u and W_i are respectively the weight losses of the aluminium alloy in uninhibited and inhibited corrosion media. The corrosion rate has been assessed based on depths of penetration in millimeter per year (mmpy).

The corrosion reactions of aluminum in aqueous solutions of NaOH may be represented as:

$Al + NaOH + H_20 \;\; Na\,AlO_2 + 3/2\,H_2$ ...(2)

$Al + NaOH + 5H_20 \;\; Na^+ + [Al\ (OH)_4\ 2H_20]+ 3/2\,H_2$ .. (3)

As aluminum hydroxide is precipitated only at pH values > 4.5 and < 10^3, there is no possibility of reduced attack due to oxide film formation outside these limits, accounting for the rapid corrosion of aluminum in NaoH solutions.

Effect of Inhibitor Concentration

The effectiveness of glucose as an inhibitor for the corrosion of aluminium alloy vessels in the industry has been clearly demonstrated in Fig.1. The corrosion rate curves of the aluminium alloy in 0.1M NaOH solution at different temperatures decreased with increasing concentration of inhibitor (glucose). These corroborates the works of several other researchers who recently developed interests in the use of plant juice extracts as inhibitors.[6] It is believed that there are some active inhibiting chemicals and/or chemical compounds in plants that inhibit corrosion in aqueous or acidic/basic environments. Tannin has for instance being identified as the active compound in plants that effectively act as inhibitor for metals corroding in the above media Moresby[8]. Empirical results from the work of Loto [6] has shown juice extracts from cashew tree (*anarcadium occidentale*) notable for its tannin as been capable of inhibiting corrosion of mild steel in 0.5M HCl at 28^oC. It is therefore suspected that glucose probably contain this same chemical for its inhibition.

In studying the inhibitive effect of *Jasmium auriculatum* and *cordia latifolia* on the corrosion of mild steel in 3% NaCl, Farouqui and Quarishi observed that plant extracts followed the Langmuir and Freudlich adsorption isotherm.[7] That is, they inhibit corrosion by adsorption. This same phenomenon is confirmed again by the results of this study. It is so because the corrosion resistance of the mild steel in 0.1M NaOH increased with increase in concentration of the glucose as inhibitor. We are of the opinion that the increased corrosion resistance has to do with increase in adsorbed film thickness.

Evidently from the graph of Fig.1 it is clear that above 3% inhibitor concentration the film will be sufficiently strong enough to slow down the corrosion of aluminium alloy. This position is corroborated by the graph of efficiency of inhibition,I versus inhibitor concentration in Fig 2. All the curves of efficiencies at different temperatures followed the same trend and essentially exhibited optimal behaviour beyond 3% concentration of glucose in the 0.1M NaOH solution.

Effect of Temperature:-

In order to study the effect of temperature on inhibitor efficiency, the corrosion of aluminum alloy was studied in 0.1M NaOH with and without inhibitor, at solution temperatures of 30^0, 40^0, 50^0 and 60^0C (Fig.3). In 0.1M NaOH (uninhibited) the corrosion rate increased from 3.171 mmpy at 30^0C to 57.224 mmpy at 60^0C, that is there was an 18-fold increase in corrosion with a 3-fold increase in temperature. Fig. 2 illustrates the effect of temperature on the inhibitor efficiency. Similarly, in 0.1M NaOH (1% inhibitor) the extent of corrosion increased from 1.927 mmpy at 30^0C to 36.609 mmpy at 60^0C that is, there was an approximately 19-fold increase in corrosion with a 3-fold increase in temperature. The result corroborates the experimental fact that corrosion doubles for every 10^0C rise in temperature.

The values of the energy of activation E, for the corrosion process in inhibited as well as uninhibited were calculated from the equation:

$$\log \rho = \frac{-E}{2.303R}\left(\frac{1}{T}\right) \qquad \text{............... (4)}$$

Where ρ is the corrosion rates (mmpy) at the temperature T [^{o}K] respectively, E is the energy of activation, and R = 1.986 kcal per mole. Fig.4 is the graph of log ρ versus 1/T (where temperature is in degrees Kelvin, K)

It may be generalized that the average energy of activation for the corrosion process in uninhibited alkali (0.1M) is approximately - 19.448 kcal/mole, for the temperature range 30 – 60^0C. A comparison of the values of E in the presence and absence of inhibitors indicate that the values of inhibited alkali are slightly higher than those for uninhibited alkali.

According to Putilora et al[9] the higher values of E in the presence of the inhibitor indicate physical adsorption of the inhibitor on the metal surface. In such case the extent of the inhibitor which would expose greater area of the metal to the corrosive medium.

Mechanisms of Glucose Inhibition: -

Glucose dissociates in aqueous solutions as shown in equation (5):

$$CHO\,(CHOH)_4\,CH_2OH + H_20 \longrightarrow CHO\,(CHOG)_4\,CH_20^- + H_20 \quad .. (5)$$

It forms gluconate ion when it is added to caustic alkalies and the equilibrium is displaced to the right:

$$CHO\,(CHOH)_4\,CH_2OH + NaOH \rightleftharpoons CHO\,(CHOH)_4\,(CH_2O^-) + Na^+ + H_2O \quad .. (6)$$

The gluconate ion because of the net negative charge, preferably on the oxygen atom, may get attached to the anodic points of the metal surface due to electrostatic attraction or may form an insoluble firm due to chemisorption. The forces of attachment are likely to be somewhat stronger, and therefore even though the temperature is raised, the energy is insufficient to break the metal – inhibitor bond and hence the relative constancy of inhibitor efficiency. The very slight decrease in inhibitor efficiency at high temperature may be traced to the stirring effect caused by evolution of hydrogen, which might disturb the inhibitive film.

CONCLUSION

It may therefore be concluded that the inhibitive efficiency of glucose increases with increase in the concentration of the inhibitor and reaches a value of about 94.30 to 97.80% at 5% concentration of the inhibitor. Temperature does not appear to have any significant effect on the efficiency of the inhibitor. The values of the energy of activation are slightly higher in inhibited than in uninhibited alkali and this suggests that the inhibitor acts by physical adsorption on the metal surface.

Based on the results of this study and in addition to the fact that glucose has no associated health hazard like most of the other inhibitors, glucose can be recommended for use to inhibit the corrosion of aluminum alloy containers when subjected to alkaline cleaning in NaOH solution.

REFERENCES

1. **Tabirizi, M.R., Lyon, S.B., Thompson, G.E., Ferguson, J.M.** (1991). The long term corrosion of aluminium in alkaline media, Corrosion Science. Vol. 32 No. 7, pp 733-742.

2. **Scully, J. C.,** "Corrosion" (Academy Press, Orlando), 349. (1983).

3. **Maayta, A.K.** (2002) Organic inhibitors for aluminium in sodium hydroxide. Journal of Corrosion Science and Engineers, Vol. 3 No. 25.

4. **Muller, B., Schubert, M. and Oughourlian, C.** (2001) Corrosion inhibition of aluminium and zinc pigments by copolymers, Corrosion Science, Vol.30, No. 1 pp 6-12.

5. **Talati, J. D. and R. M. Modi**, Phenols and Methyl Phenols (cresols) as Corrosion Inhibitors for Al – Cu Alloy in Sodium Hydroxide, J. Corrosion Prevention and Control, Vol. 24, No 2, pp 6 – 10 (1977).

6. **Loto, C.A. and Mohammed, A.** The effects of cashew juice extract on corrosion inhibition of mild steel in HCl (2000).

7. **Farouqui, I.H. Nasir, M.A. and Quarishi(1997)** Environmentally friendly formulation for industrial cooling system, Corrosion Prevention and Control 45, 5.

8. **Moresby, J.** (1988)Toxic inhibitors, Corrosion Australia, 10, 2 10-12.

9. **Putilora, I. N., V. P. Barannik and Balezin, S. A.**,(1960) "Metallic Corrosion Inhibitors" (Pergamon Press, Oxford), 30.

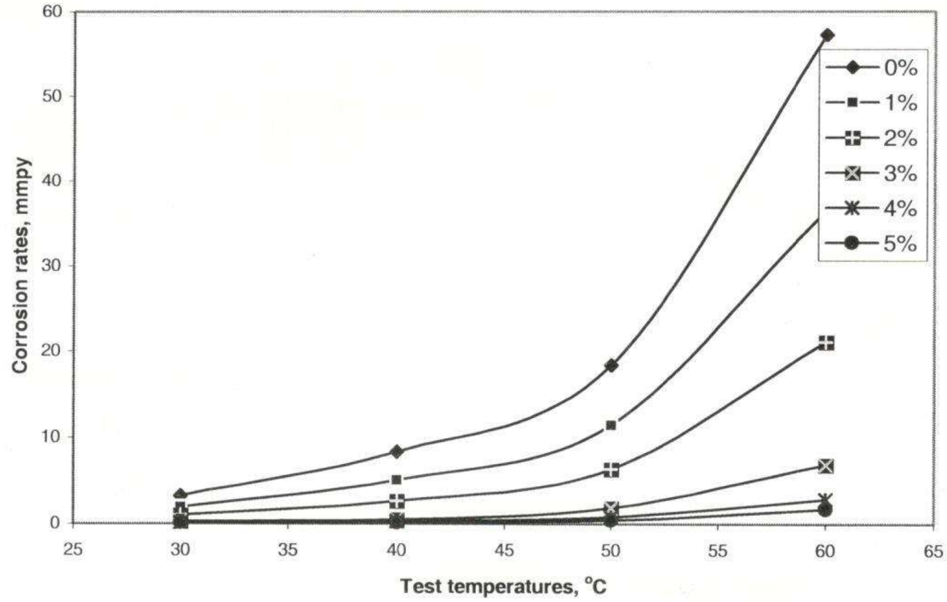

Fig.1. Effect of inhibitor concentration on the corrotion rates of aluminium alloy at different temperatures

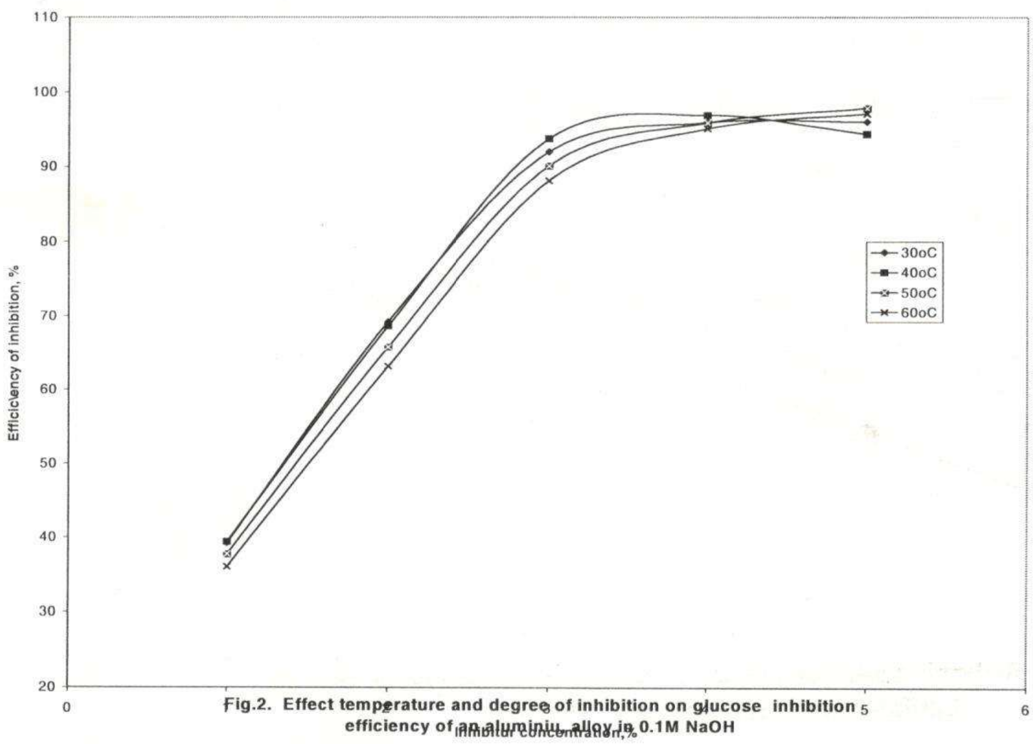

Fig.2. Effect temperature and degree of inhibition on glucose inhibition efficiency of an aluminiu alloy in 0.1M NaOH

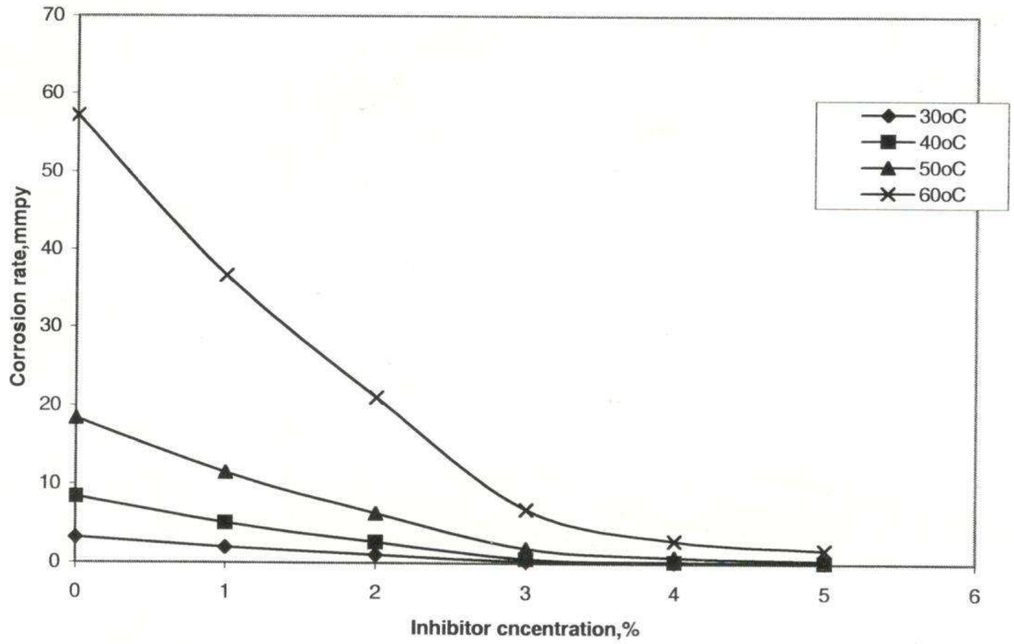

Fig.3 Effect of temprature on the corrosion rate of an aluminium alloy in 0.1M NaOH with different proportions of glucose inhibition

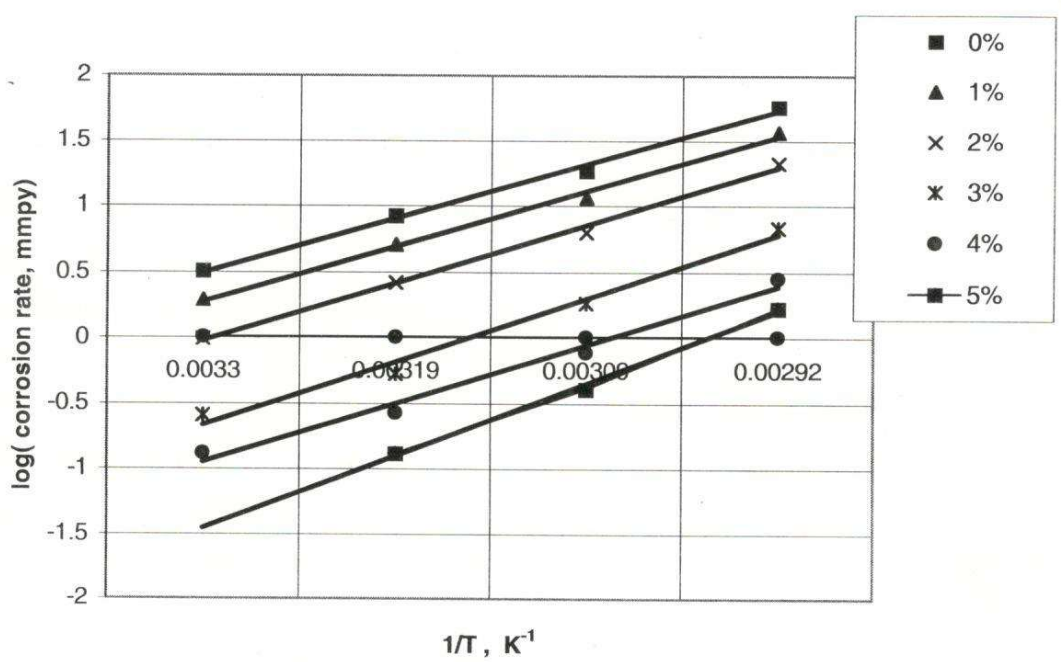

Fig.4 Arrhenius plot for corrosion of an aluminium alloy in inhibited and uninhibited 0.1M NaOH