

THE USE OF *Vernonia amygdalina* (BITTER-LEAF) EXTRACT AS CORROSION INHIBITOR FOR AA7075 ALUMINIUM ALLOY IN HCl AND NaOH MEDIA

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ABSTRACT

The effect of machining on corrosion behavior of AA7075 in 0.5M HCl and 0.5M NaOH solution was investigated using Gravimetric-based mass loss method at different concentrations of *Vernonia amygdalina* (inhibitor) and exposure time of 72, 144, 216 and 288 hours. The alloy was sand cast by the conventional sand casting technique, after which two sets of coupons of dimension 12 mm by 20 mm were obtained by orthogonal and oblique machining operations at a cutting speed and feed rate of 556 rev/min and 4 mm/rev respectively. They were then immersed in two different corrosive media (0.5M HCl and 0.5M NaOH) in the absence and presence of Bitter leaf extracts (inhibitor) at different concentrations of 0.25M, 0.5M and 1.0M. From the results obtained, the susceptibility of the coupons to corrosion when immersed in HCl solution in the presence of inhibitor was lower compared to those exposed to NaOH solution. It was also observed that obliquely-machined samples were less susceptible to corrosive attack than orthogonally-machined samples in NaOH solution at room temperature. The maximum Inhibition Efficiencies (IE%) for the obliquely-machined samples were 88.9% and 82.1% in HCl and NaOH respectively. Similarly, maximum IE% values of 90% and 80% were achieved for the orthogonally-machined samples in HCl and NaOH respectively.

Keywords: Aluminium alloy AA7075, corrosion rate, inhibition efficiency, bitter leaf, oblique, orthogonal machining.

1.0 INTRODUCTION

Aluminium is second to Iron in terms of production and consumption and is the most important metal of commerce in the United States (Schweitzer, 2007). Attention has been given to alloys of aluminium and other low-density metals e.g. Mg, Ti as engineering materials for transportation to effect reduction in weight and fuel consumption (Callister, 2007). AA7075 is categorized as an alloy of aluminium containing about 5.6% zinc as its major alloying element with small percentages of magnesium, copper and chromium.

Machining is the most effective method of producing desired shape and size of a metallic material by removal of excess material from selected areas. It is well understood that during machining of metals, the quality of the surface finish generated depends on the cutting parameters such as the cutting speed, feed rate, tool materials, tool geometry, and presence of lubricant in the cutting region. The machined surface of

the material contains residual stresses, the magnitude and nature of which depend on the parameters above. The geometric defects on the surface consist of grooves parallel to the direction of relative motion of tool, fine scale, chatter marks, cavities, surface roughness and other stress raisers (Ramankurishnan, 1985).

Most aluminum alloys are susceptible to corrosion in both acidic and basic environment and as such inhibitors are used to curtail the effect of corrosion. It is generally established that organic molecules inhibit corrosion by adsorption at the metal/solution interface; the degree of adsorption depends on the chemical structure of molecules, chemical composition of solutions, the nature of metal surface, the temperature and the electrochemical potential. The main types of adsorption are electrostatic, chemisorptions, and π -bond (delocalized electron) (Kirk, 1989).

Hosary and Selim (1984) reported that products of plant origin contain different organic compounds (e.g. alkaloids, tannins, pigments, organic and amino acids) and are mostly known to inhibit corrosion. Most of the well known acid inhibitors are organic compounds that contain nitrogen, sulphur, oxygen and multiple bonds in their molecules through which they adsorb onto substrates (Martinez and Stern, 2003). The inhibitive action of some plants was attributed to the presence of different phytoconstituents (e.g tannins) in their chemical composition. Tannins are natural products characterized by their ability to precipitates proteins. They are high molecular weight compounds with many phenolic groups, distinguished by three principal groups the condensed, the hydrolysable (gallotannins and ellagitannins) and the pholorotannins (Ramesh *et al*; 2003; Hagerman, 1988).

The present investigation is centered on evaluating the corrosion behaviour of machined AA7075 aluminum alloy in the presence of bitter-leaf extract as an inhibitor.

2.0 EXPERIMENTAL

The aluminum alloy AA7075 was cast, by conventional sand casting method, to cylindrical shapes of dimension 22mmx30mm and then machined (orthogonal and oblique) with the aid of a lathe machine to average size of 12mmx20mm at a cutting speed and feed rate of 556rev/min and 4mm/rev respectively. The samples (coupons) were then abraded with series of emery/ grinding papers (220-600 grades), polished, rinsed with distilled water, degreased with ethanol, and dried at room temperature. They were then weighed using analytical balance and the readings recorded as the initial weight (W_i) of the coupons before being stored in a desiccator.

Extraction of the desired phytoconstituents of *Vernonia amygdalina* (Bitter leaf) was achieved through the use of a Soxhlet extractor according to the method reported by Hagerman (1988) and Vashi and Champaneri (1997). Initially, leaves of *Vernonia amygdalina* (Bitter leaf) plant

were obtained, sun-dried and pulverized using mortar. 500g of the pulverized powder was placed in a thimble and loaded into the main chamber of the Soxhlet extractor. The extractor was then placed on a flask containing ethanol (the extraction solvent), heated to reflux and the vapour flooded to the chamber housing the powder via the distillation arm of the extractor. Consequently, some of the powdered plant materials that dissolved in the warm solvent were emptied by a siphon. The solvent was channeled back to the distillation flask and the cycle repeated many times to achieve maximum extraction of some phytoconstituents. Different concentrations (0.25M, 0.5M and 1.0M) of *Vernonia amygdalina* (Bitter leaf) were prepared from the crude extract and kept in a cool, dry place. The phytochemical screening of the extracts was carried out in a similar fashion adopted by Auwal (2008).

The electrolytes used were 0.5M HCl acid dissolved in 1dm³ of distilled water and 0.5M of alkaline solution prepared by dissolving beads of appropriate weight of NaOH in 1dm³ of distilled water.

Four (4) beakers were washed and cleansed using a smooth cloth and the acid electrolytes were poured in. Three of the beakers each contained 0.5M HCl acid with 0.25, 0.5 and 1.0M concentrations of Bitter leaf extracts (inhibitor). The fourth beaker, the control, contained only the acidic solution. In each beaker, obliquely-machined coupons were totally immersed (suspended by a piece of thread) and were left for 3 days (72 hours). The procedures were repeated at different exposure times of 6 days (144 hours), 9 days (216 hours) and 12 days (288 hours) using fresh samples. The orthogonally-machined samples were also subjected to the same procedures elucidated above. After the lapse of each period, the samples were removed, washed with brush, dried and re-weighed. The final weights (W_f) were recorded and the weight losses computed using equation (1).

$$\Delta W = W_i - W_f \quad (1)$$

ΔW is the mass loss (g)

W_i is the initial mass of the coupon (g)

W_f is the final mass of the coupon (g)

In each case, also, the Corrosion Penetration Rate (CPR), in mpy, was computed using equation (2) below:

$$CPR = \frac{534\Delta W}{\rho At} \quad (2)$$

ΔW , ρ , A , and t are specified in units of milligrams, grams per cubic centimeter, square inches, and hours, respectively (Callister, 2007).

The Inhibition Efficiencies (IE%) were also calculated using equation (3), adopted from Quraishi and Jamal (2002), as follows:

$$IE\% = \left(\frac{r_o - r}{r_o} \right) 100\% \quad (3)$$

r_o and r are the corrosion rates in the absence and presence of inhibitors respectively.

3.0 RESULTS AND DISCUSSION

Table 1 below shows the results of phytochemical screening of the bitter leaf extracts. The presence of some of these phytoconstituents, most especially tannins, in the bitter leaf extracts might be responsible for its inhibitive action. Furthermore, the twin presence of heteroatoms of nitrogen and sulphur might have provided active centers of adsorption of the extracts onto the surfaces of the test coupons, thereby facilitating the adsorption of some phytoconstituents onto the substrate. This is in agreement with earlier research by Tang *et al.* (2003).

Table 1: Results of the phytochemical screening of Bitter leaf extract.

Chemical constituent	Bitter leaf
Alkaloids	+
Anthraquinones	+
Saponins	+(0.64%)
Tannins	+(0.9%)
Steroids and Terpenoids	+
Nitrogen	+
Sulphur	+

Note: + indicates presence, - absence

Visual Examination of the Coupons Exposed to the Aggressive Sodium Chloride Medium

The shiny appearance of the coupons was compromised after exposure to the different systems, probably due to corrosion products

and adsorbed substances. The observed high corrosion rates of the alloy might not be unconnected with the large amounts of alloying additives which make the alloy susceptible to different types of corrosion.

From Figures 1-4, it could be seen that the corrosion rate is higher for uninhibited (Blank) samples in all the cases examined. A decrease in corrosion rate was observed as the inhibitor concentration and exposure time were increased. The decrease in corrosion rates in the presence of bitter leaf extract could be as a result of adsorption of some molecules of the bitter leaf onto the surfaces of the alloy which might prevent the permeation of ions into the metal and is accomplished by forming a protective film or layer on the metal surface. The protective film or protective barrier film formed might have effectively isolated the metal from the corrosive environment, or induced the formation of precipitates that block the corrosive agents from accessing the metal as reported in earlier works by Tang *et al.* (2003) and Quraishi and Jamal (2002).

It is possible that inhibition might not only be due to adsorption. Recent investigation has highlighted the importance of electrochemical reactions between the different ions and the substrates, leading to formation of compounds that may shield the metal from aggressive electrolyte, as the major factor in the formation of protective films. Additionally, the interactions of inhibitors with the corrosion products might have altered the electrophysical properties of surface atoms by donor-acceptor inhibitor/metal reaction, rather than screening the metal surface from the corrosive environment. Furthermore, corrosion products may be present as a thin, well-adhering, oxidic surface film which protects the underlying metal from further corrosion by formed a passive film. There is evidence that many organic and inorganic inhibitors become effective through interaction with one of several corrosion products to form a new protective phase rather than by adsorption onto the metal surface. This is in line with other publications by Fontana and Greene (2005), Frankel (2003) and Fisher (1971).

From Figures 5-8, it could be seen that the corrosion rates for inhibited samples were high at first and then maintained constant rates and gradually decreased as the concentration and exposure time were increased.

It could also be seen that the orthogonally machined samples had higher corrosion rates than the obliquely machined samples in both NaOH and HCl solutions.

The high corrosion rates of orthogonally-machined coupons could be due to improper/or no clearance angle between the tool face and work piece attributed to this type of machining; this might have introduced some residual stresses which may change the internal orientation and structure of alloy and render it vulnerable to corrosive attack as reported by Ramakrishna (1985).

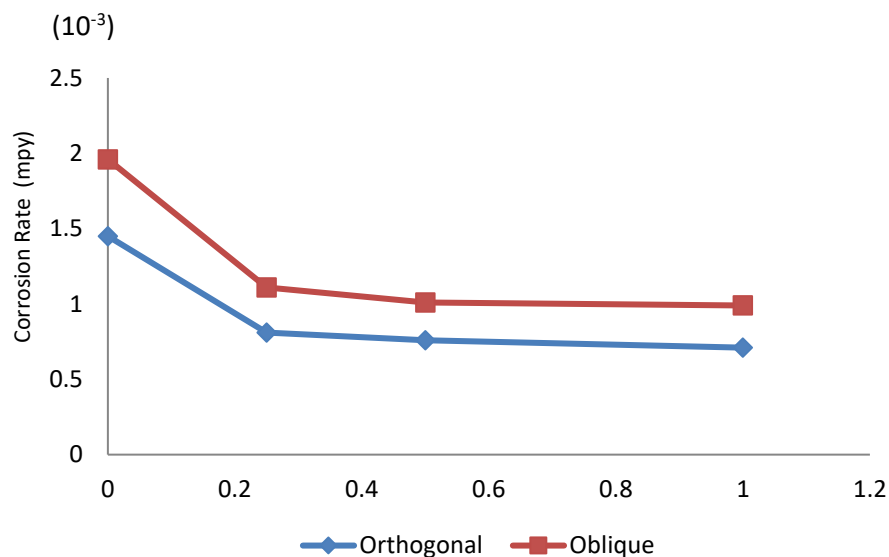


Figure 1: Variation of corrosion rates with inhibitor concentrations for both orthogonally and obliquely machined samples in 0.5M HCl after 72 hours

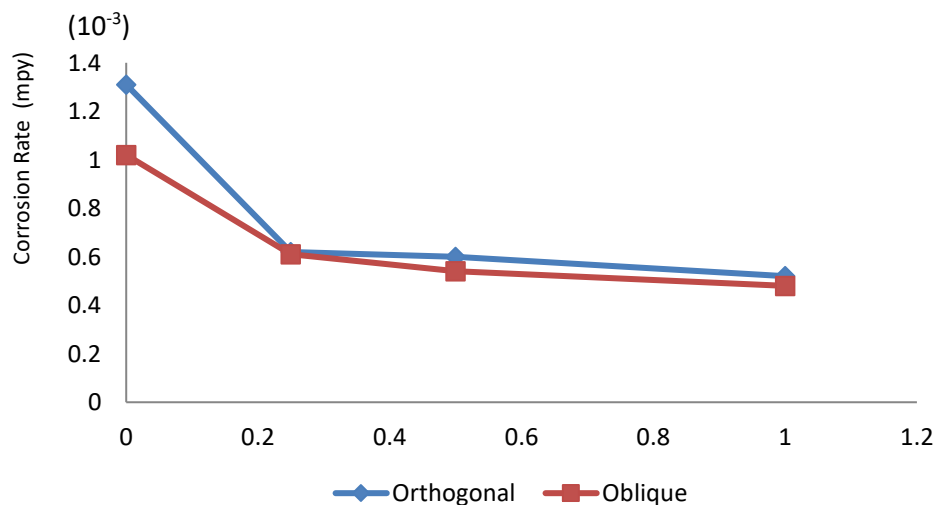


Figure 2: Variation of corrosion rates with inhibitor concentrations for both orthogonally and obliquely machined samples in 0.5M HCl after 144 hours.

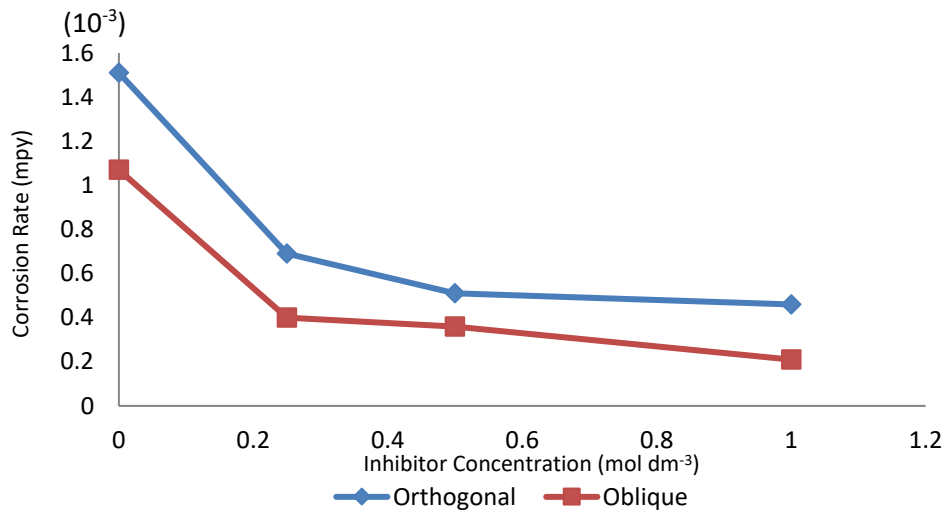


Figure 3: Variation of corrosion rates with inhibitor concentrations for both orthogonally and obliquely machined samples in 0.5M HCl after 216 hours.

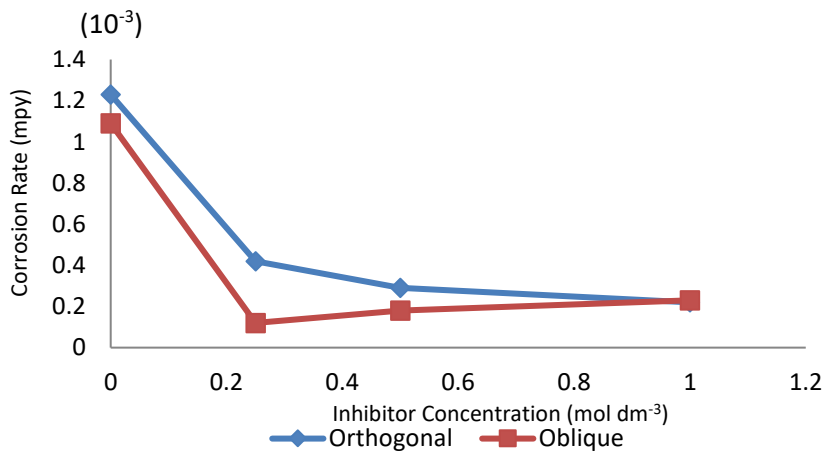


Figure 4: Variation of corrosion rates with inhibitor concentrations for both orthogonally and obliquely machined samples in 0.5M HCl after 288 hours.

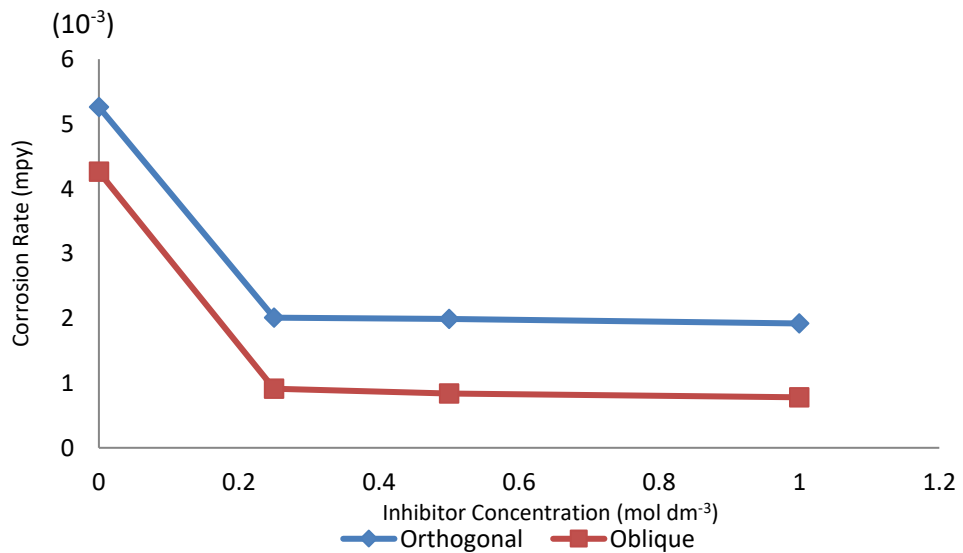


Figure 5: Variation of corrosion rates with inhibitor concentrations for both orthogonally and obliquely machined samples in 0.5M NaOH after 72 hours.

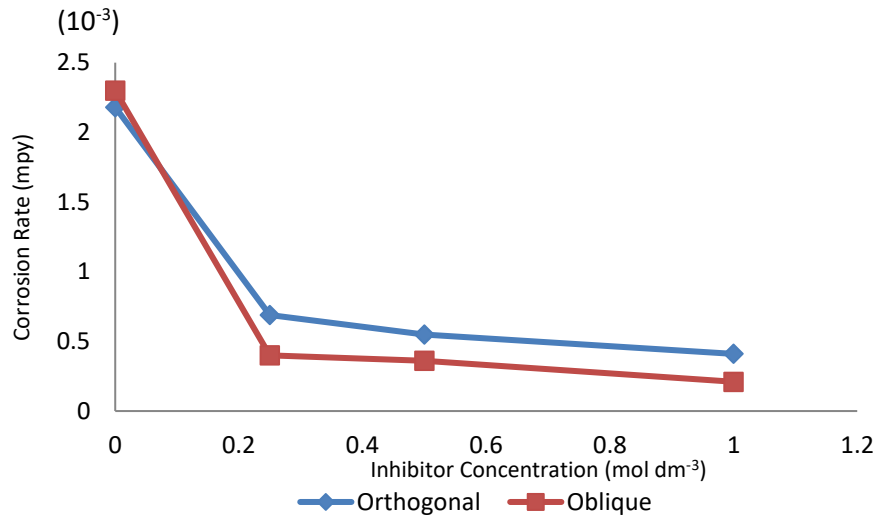


Figure 6: Variation of corrosion rates with inhibitor concentrations for both orthogonally and obliquely machined samples in 0.5M NaOH after 144 hours.

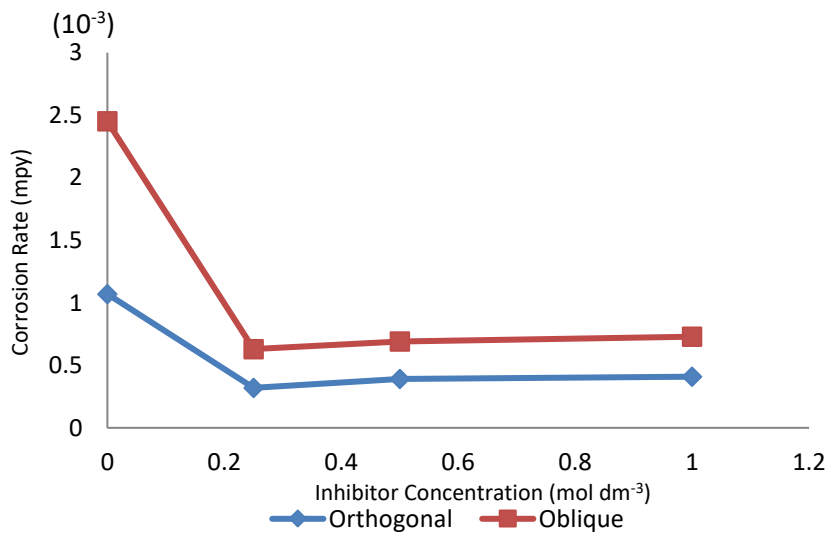


Figure 7: Variation of corrosion rates with inhibitor concentrations for both orthogonally and obliquely machined samples in 0.5M NaOH after 216 hours.

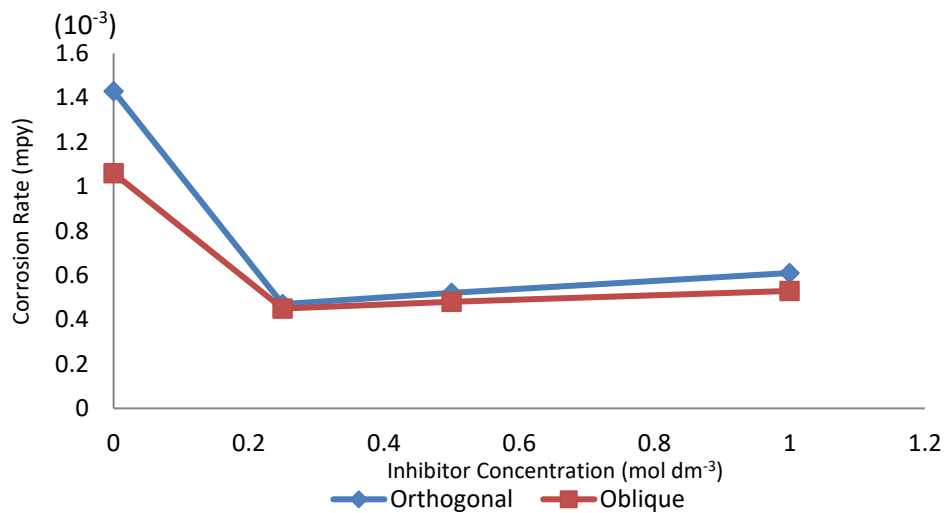


Figure 8: Variation of corrosion rates with inhibitor concentrations for both orthogonally

From Figures 9-16, it could be seen that the inhibition efficiencies for both orthogonally and obliquely-machined samples increased with increase in inhibitor concentration and exposure time in all the cases examined. In HCl, the maximum and minimum inhibition efficiencies (IE%) for oblique and orthogonal machined samples were 88.3% and 82.1%, 44.1% obtained at 72 hours and 288 hours exposure time respectively. It was observed that as the concentration of the extract and exposure time were increased, the inhibition efficiencies increased, probably due to increased adsorption of the extract molecules onto the alloy surfaces, leading to the blockage of the active corrosion sites.

This is in agreement with earlier researches by Auwal (2008) and Ebenso *et al.* (2004). The maximum and minimum inhibition efficiencies (IE%) in case of obliquely and orthogonally machined samples in NaOH were respectively 90%, 55% and 80%, 62% obtained after 144 hours. Similarly, the inhibition efficiencies increased as the inhibitor concentration was increased. A gradual reduction of inhibition efficiency with increase in concentration and exposure time was observed, this might be due to the attainment of optimum inhibitor concentration beyond which further increase in concentration has negligible effect on the mechanism or efficiency of inhibition. This is in line with earlier research by Ekpe *et al.* (1994).

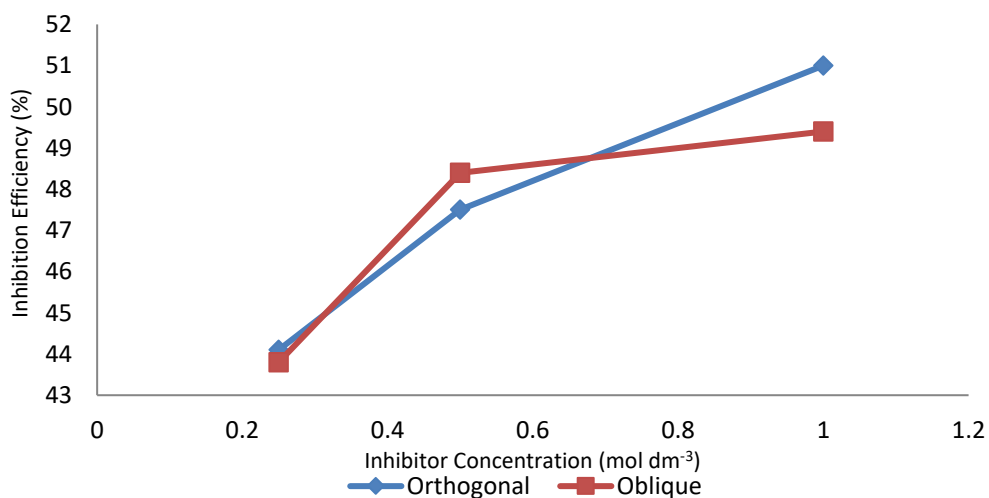


Figure 9: Variation of inhibition efficiencies with inhibitor concentrations for both orthogonally and obliquely machined samples in 0.5M HCl after 72 hours.

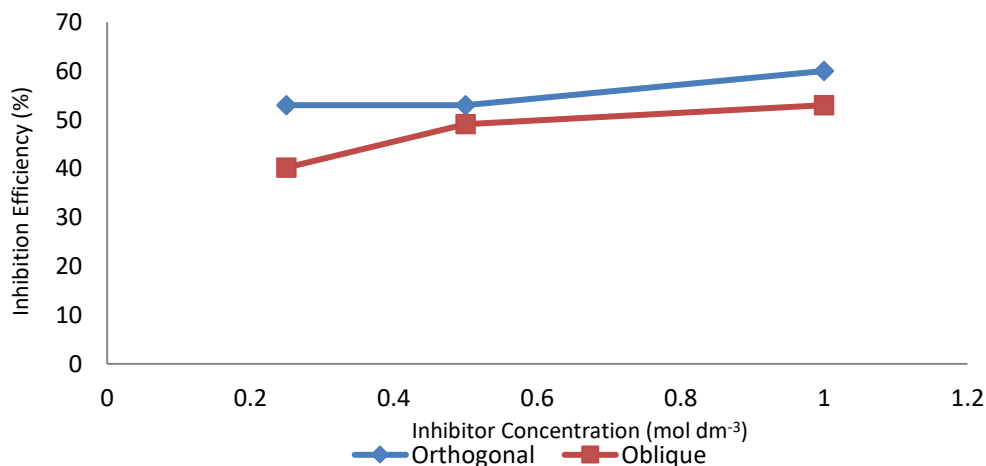


Figure 10: Variation of inhibition efficiencies with inhibitor concentrations for both orthogonally and obliquely machined samples in 0.5M HCl after 144 hours.

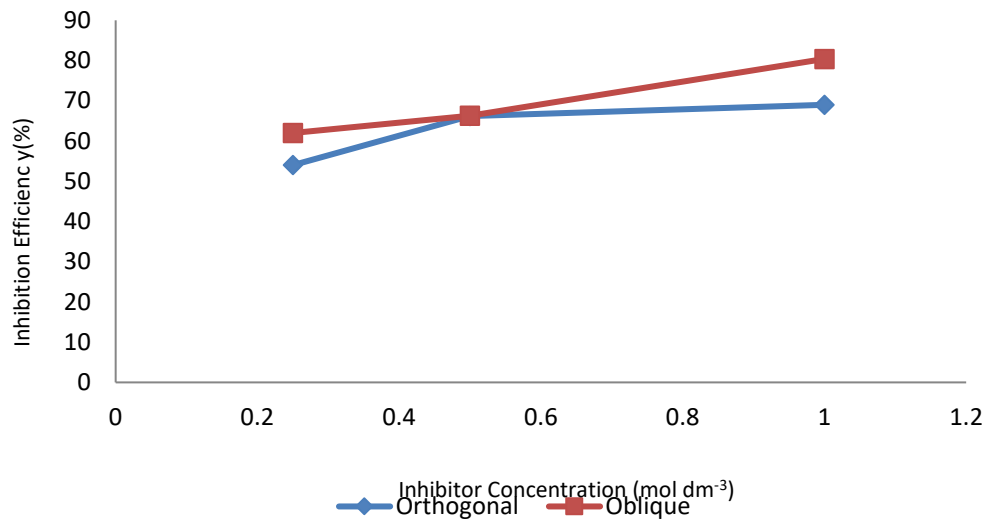


Figure 11: Variation of inhibition efficiencies with inhibitor concentrations for both orthogonally and obliquely machined samples in 0.5M HCl after 216 hours.

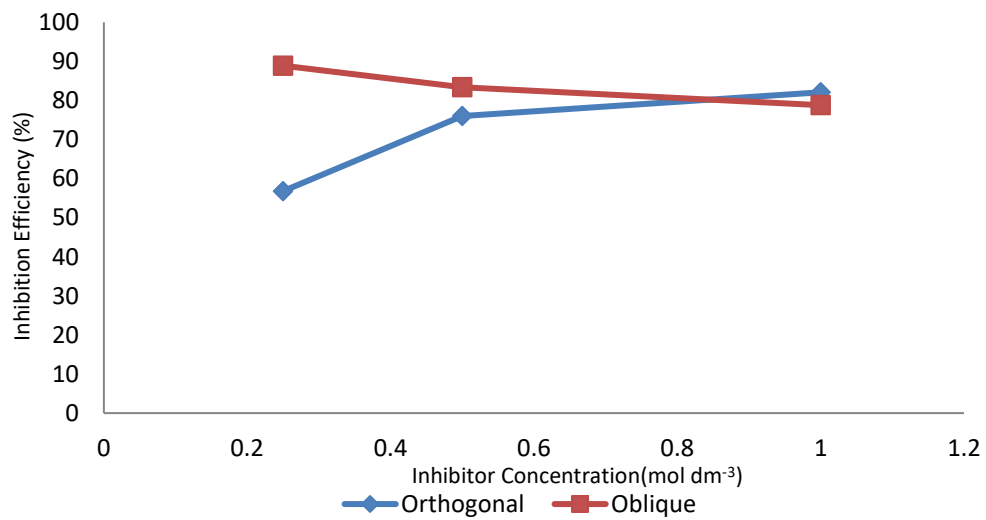


Figure 12: Variation of inhibition efficiencies with inhibitor concentrations for both orthogonally and obliquely machined samples in 0.5M HCl after 288 hours.

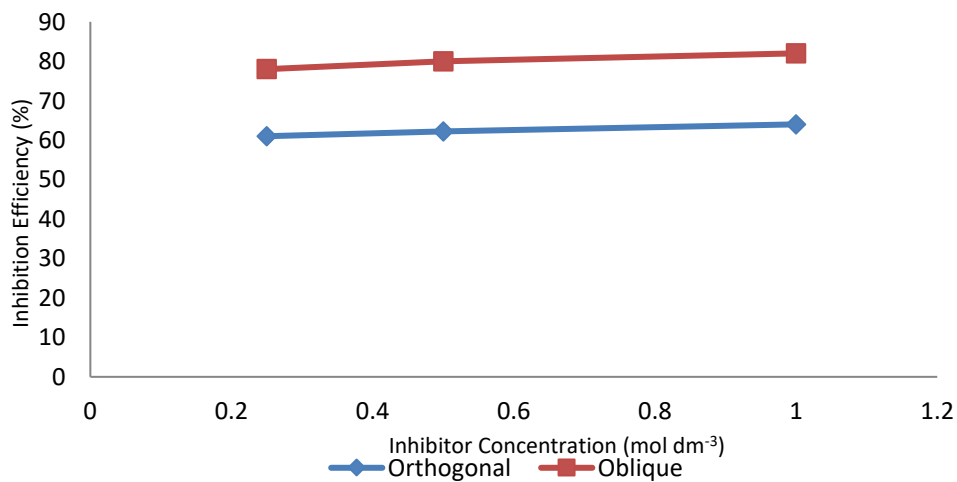


Figure 13: Variation of inhibition efficiencies with inhibitor concentrations for both orthogonally and obliquely machined samples in 0.5M NaOH after 72 hours.

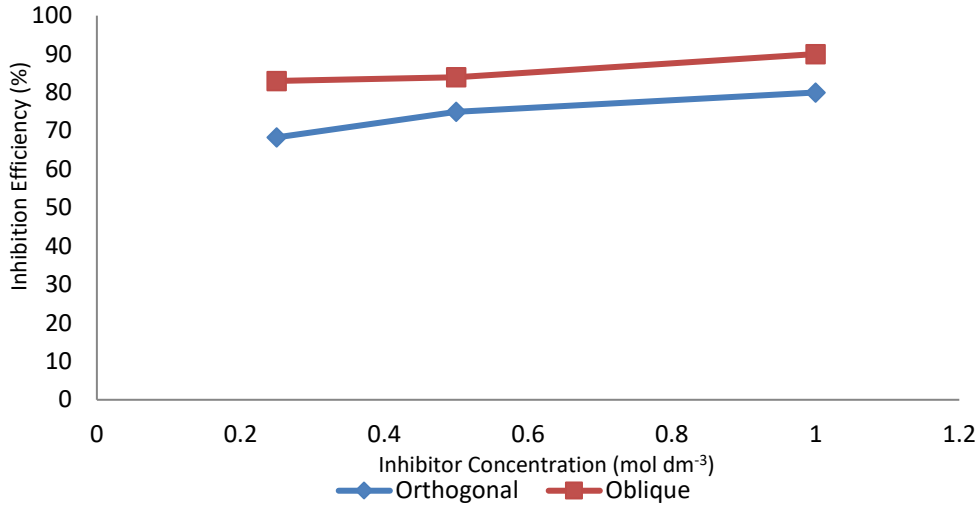


Figure 14: Variation of inhibition efficiencies with inhibitor concentrations for both orthogonally and obliquely machined samples in 0.5M NaOH after 144 hours.

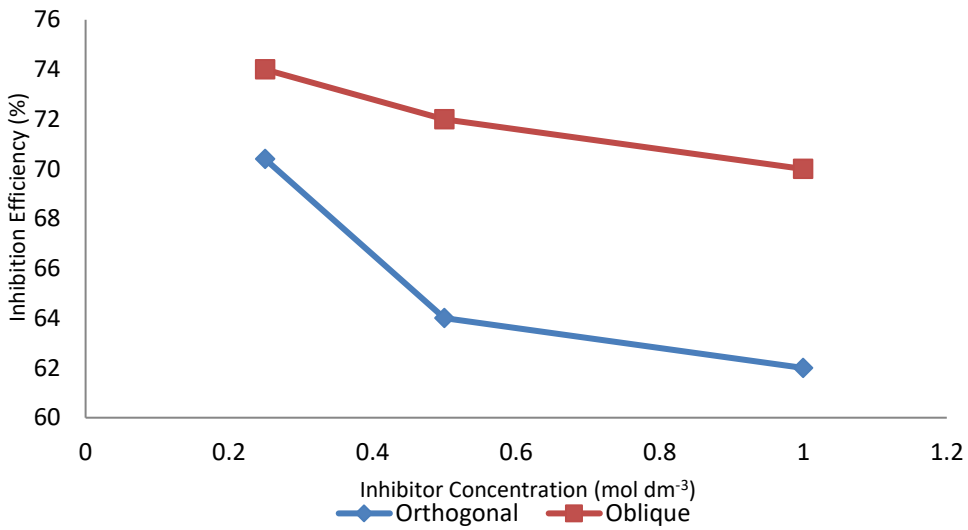


Figure 15: Variation of inhibition efficiencies with inhibitor concentrations for both orthogonally and obliquely machined samples in 0.5M NaOH after 216 hours.

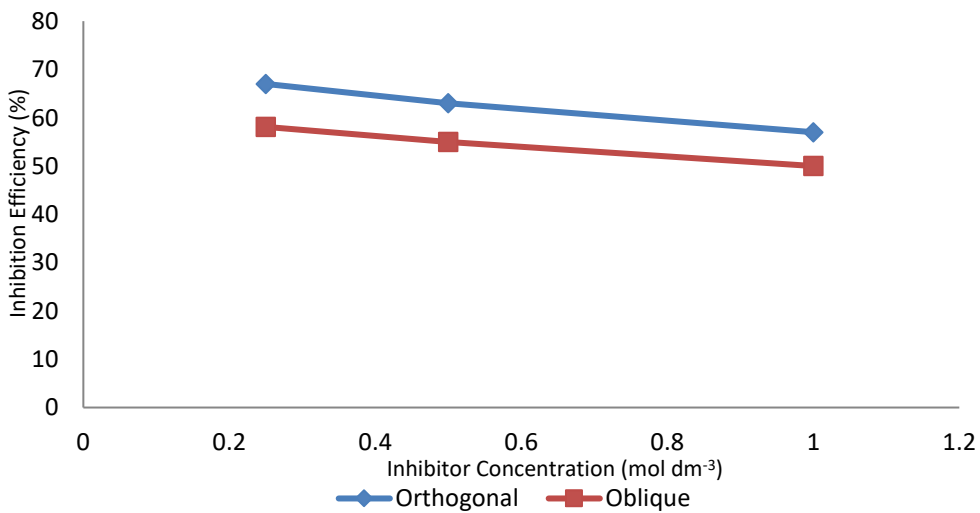


Figure 16: Variation of inhibition efficiencies with inhibitor concentrations for both orthogonally and obliquely machined samples in 0.5M NaOH after 288 hours.

4.0 CONCLUSION

Bitter leaf extracts (inhibitor) could serve as a good corrosion inhibitor for both orthogonally and obliquely-machined AA7074 samples in acidic and basic media. The inhibition efficiencies were observed to increase with increase in inhibitor concentration and exposure time in all the cases examined.

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