Comparative Analysis of Corrosion of Aluminum Plates in Different Concentrations of Lime Solution.

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ABSTRACT

Aluminum samples were cut into 5x5mm pieces and treated using four lime solutions with different molarities varying 0.5, 1.0, 1.5, and 2.0. Sixteen samples of aluminum plates were produced from each thickness. These were further subdivided into four thicknesses (0.3 mm, 0.6 mm, 0.9 mm and 1.2 mm). Each group was then immersed into different solutions of lime for different time intervals. The samples were first weighed before and after immersion with a Miller balance. Weight losses were calculated for all samples. The corrosion rate of 8.250 mm/yr was obtained for the 0.3 mm sample of aluminum at 72 hours while the rate of corrosion decreased to 1.295 mm/yr at 288 hours. The photo micrographs of the aluminum samples both soaked and un-soaked were taken. It was observed that corrosion rates of the aluminum samples decreased with increase in thickness while the rates of corrosion decreased with time of immersion.

(Keywords: corrosion, weight loss, Al, lime water, aluminum, aluminium, $Ca(OH)_2$, hydrated lime).

INTRODUCTION

Comparative analysis of corrosion behavior of different aluminum plates in various solutions has continued to attract considerable attention because of the many application of the metal. Aluminum relies on the formation of a compact, adherent passive oxide film for its corrosion immunity in various environments. This surface film is amphoteric and dissolves substantially when the metal is exposed to high concentrations of acids or bases [7, 9].

Aluminum compounds have proven to be useful for thousands of years. Around 5,000 B.C., Persian potters made their strongest vessels from clay that contained aluminum oxide. Ancient Egyptians and Babylonians used aluminum compounds apart not only for making vessels but also for cosmetics, fabric dyes, and medicines. However, it was not until the early nineteenth century that aluminum was identified as an element and isolated as a pure metal. Aluminum compounds occur in aluminum types of clay, but the ore that is most useful for producing pure aluminum is bauxite. Bauxite consists of 45.60% aluminum oxide, along with various impurities such as sand, iron and other metals.

Aluminum metal is a soft, lightweight, malleable metal with an appearance varying from silvery to dull gray, depending on the surface roughness. Its light in weight and its flexibility has made it a good material for domestic use in making cooking utensils and others items such as containers, appliances, and building materials [4].

As a result of the good thermal and mechanical properties, aluminum is often used in making cooking pots. Aluminum pots have a rounded-bottom shape that provides good thermal efficiency. It has much better hear-transfer characteristics and provides an improved and uniform thermal dispersion into the substance being cooked. This has actually helped and attributed important economic considerations, where fuel is both scarce and expensive.

Calcium hydroxide is also known as hydrated lime, slaked lime, lime water, and calcium hydrate [6]. Certain properties of calcium hydroxide which are crystals or soft, odorless granules or powder are: (1) it has a slightly bitter, alkaline taste [2]; (2) it readily absorbs carbon II oxide from air, forming calcium oxide and it is slightly soluble in water; (3) a solution of lime water is a medium to strong base, and reacts violently with acids; and (4) it attacks many metals in the presence of water forming flammable explosive hydrogen gas.

Calcium hydroxide is used as liming in agriculture, particularly when a rapid change in pH is needed and majorly in water treatment. Calcium hydroxide dissolves in water to form Ca^{++} and OH^{--}. Aluminum has a special reaction that is called amphoteric which exhibits both acidic and basic reactions. Aluminum loses its electrons by reacting with the dissolved ions of calcium hydroxide and this attack leads to reduction in weight of the aluminum cooking pot termed corrosion. Corrosion means the breaking down of essential properties in a material due to chemical reactions with its surroundings and the loss of electrons of aluminum metal react with water and oxygen.

The corrosion can be generally concentrated locally to form pits and cracks, or it can extend across a wide area to produce general deterioration [8]. The major percentage of domestic (kitchen and restaurant) utensils used today is made up of aluminum. The question then arises as to how durable are these aluminum utensils are related to incessant replacement due to perforations and wear caused by corrosion. Since aluminum cooking pots are common household utensils for cooking, the study of its reaction with lime (calcium hydroxide) is of importance as reactions occur between the cooking pots and water or soup which is major source of lime contacts. The investigation of the durability of aluminum plates in lime water is the broad objective of this study. As a result of the problems mentioned above, the specific objectives of the study are:

- To investigate the corrosion rates of aluminum at different times of immersion and different pH levels of lime

- To examine the corrosion rate of different thickness of aluminum plate in the solution of lime

- To investigate the effect of temperature on the pitting of aluminum cooking pots

- To investigate the effect of different concentrations of lime solution on corrosion rates of aluminum.

MATERIALS AND METHODS

The four thicknesses of aluminum specimens used for the study were been obtained from the Aluminium Rolling Mills Sango- Otta, Ogun State, Nigeria in form of flat sheets. The two aluminum cooking pots used were made from Aluminium Rolling Mills with 1.5 mm thickness, diameter of 153 mm and a height of 84 mm.

Sixteen (16) different 5mm x5mm were cut from each of the four thicknesses, making a total of sixty- four (64) samples. These samples were cut from the parent materials with the help of shears, while a steel rule and scriber were used for the dimensioning.

EXPERIMENTAL PROCEDURES

The four different concentrations of lime solutions [calcium hydroxide, Ca (OH_2)] were prepared from Chemistry Department's Laboratory, University of Agriculture, Abeokuta. The four different concentrations of lime were prepared with distilled water a week before starting the experiment. These solutions were stored in four different plastic kegs. The four lime concentrations were 0.5 molar, 1.0 molar, 1.5 molar, and 2.0 molar. Each of the measured samples was inserted into the identified plastic containers and different concentrations of lime were been poured as each was labeled. The chemical compositions of each of the four different thicknesses of aluminum samples were analyzed by a Quatometer/Metal Analyzer from the Quality Control Department of Aluminium Rolling Mills Sango-Otta. These compositions are shown in Table 1 with aluminum thickness of 0.3mm, 0.6mm, 0.9 mm, and 1.2mm.

Table1: Chemical Compositions of Aluminum Plates.

Al Plates	Fe	Si	Mn	Cu	Ti	Al
0.3mm	0.561	0.155	0.023	0.012	0.006	99.19
0.6mm	0.493	0.194	0.005	0.004	0.150	99.27
0.9mm	0.454	0.183	0.032	0.035	0.011	99.17
1.2mm	0.397	0.221	0.011	0.011	0.016	99.32

The total surface area of the samples exposed was 5mm x 5mm (25 mm^2). The sixteen sub-samples from each of the four samples were first weighed as the initial weights by mean of weigh balance. The weighed samples were inserted into each of the separate plastic containers. The first numbered one to sixteen plastic containers contained the same aluminum thickness of 0.3mm.

The first sixteen plastic containers were then divided into four groups with four plastic containers in a group. In each of the four groups different concentrations of lime solutions were poured. The pH values of each of the four solutions and the initial temperature were determined by using pH meter and thermometer as shown in Table 2. These were repeated for other samples making a total of sixty-four (64) samples.

The aluminum cooking pot was filled with 0.5 molar concentration of lime solution (calcium hydroxide) with a pH of 12.55. The pot filled with lime solution was placed on a heater. This was boiled to 100^oC, as measured by a thermometer and was held for another 30 minutes (until the pot boiled dried).The pot was then soaked in water for some days in order to wash and remove the lime that had reacted with the pot during the heating process. This could not be removed by detergent, due to aluminum oxide being formed. A 6 molar solution of hydrochloric acid (HCl) was added which remove all of the attack of the lime solution.

One sample was taken out from each of the four a single sample. Each sample of the four concentrations of lime solutions was timely labeled. The first 3 days (72 hours), the samples were removed by using tongs. The aluminum samples were firstly washed with distilled water in order to remove the un-dissolved lime attached to the samples. The samples were then cleaned with tissue paper, rinsed with acetone solution, dried under a ceiling fan and re-weighed for the final weight. An electronic digital weighing balance of 100g and of four decimal places was used for measuring both initial and final weight of the samples.

After some days of soaking the cooking pot with 2.0 molar lime solutions, the pot developed many pitting corrosion spots. Since the pitting was relatively great, a square 5mm x 5mm portion was dimensioned, within the covered area. The number of pits was counted and this was calculated in response to the total surface area of the experimental pot.

RESULTS AND DISCUSSION

The analysis exhibited that 1.2mm thickness of aluminum has the highest percentage of aluminum purity while the least is 0.9mm thickness. The first 72 hours of all the samples in respective of the lime concentrations and samples thickness have the highest corrosion rates compared to the longest duration of 288 hours.

Table 3 also showed that the corrosion rates of the same sample that is the same thickness depended majorly on the level of lime concentrations. The corroding medium of 2g/dm^3 (molarity) has the highest corrosion rate compared to the lower lime solutions.

Table 2: The pH value of Lime solutions.

Lime (g/dm3)	pH 0 HR	pH 72 HRS	pH 144 HRS	pH 216 HRS	pH 288 HRS
0.5	12.68	12.64	12.62	12.59	12.58
1.0	12.66	12.6	12.65	12.61	12.6
1.5	12.58	12.55	12.65	12.6	12.6
2.0	12.57	12.54	12.64	12.6	12.58

Table 3: Corrosion Rates of Aluminum Plates (mm/yr).

Lime (g/dm^3)	Al plates (mm)	CR 72HR 3DAYS	CR144HR 6DAYS	CR 216HR 9 DAYS	CR 288HR 12 DAYS
0.5	0.3	8.2500	3.3672	2.4084	1.2948
1.0		10.3848	4.2744	3.1056	1.8300
1.5		11.2044	1.9260	1.4424	0.1140
2.0		12.9804	1.6764	0.8196	1.4904
0.5	0.6	8.6568	4.9452	3.3900	2.1552
1.0		8.6388	2.7300	2.4864	1.9308
1.5		9.5760	3.7716	2.8524	2.1360
2.0		11.0544	3.1392	2.1924	1.7328
0.5	0.9	5.1264	5.2956	3.5316	2.6520
1.0		5.4480	3.9132	2.0796	2.0544
1.5		9.1368	4.2744	2.9220	2.2620
2.0		11.5356	2.1744	2.1324	1.7748
0.5	1.2	3.9264	6.4128	4.4160	3.3816
1.0		5.9616	3.8820	3.4992	2.8896
1.5		7.6812	5.1960	3.5280	2.8668
2.0		8.6172	3.8676	2.6784	2.0988

The graphs (Figures 1 to 3) showed the corrosion rate against time of immersion in different concentration of lime solutions (molarities). The sample that was immersed in highest molarity had the highest corrosion rate due to high level of the aggressive interaction between the aluminum samples and the molarity.

From Table 3, the weight loss per area showed a decreasing trend with immersion time. The highest value was observed for 1.2mm aluminum plate at 72 hours of immersion while the lowest value was obtained for 0.3 mm aluminum at an immersion time of 288 hours.

From Table3, Aluminum samples of 0.3mm thickness showed the highest corrosion rate compared to other thicknesses. Pitting of an aluminum cooking pot was observed when soaked in lime solution and the pot heated to 1,000C and held for 30 minutes.

The corrosion rates of all of the samples decreased drastically with increase in period (duration) of immersion in respect of thickness and the concentration of the corroding medium (molarities).

Both the level of lime concentrations and the thickness of the samples played a significant role in the level of corrosion rate. For example, a sample of 0.3 mm thickness has the highest corrosion rate of 0.6875 mm/yr been immersed in 0.5 g/dm3 of lime solution while the sample immersed in 2.0g/dm3 of lime solution had an highest corrosion rate of 1.2980 mm/yr which has a difference of 0.4730mm/yr as shown in Table 2.

The first 72 hours of the corrosion rate of 0.3mm is 0.8250 mm/yr while the corrosion rate of 1.2 mm sample immersed in the same corroding medium (molarity) has a corrosion rate of 0.3926mm/yr.

CONCLUSION

The results obtained from this study indicate the negative but significant effect of lime solution (calcium hydroxide [CaOH2] on aluminum plates. The general reaction is known as corrosion effect which led to a reduction in the weight and thickness of aluminum cooking pots.

The highest corrosion rate of all the aluminum samples were observed in the first three days (72 hours) of immersion while the lowest was in the last 12 days (288 hours). The corrosion rate was also observed at the highest concentration of calcium hydroxide (2.0g/dm^3) and the lowest pH value. The thinnest of the aluminum samples also gave the highest corrosion rate while the thickest aluminum sample (1.2mm thickness) gave the least corrosion rate.

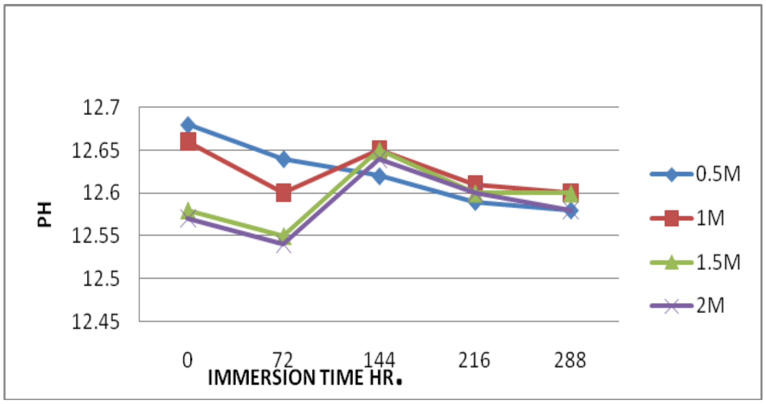

Figure1: Graph of pH Values of Lime Solution against Time of Immersion.

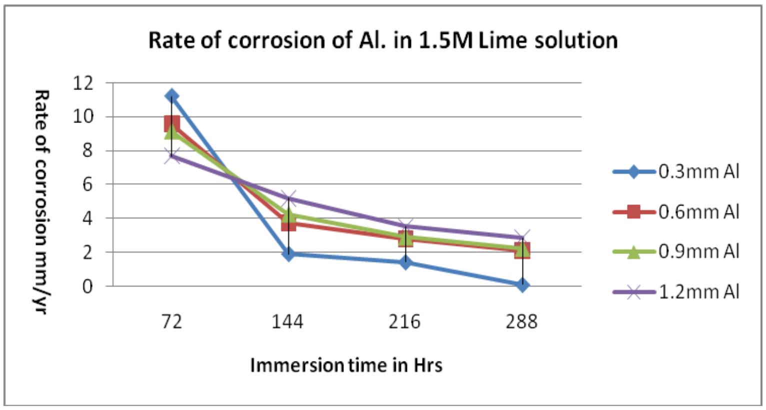

Figure 2: Graph Rate of Corrosion of Aluminum (Al) against Time of Immersion.

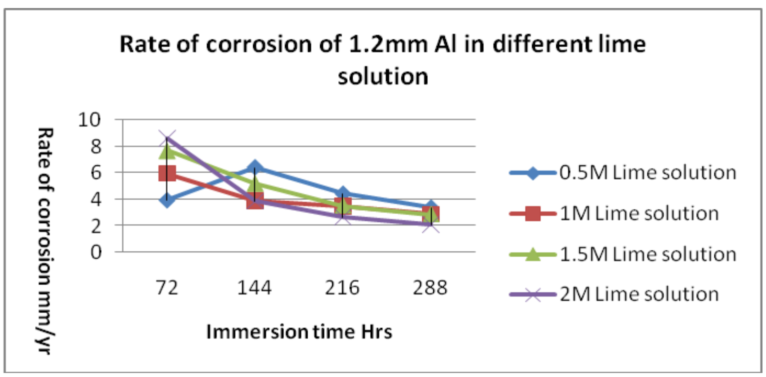

Figure 3: Graph of Rate of Corrosion of 1.2mm Aluminum in Different Lime Solution against Time of Immersion.

Plate 1: Initial state of SEM 0.6mm Al, Mx400, 2% Nitric acid and 98% Ethyl Alcohol.

Plate 2: Immersed SEM 0.6mm of Al, Mx400, 2% Nitric acid and 98% Ethyl Alcohol.

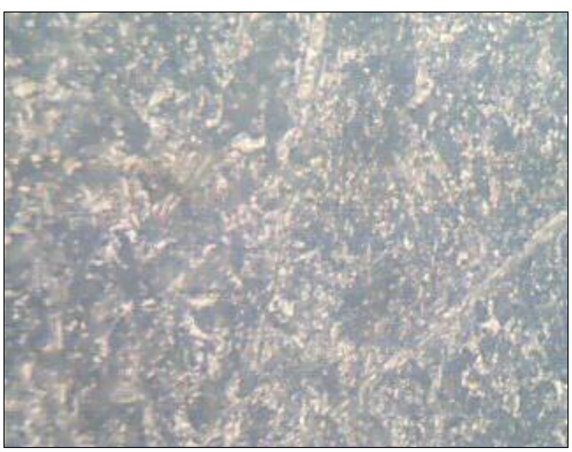

Plate 3: Immersed SEM 0.9mm of Al, Mx400, 2% Nitric acid and 98% Ethyl Alcohol.

Plate 4: Immersed SEM 1.2mm of Al, Mx400, 2% Nitric acid and 98% Ethyl Alcohol.

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