THE INFLUENCE OF Fe VARIATION ON THE CORROSION BEHAVIOUR OF HEAT TREATED ALUMINIUM ALLOYS IN TOMATO JUICE.

B.O. ADEWUYI
Dept. of Metallurgical and Material Engineering,
Federal University of Technology, Akure.

ABSTRACT

The corrosion susceptibility of aluminium alloys immersed in tomato juice after heat treatment was investigated. The metals in as cast, annealed, normalized and quenched states were analysed in various solutions containing sodium chloride. The result shows that the annealed samples are less corrosive while the quenched samples exhibit the highest tendency to corrode in tomato juice. The author concluded that the composition of the alloys plays very significant role in the corrosion behaviour. He deduced that certain elements present in aluminium are beneficial and retard corrosion while excess of some elements will promote localized pitting as a result of precipitation occurring at the grain boundaries. The optimal value of concentration of elements that will be in a state A1-alloy solubility is very important in corrosion evaluation of aluminium alloys.

Key words: Tomato, corrosion, cast alloys, heat treatment.

INTRODUCTION

Aluminium is used largely in the food and chemical industries and also in the manufacturing of domestic and cooking utensils. On the surface of hollowares in contact with agro fluids, pitting is usually observed in form of black corroded sport rust after some time. Aluminium is a reactive metal with a high affinity for oxygen. The metal is nevertheless highly resistant to most adverse environmental conditions and to a great variety of chemical agents. Pitting and intergranular corrosion has been identified as the most commonly encountered form of aluminium corrosion [1]. Where perforation is the criterion of failure, statistical analysis may be judiciously applied to the distribution and depth of pits [2].

Several works on intercrystalline corrosion of aluminium alloys had been done. For example, Rogozhina [3] revealed that analytical study of the corrosion coupon surfaces shows samples of the alloys to corrode rapidly during initial hours of immersion, and this was followed by a period in which pitting dominated. Effect of composition of copper and magnesium had been well studied. In their work Sheppard and Ragamathan [4] discovered that precipitation of Cu.Al, particles at the grain boundaries during heat treatment leaves the adjacent solid solution anodic and prone to corrosion. However, with the aluminium/magnesium alloys, a different situation occurs. When the magnesium content exceeds the limit of solubility in aluminium, Mg_2Ab is precipitated at the grain boundaries on cooling. This compound is less noble than the solid solution and so becomes the anode, where it forms a continuous grain boundary film. In this case severe intercrystalline attack can occur. But when it is present as discontinuous particles, intergranular attack is substantially avoided [5].

Iron is required in aluminium alloy as a hardener because pure aluminium is too soft for domestic hollowware and structures. However, the optimal concentration of iron content that will be in a state of A1-Fe solubility is very important. Excess will result in localised pitting in the alloy and insufficient amount of iron content will not give the desire strength. However, it is known that iron and silicon present in aluminium are beneficial and retard corrosion [5]. Tomato fruits contain weak organic acids which are mainly ascorbic (Vitamin C) and benzoic acids. Studies of the effect of immersion of aluminium and its alloys in tomato juice are not known. In studying the corrosion of aluminium alloys and commercial pure aluminium under conditions of enclosed agricultural production facilities (with and without heating), such as greenhouses, canneries, storage deports, etc, Rogozhina [3] concluded that aluminium alloys can be effectively protected against corrosion by anodizing. Studies on corrosion inhibition of aluminium by organic compound had revealed that organic acid usually have low rates of attack on aluminium [2]. However, with the presence of extraneous ions, the rate of attack increases.

The purpose of the present investigation is to ascertain the type of aluminium alloy (and the heat treatment required if necessary) that can be suitable for domestic and industrial use, especially in the area of canning and storage. Such evaluation become necessary when determining standard practices for manufacturing operations such as hot forming and straightening, adhesive bonding, and paint and dry film lubricant curing, and when evaluating the effects of both short term and long term exposure to elevated temperatures in service. This research is expected to have significant practical application in the aluminium industries.

MATERIALS AND METHODS

Cast aluminium alloys of three different chemical compositions were used for this study. The chemical analysis of the cast aluminium alloys obtained from Aluminium Rolling Mills, Ota in Ogun State is given below:

Table 1: Chemical composition of the alloys (wt %).

Alloy	Mg	Mn	Si	Cu	Zn	Ti	Fe	Al
CAST A	0.01	0.007	0.263	0.065	0.017	0.016	0.422	others
CAST B	0.052	0.073	0.313	0.075	0.138	0.132	0.642	othe
CAST C	0.081	0.05	0.127	0.054	0.234	0.Q1	0.884	othe

The samples used for the corrosion studies were machined to rectangular shapes of dimension 16 by 12-mm. The specimens were ground on 240mm grade emery paper to standardize the surface profile. Surface grinding of specimen was done under running water to avoid heating, which may alter surface structure of the specimen. Cleaning in alcohol followed this. Cleaned specimens were then dried and kept in a desiccator ready for use. Fresh tomato fruits were ground and the juice extracted. Small quantity of distilled water was added to obtain the juice solution.

Tests for corrosion susceptibility was carried out as follows: The samples were machined to rectangular test specimen shape of 16mm long by 12mm thick. All the cladding on the metal surface was removed by etching. The samples were further cleaned by immersing them for min in a 5% concentrated nitric acid - 0.5% hydrofluoric acid solution, and later rinsed in distilled water; immersed for 1 min in concentrated acid at room temperature, and then rinsed in distilled water. All heat-treated samples were solution treated at 460°C. The soaking time was 60 mins for general corrosion studies. The subsequent cooling to room temperature was achieved in a number of ways to obtain desired structures. Samples with varying Fe compositions (Cast A, 0.4%Fe; B-0.6%Fe, and C-0.8%Fe) were annealed, quenched and normalized. Corrosion evaluation was carried out by complete immersion of the samples in tomato juice solution contaminated with different concentration of NaCl (3, 6, and 9% by weight). Different containers were used for each test specimen. On a daily basis, the weight loss was measured for a period of 30 days, being the total period for the corrosion tests. Before measurement, the samples were dried with a soft measured cloth and soft bristle brush to remove any loose corrosion product from the surface. The specimens were placed back into the solution after the weighing operation was completed. This procedure was repeated each day throughout the duration for the test. The criterion used to express corrosion susceptibility is the corrosion rate expressed red in terms of weight loss per day.

The weight and the surface area of the test piece were measured before suspension in various solutions. CRISON micro pH 200 microcompressor controlled pH meter was used to monitor and measure the pH variation of the media

RESULTS AND DISCUSSIONS

Figure 1. Shows the pH variation with exposure time. The solution was mostly acidic between 2 and 4 days of exposure. The pH changes from 3.47 to 3.34. This change was caused by the dissolution of hydrogen evolution. With increase in days of exposure there is significant increase in pH, signifying reduction in aggressiveness of the media.

Effect of Fe Variation.

Figures 2 to 5 show the effect of Fe variation on corrosion susceptibility. Alloy A exhibited high resistance to corrosion while alloy C shows higher tendency to corrode. Sheppard and Raghamathan [4] had earlier postulated that precipitation occurs first along grain boundaries and when exposed to corrosive environment such as salt water, an electric current flows between the anodes (grain boundary) and cathodes (grain centers). Corrosion penetrates rapidly through the anodic grain boundaries, leaving the catholic regions comparatively untouched. The insidious nature of this attack results from the fact that very little corrosion or corrosion product is visible on the surface. The grains usually remain mechanically locked together, although they are unbounded metallurgically. Therefore, it can be deduced that precipitation of compounds such as $CuAl_2$, and Mg_2Al_3 particles at the grain boundaries during heat treatment leaves the adjacent solid solution anodic and prone to corrosion.

Effect of Heat Treatment and Concentration of NaCl.

The nature of the corrosion rate variation with the concentrations of sodium chloride solution for all the samples are shown in Fig.6 to 8. Corrosion rate increases with increasing concentrations of sodium chloride solution. From the graphs, it could be seen that corrosion rate changes with heat treatments. For specimen A, B and C progressive increase in corrosion rate was observed. From the analysis of these graphs it can be concluded that the sour environment least affects annealed samples while the quenched samples exhibited higher corrosion susceptibility. This result can be explained considering the fact that the purpose of annealing is to produce the structure containing fine grains. This smaller grain size in a metal improves its strength by providing a longer and more complex path of slip lines that slow down the rate of corrosion. Also in the case of the normalized samples there is recrystallization of the grain structure, which the cast alloy must have undergone during cold rolling operation. In case of the quenched samples, high residual tensile stresses were induced after quenching. This tends to increase corrosion susceptibility in the quenched samples due to distortions, which favour corrosion attack.

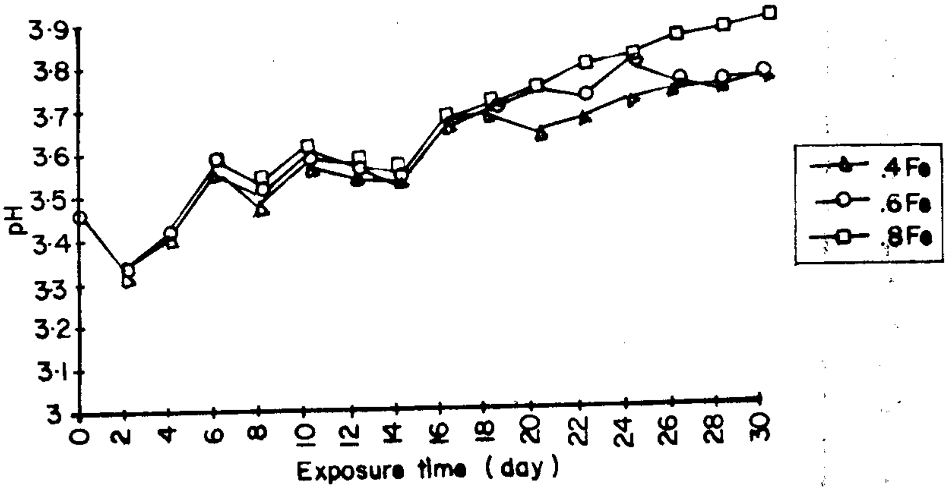

Fig. 1: pH variation against exposure time in tomatoes juice

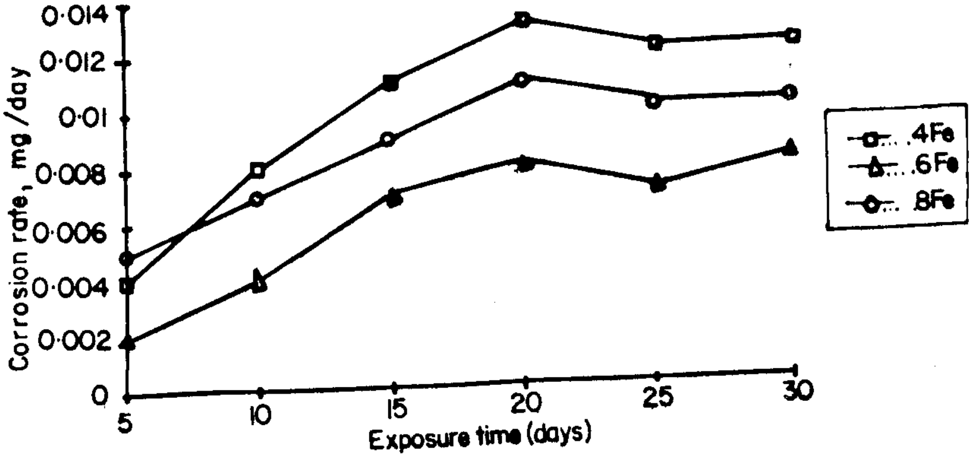

Fig. 2: Corrosion rate with exposure time at % Fe content, (Annealed)

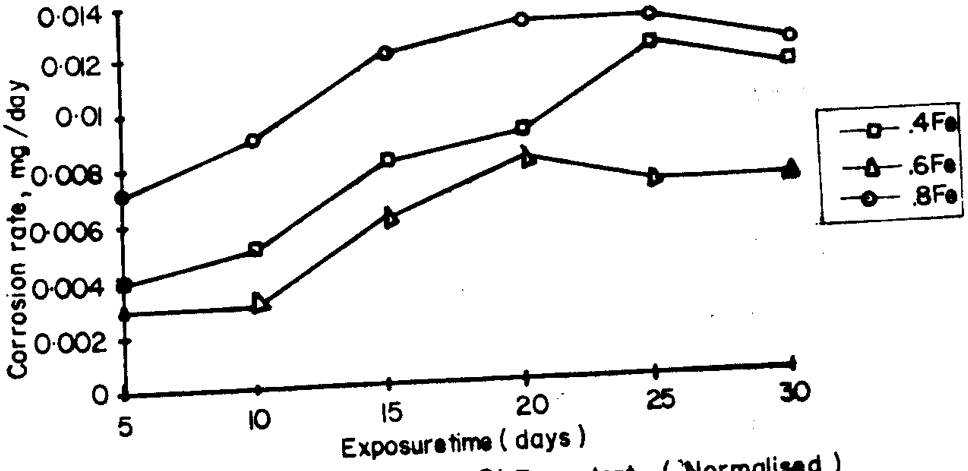

Fig. 3: Corrosion rate with exposure time at % Fe content, (Normalised)

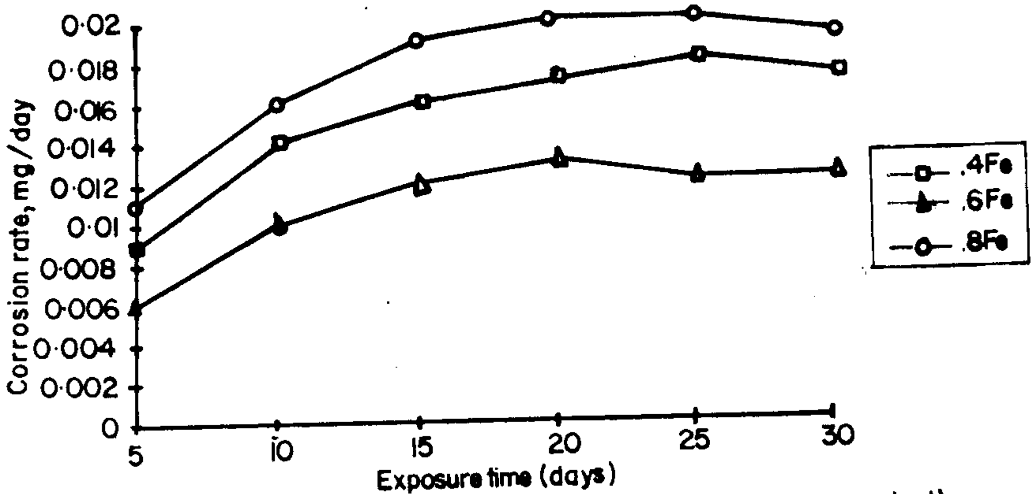

Fig.4: Corrosion rate with exposure time at % Fe content, (Water Quenched).

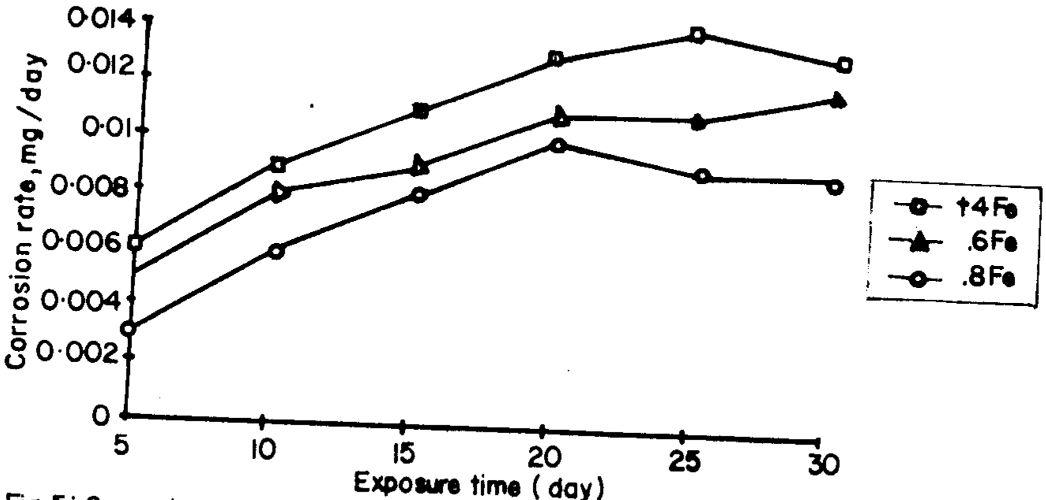

Fig. 5: Corrosion rate with exposure time at % Fe content, (control)

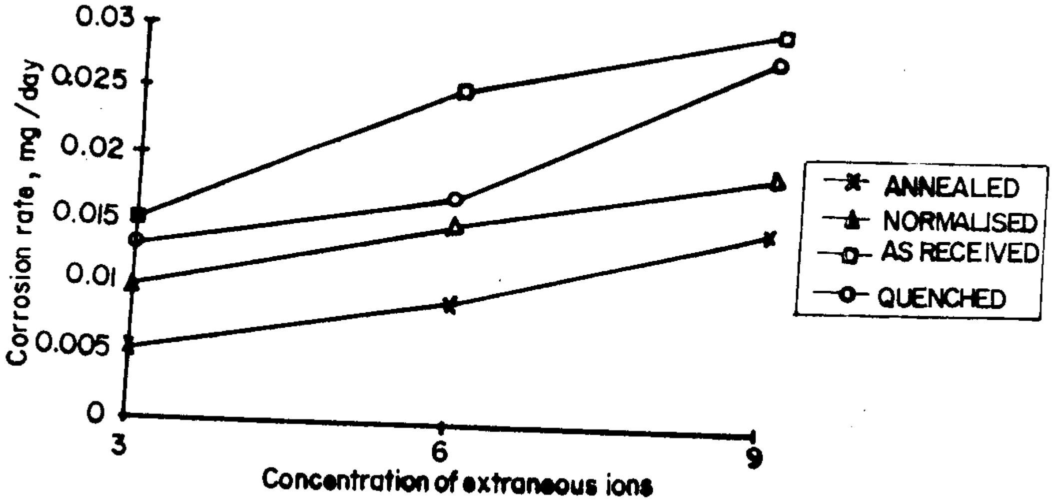

Fig.6: Corrosion rate with Concentration of extraneous Ions at %0.4Fe content.

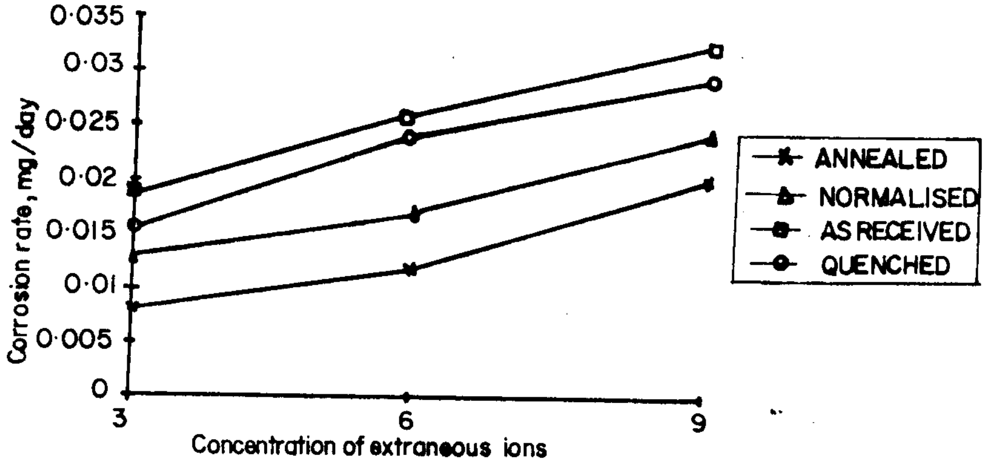

Fig.7: Corrosion rate with Concentration of extraneous ions at %0.6 Fe content.

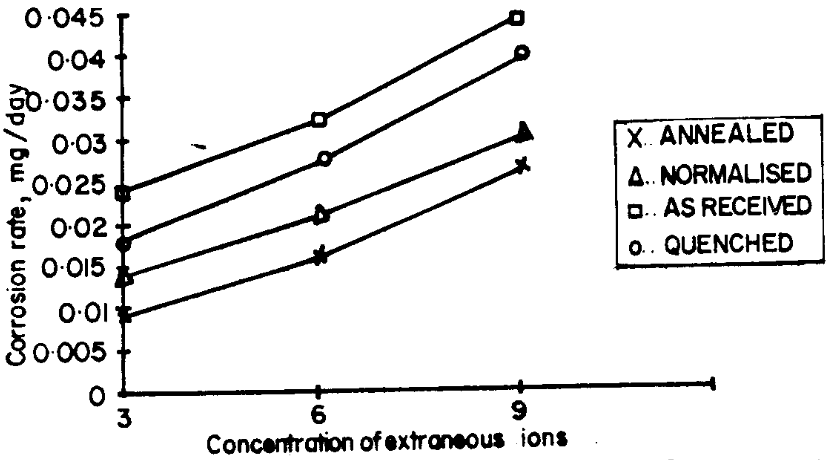

Fig.8: Corrosion rate withConcentration of extraneous ions at %.0.8Fe content.

All the graphs show that the rate of corrosion rate increases with increase in the concentration of the extraneous ions. Sample C with higher amount of manganese and iron than samples A and B recorded the highest value of corrosion rate. The reason for this can be connected to the fact that as the samples are immersed in the media, galvanic cell is developed and the potential difference is created between the surface and the inner matrix. The surface of the material becomes anode while the inner matrix becomes cathode. According to Sheppard and Raghamathan [4], with increase in iron content, the precipitation of Mg_2Al_3 at the grain boundaries is promoted. This compound is less noble and becomes the anode, which is prone to corrosive attack.

CONCLUSION

Property changes accomplished in the heat treating of aluminium alloys can be traced to solution and precipitation of hardening phases. Such property changes can be both beneficial and deleterious. To accurately recommend a material for selection for a particular service use, there is need to know the processing history of the material. Such factors as the knowledge of the chemical composition is not enough to accurately predict the behaviour of a material in a particular environment. The nature of the heat treatment carried out and the type of environment are very vital.

ACKNOWLEDGEMENT

The author wishes to acknowledge the immense contribution of Mr. A. Omogoke for his technical assistance and also the management of Aluminim Rolling mills, Ota for releasing their equipment for this research.

REFERENCES

1. Beny, W.E. Corrosion and compatibility, Corrosion Awareness Bulletin, 1989.

2. Ohsawa, S., Takeda, 1. Studies on corrosion inhibition of aluminium by organic compound, *Journal of Fac. of Eng'g.*, Ibaraki Univ. Vol. 36, No. 12 1988, pp.149 - 159.

3. Rogozhina, E.P. Corrosion of aluminium alloys in enclosed. agricultural facilities. *Zashsh met.* Vol. 25, No.1 1989, pp.120 -124.

4. Sheppard, T.L, Raghamathan, N. Modification of cast structure in AI-Mg alloys by thermal treatment, *Material Science Technology,* Vol. 5, No.3, 1989, pp.268 - 280.

5. Metal Handbook, V.2, 8th edition, 271- 283.

6. Merchant D.I. Homogenization of aluminium alloys, Conf. Proceedings, Cincinati, Ohio, USA, 1987.