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Examination of abrasive rate and weight loss of bi-metals and tri-metal in acidic environment

Okumakebe U. B, Erhinyoja E. N

Bells University of Technology, Ota

ABSTRACT

Investigation of weight loss and corrosion rates of bimetals and tri-metal in acidic environment was considered in this research. Samples of bi-metals and tri-metal were taken from Jasmetals and Jasalloys (JasA1013, JasB2013, JasC3013, JasD4013, JasE5013, JasF6013 and JasG7013) for investigation. The JasA1013, JasB2013 and JasC3013 represented Al, Zn and Pb metals, while JasE5013, JasF6013 and JasG7013 represented Al-Zn, Al-Pb and Zn-Pb alloys It was aimed at evaluating the weightlessness and the corrosion rates of the alloys. The coupons were immersed in seven different beakers containing diluted H_2SO_4 for seven days. The corrosion rates were determined from the weight loss of the alloys after seven days. Results showed that the trimetal and Zn-Pb weight reduced drastically while the bimetals (Al-Zn and Al-Pb) resisted corrosion. The corrosion rate results were within the equivalent matrix rate (standard) established by Fontana in 1987.

Keywords: Weight loss, Acidic environment, Corrosion rate, Investigation, Bi-metals and Tri-metal.

INTRODUCTION

Alloy is a mixture or metallic solid solution composed of two or more elements (A.H.D 2009) Complete solid solution alloys give single solid phase microstructure, while partial solutions give two or more phases that may or may not be homogeneous in distribution, depending on thermal (heat treatment) history. Alloys usually have different properties from those of the component elements. Alloy with composition of two metals is called bi-metal while alloy with composition if three metals is called tri-metal.

All metals and alloys undergo corrosion when exposed to acidic environment, which is defined as the destructive attack of a metal by the environment, by chemical or electrochemical processes. The driving force is the free energy of reactions of the metal to form a metal oxide. Since corrosion reactions generally occur on the metal surface, they are called interfacial processes (Ndubuisi et al., 2006). The corrosion process takes place at the metal medium phase boundary and therefore is a heterogeneous reaction in which the structure and condition of the metal surface have a significant role (e.g., whether the surface is uncoated, coated with an adhesive, compact, or loose porous coating, or whether its properties have been changed by machining and processing). Therefore, material transport phenomena, including free convection and diffusion into adjacent surface layers, must also be taken into account (Idenyi and Ekuma, 2006). Corrosion also exists on alloy because it is an intentional mixing of two or more chemical elements that have at least one metallic property (Ndubuisi et al., 2006); examples are being stainless steel, brass, and bronze, which are three of the most commonly used alloys. The major metals in these alloys understudy are aluminum, zinc and lead.

Rosliza Ramli (2006) Corrosion Behavior of Aluminum Alloys in Acidic Media This study reported the results of weight loss, polarization and electrochemical impedance spectroscopic (EIS) measurements on the corrosion inhibition of AA6061 and AA6063 aluminum alloys in acidic media using sodium benzoate as an inhibitor. The results showed that addition of sodium benzoate retards the rate of dissolution and hence inhibits the corrosion of the aluminum alloy in acidic media. The inhibition efficiency increases with the increase of immersion time

Table 1. Day 1 Weight loss in Al, Zn, Pb, Al-Zn, Al-Pb, Zn-Pb and Al-Zn-Pb

Specimen	Day 1
Al	18.7
Zn	48.2
Pb	51.7
Al-Zn	20.0
Al-Pb	28.0
Zn-Pb	30.9
Al-Zn-Pb	22.9

Where, A = Al
B = Zn
C = Pb
D = Al-Zn
E = Al-Pb
F = Zn –Pb
G = Al-Zn-Pb

Table 2. Day 2 Weight loss in Al, Zn, Pb, Al-Zn, Al-Pb, Zn-Pb and Al-Zn-Pb

Specimen	Day $1_{(g)}$	Day $2_{(g)}$	Weight $loss_{(g)}$
Al	18.7g	16.2g	2.25g
Zn	48.2	37.4g	10.8g
Pb	51.7	44.5	7.2g
Al-Zn	20	18.4	1.6
Al-Pb	28	23.6	4.4
Zn-Pb	30.9	22.8	8.1
Al-Zn-Pb	22.9	14.7	8.2

in acetic acid however it displays a different behavior in sulfuric acid.

Geetha and Jagannath (2009) studied the Corrosion Behaviour of 6061 Al-15vol. Pct. SiC Composite and its Base Alloy in a Mixture of 1:1 Hydrochloric and Sulphuric acid media. The results obtained showed an increase in the corrosion rate with increases in temperature as well as the increase in the concentration of the corrosion media.

Singh (1997) investigated the Corrosion Behavior of Rapidly Solidified Lead-Aluminum alloys for Battery Grids. The RS showed more corrosion resistant behavior than all other alloys and metal under investigation and oxygen evolution potential was not affected by aluminum addition to the lead alloy.

Syed S. (2006) studied the Atmospheric Corrosion of Materials. This reviewed work revealed that bridges, buildings and other industrial materials are exposed to atmosphere and attack by pollutant and water.

Cevik et al (2012) investigated the Effect of Peak-Aged Heat Treatment On Corrosion Behavior of The Aa6063 Alloy Containing AL_3Ti. The microstructure of the homogenised and aged alloys was examined using an optics microscope, and scanning electron microscope. The microstructure characterization of the investigated alloys shows the Al (matrix), non-shaped dark globular grey-coloured phase and rod-shaped phases formed at the grain boundaries

Gregory and Igho (2003) studied the Inhibitive action of Vernonia amygdalina on the corrosion of aluminum alloys in acidic media. The results showed the highest inhibition efficiency of 49.5% for the 0.1 M HCl and 72.5% for 0.1 M HNO3, respectively. However, the 0.2g/l concentration showed a better performance in the

Table 3. Day 3 Weight loss in Al, Zn, Pb, Al-Zn, Al-Pb, Zn-Pb and Al-Zn-Pb

Specimen	Day 1$_{(g)}$	Day 3$_{(g)}$	Weight loss (g)
Al	18.7	16.1	2.6
Zn	48.2	37.6	10.6
Pb	51.7	43.5	8.2
Al-Zn	20.4	18.0	2.0
Al-Pb	28.6	23.3	4.7
Zn-Pb	30.9	22.8	8.1
Al-Zn-Pb	22.9	14.4	8.5

Table 4. Day 4 Weight loss in Al, Zn, Pb, Al-Zn, Al-Pb, Zn-Pb and Al-Zn-Pb

Specimen	Day 1$_{(g)}$	Day 4$_{(g)}$	Weight loss$_{(g)}$
Al	18.7	15.9	2.8
Zn	48.2	37.6	10.6
Pb	51.7	43.5	8.1
Al-Zn	20	17.8	2.2
Al-Pb	28	23.06	4.94
Zn-Pb	30.9	22.8	8.1
Al-Zn-Pb	22.9	15.4	7.5

Table 5. Day 5 Weight loss in Al, Zn, Pb, Al-Zn, Al-Pb, Zn-Pb and Al-Zn-Pb

Specimen	Day 1$_{(g)}$	Day 5$_{(g)}$	Weight loss$_{(g)}$
Al	18.7	15.8	2.9
Zn	48.2	37.60	10.6
Pb	51.7	43.5	8.0
Al-Zn	20.00	17.7	2.3
Al-Pb	28.00	23.04	4.96
Zn-Pb	30.9	22.9	8.0
Al-Zn-Pb	22.9	14.96	7.94

inhibition of 0.1 M HCl for all samples.

Ekama et al (2007) investigated the Effects of Zinc Additions on the Corrosion Of Susceptibility of Aluminum Alloys in Various Tetraoxosulphate (VI) Acid Environments.

The results show that although, there was a normal corrosion rate profile (for passivating metal) of an initial steep rise, then a progressive decline was observed in all the media as a fraction of the solute in the alloy increased, there was a severity of attack on the Zn alloy.

Table 6. Day 6 Weight loss in Al, Zn, Pb, Al-Zn, Al-Pb, Zn-Pb and Al-Zn-Pb

Specimen	Day $1_{(g)}$	Day $6_{(g)}$	Weight $loss_{(g)}$
Al	18.7	15.6	3.1
Zn	48.2	37.6	10.6
Pb	51.7	43.5	8.2
Al-Zn	20.0	17.5	2.5
Al-Pb	28.0	22.7	5.4
Zn-Pb	30.9	22.8	8.1
Al-Zn-Pb	22.9	14.8	8.1

Table 7. Day 7 Weight loss in Al, Zn, Pb, Al-Zn, Al-Pb, Zn-Pb and Al-Zn-Pb

Specimen	Day $1_{(g)}$	Day $7_{(g)}$	Weight $loss_{(g)}$
Al	18.7	15.4	3.3
Zn	48.2	37.6	1.1
Pb	51.7	43.2	8.5
Al-Zn	20.0	17.3	2.7
Al-Pb	28.0	22.6	5.4
Zn-Pb	30.9	22.8	8.0
Al-Zn-Pb	22.9	14.78	8.12

This attack on Zn resulted from the increased in grain boundary.

MATERIALS

1. Beakers.
2. H_2SO_4
3. Al, Zn and Pb

METHOD

The molar volume of the diluted acid (H_2SO_4) solution was pour into seven beakers. Each was marked against various coupons type. The weights of the coupons were determined the first day. The coupons were released into each beaker, and allowed for 24 hours. Each coupon was removed from the beaker at every 24 hours for washing; this was allowed to dry and reweighed. The experiment continued for seven days.

RESULTS AND DISCUSSION

The results of the weight loss testing are shown in table 4.8 to 4.15 and table 4.16 is the corrosion rate result, while the graphs of corrosion rate is shown in figure 4.1.

The behavior of the metals and alloys in the acidic environment are as follows; on the first day there was little or no noticeable bubbling in aluminum (Al), Pb and Al-Pb beakers. In that of Zn and Al-Zn beakers, slight bubbles were noticed. More bubbles were seen in Zn-Pb beaker while the bubbling in the tri-metal beaker was vigorous

Table 1 to 7 shows the results of the weight loss and corrosion rate. The rate of corrosion increase with time, as shown from the weight loss experiment, the tri-metal (Al-Zn-Pb) corroded faster than every other metal and alloys with 1.86×10^{-3}mpy, and was accompanied with vigorous deterioration of the alloy on the first and second day. The ability of aluminum and its alloys to form barrier oxide micro – film: alumina (Al_2O_3) in most environments which has affinity for oxygen, coupled with excellent

Table 8. Comparison of Millimeters Penetration Per Year (mpy) with Equivalent Metric- rate (mm/y)

Relative Corrosion Resistance	Imperial Value (mpy)	Equivalent metric value (mm/yr)
Oustanding	<1	<0.02
Excellent	1 – 5	0.02 – 0.1
Good	5-20	0.1 – 0.5
Fair	20 – 50	0.5 – 1
Poor	50-200	1 – 5
Unacceptable	200+	5+

Source. Fontana (1987).

Table 9. Corrosion Rate In mpy of Al, Zn, Pb, Al-Zn, Al-Pb, Zn-Pb & Al-Zn-Pb

SPECIMEN	DAY1 g	DAY2 g	DAY3 g	DAY4 g	DAY 5 g	DAY 6 G	DAY 7 g	CORROSION RATE mpy (x 10^{-3})
Al	18.7	16.2	16.1	15	15.8	15.6	15.4	0.088
Zn	48.2	37.4	37.6	37.6	37.60	37.6	37.6	0.298
Pb	51.7	44.5	43.5	43.5	43.2	43.5	43.2	0.122
Al-Zn	20.0	18.4	18.0	17.8	17.7	17.5	17.3	0.556
Al-Pb	28.0	23.6	23.3	23.04	23.04	22.65	22.64	1.412
Zn-Pb	30.9	22.8	22.8	22.8	22.9	22.8	22.9	1.648
Al-Zn-Pb	22.9	14.7	14.4	15.4	14.96	14.8	14.78	1.860

The corrosion rate was determined using the following equation;

Mpy = KW/DAT

Mpy = 534W/DAT

W = Weight loss (g) of the alloys

D = Density of the specimen

A = Area of specimen

T = Exposure time 24 hours (7 days)

K = Corrosion constant (534)

Mpy - means Mils Penetration per Year

corrosion resistance has made it one of the primary metals of commerce. This is evident in the sole aluminum with corrosion rate of 0.088×10^{-3}mpy. Also, in environments harboring aluminum (and some of its alloys) like Al-Zn with corrosion rate of 0.56 $\times 10^{-3}$mpy is an indication that Al-Zn is a good anti-node (anti corrosion agent or sacrificial anode) thus conformed with Muazu work of 2011(who studied the effect of zinc addition on the performance of aluminum-based sacrificial anode in seawater, and the alloys were tested to be sacrificial anode for the protection of mild steel). This film (Al_2O_3) assists in the formation of passive surface layer bonded strongly to its surface which, is stable in aqueous media within pH range of about 4.0 and 8.5, and if abraded, re – forms almost immediately in most environments. Similarly, Al-Pb have the same behavior like the Al-Zn alloy, but in this hydrogen is displaced.

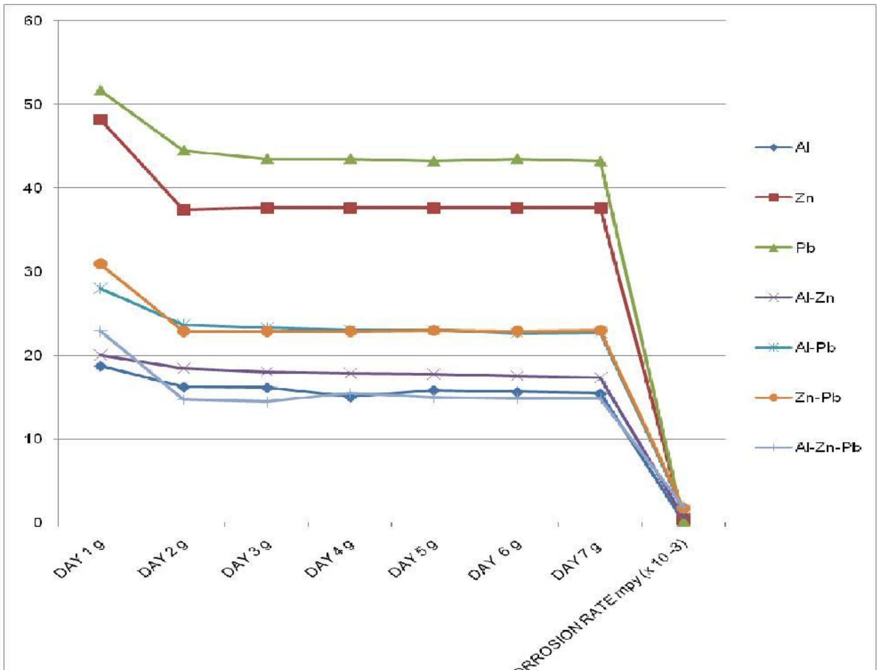

Figure 4.1. Specimen Weight Against Corrosion Rates

CONCLUSION

The grain boundary has little or no effect on the corrosion of this casting but influenced the coarseness and finess of the structure. The tri-metal weight reduced drastically with evidence in vigorous bubbling while the bimetals (Al-Zn and Al-Pb) resisted corrosion. The samples corrosion rate results are within the equivalent matrix rate (standard) established by Fontana in 1987 (Table 4.5).

Corrosion types can be control by altering the environment, using corrosion resistance during construction, cathodic protection, good engineering design, using corrosion allowance materials, using barrier between materials and environment.

RECOMMENDATION

Further research should consider hardness test, spark test analysis and micrographic examination of samples, to determine samples hardness, composition and grain boundary formation matrix.

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