RESEARCH ARTICLE OPEN ACCESS

# Corrosion studies of ZA-27 / Red Mud Composites in Neutral Chloride Medium

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**ABSTRACT**
Metal matrix composites are heterogeneous systems containing matrix and reinforcement. They are used in automobile, aircraft and marine industries because of their increased corrosion resistance. In this paper weight loss corrosion tests are conducted onZA-27/ Red Mud metal matrix composites in different concentrated sodium chloride solutions. ZA-27 is the matrix and the reinforcement is red mud. Composites are prepared by liquid melt metallurgy technique using vortex method. The corrosion rate decreases with increase in the exposure time for all specimens in all corrodents. Corrosion rate also decreases with the increase in reinforcement content of the composites.

***Keywords***: ZA-27, Red Mud, Vortex, Corrodent, Neutral chloride

Date of Submission: 07-09-2017 Date of acceptance: 20-09-2017

## I. INTRODUCTION

Metal matrix composites are engineering combination of two or more materials (one of which will be metal or alloy) where tailored properties are achieved by systematic combination of different constituents. Composites are metal systems consisting of a mixture of two or more constituents insoluble in each other and differing in form and material composition. They are heterogeneous materials consisting of two or more phase, which are in intimate contact with each other on a microscopic scale. They are also homogeneous material in sense that any part of it will have the same physical properties on a microscopic scale.

Zinc alloys are feasible matrices for MMCs and are suitable replacements for cast iron, brass or alluminium alloys. These alloys have excellent pressure tightness, good bearing and wear properties.[1] Among the zinc based foundry alloys; the ZA family of alloys has been used increasingly during the past few years. The three common ZA casting alloys are ZA-8, ZA-12 and ZA-27. These alloys present advantages in comparison with alluminium based alloys, especially because of their high strength and low casting temperatures and have been used for lower cast replacements of bronze and brass castings. ZA-27 alloys have been used in bearings and bushing applications as a replacement for bronze bearings because of their lower cost and equivalent or superior bearing performance.[2] ZA-27 alloy was developed by Noranda Mines Limited, a Canadian organization, because of its low initial cost, excellent foundry castability, good mechanical properties and good machinability

The corrosion behaviour of the composites in the various environments that the material likely to encounter is one important consideration when choosing a suitable material for a particular purpose. There is very little information available about the corrosion behaviour of zinc-based composites. According to various researchers[3-4] the corrosion behaviour of alluminium alloy reinforced with graphite has received relatively little attention. But corrosion behaviour of ZA-27 reinforced with graphite[5] in hydrochloric acid and SAE40 engine oil has been reported. It has been established by various research studies that the corrosion behaviour of a metal matrix composite is decided by numerous factors such as composition of the alloy, the matrix microstructure, the dispersoid used, its size and distribution in the matrix and even the technique adopted for preparing the composite. Even a small change in any one of these factors can seriously affect the corrosion characteristics of the material.[6-7]

## II. EXPERIMENTAL PROCEDURE

In this research, materials used are, matrix alloy ZA-27 and reinforcement quartz. The composition of ZA-27 is given in Table1.

Table1: Composition of ZA-27

| Aluminium | Copper | Magnesium | Zinc |
|---|---|---|---|
| 26-28% | 2-2.5% | 0.01-0.02% | Balance |

The reinforcement selected is red mud which is a waste obtained after the removal of aluminium from its ore. Procured from HINDALCO, Renikoot district, UP

The corrosion medium used was 0.035%, 0.35% and 3.5% solutions of neutral chloride like sodium chloride solutions

**2.1 Preparation of composites**

The liquid metallurgy route using vortex technique[8] is employed to prepare the composites. A mechanical stirrer was used to create the vortex. The reinforcement material used was Red Mud particulates of size varying 50-80 µm. The weight percentage of Red Mud used was 2-6 weight percentages in steps 2%. Addition of Red Mud in to the molten ZA-27 alloy melt was carried out by creating a vortex in the melt using a mechanical stainless steel stirrer coated with aluminite (to prevent migration of ferrous ions from the stirrer material to the zinc alloy). The stirrer was rotated at a speed of 450 rpm in order to create the necessary vortex. The Red Mud particles were pre heated to 200°C and added in to the vortex of liquid melt at a rate of 120 g/m. The composite melt was thoroughly stirred and subsequently degassed by passing nitrogen through the melt at a rate 2-3 l/min for three to four minutes. Castings were produced in permanent moulds.

Castings were produced in permanent moulds in the form of cylindrical rods. [Diameter 30mm and length 150mm] The material was cut into 20x20mm pieces using an abrasive cutting wheel. The matrix alloy also cast under identical conditions for comparison.

**2.2 Specimen preparation**

The samples were successively ground using 240, 320, 400 and 600 SiC paper and were polished according to standard metallographic techniques and degassed in acetone and dried. The samples were weighed up to fourth decimal place using electronic balance and also the specimen dimensions were noted down using Vernier gauze.

**2.3 Corrosion Test**

The corrosion behaviour of ZA-27 alloy was studied by immersion test. The static immersion corrosion method was adopted to measure the corrosion loss. 0.035%, 0.35% and 3.5% sodium chloride solutions as corrodent were used to characterize the corrosion behaviour. 200 ml of the prepared solution was taken in a beaker. Samples were suspended in the corrosive medium for different time intervals up to 40 days and taken out in the steps of 10 days. To minimize the contamination of the aqueous solution and loss due to evaporation, the beakers were covered with parafilm during the entire test period. After the specified time the samples were cleaned mechanically by using a brush in order to remove the heavy corrosion deposits on the surface. The corresponding changes in the weights noted. At least three samples were tested and average value was taken. Corrosion rates were computed using the equation

Corrosion rate = 534 W/DAT mpy

Where W is the weight loss in gms, D is density of the specimen gm/cc, A is the area of the specimen (inch$^2$) and T is the exposure time in hours.

## III. RESULTS AND DISCUSSION

Red mud was subjected to XRD analysis to know the composition.

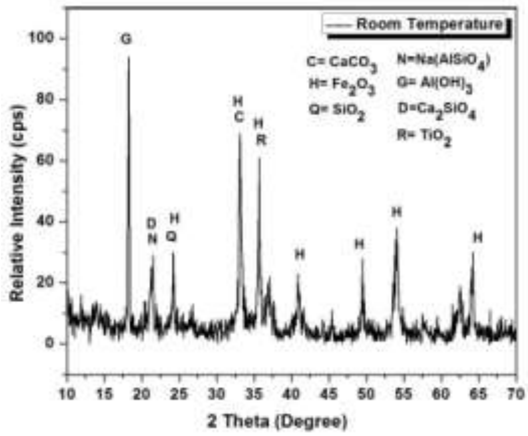


**Fig 1**: XRD analysis of red mud.

Figure 1 shows the XRD analysis of Red Mud particulates. The main components found in the XRD analysis are hematite (Fe2O3), Gibbsite (Al(OH)3), Rutile (TiO2), Calcite (CaCO3), sodium aluminium silicate (NaAlSiO4), Dicalcium silicate (Ca2SiO4) and quartz (SiO2).(21)[14].

Fig 2to 4 give the corrosion rate of composites with different percentage of Red Mud in 0.035%, 0.35% and 3.5% sodium chloride medium.

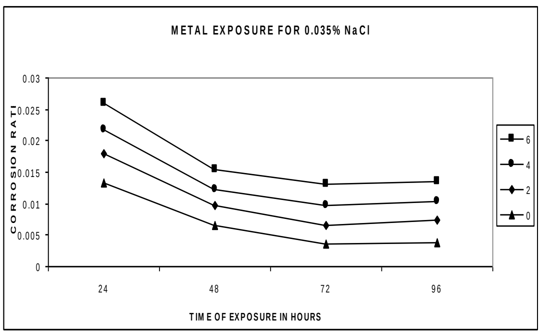


**Fig 2**- Weight loss corrosion of composite with matrix alloy in 0.03 5 3% Sodium chloride solution

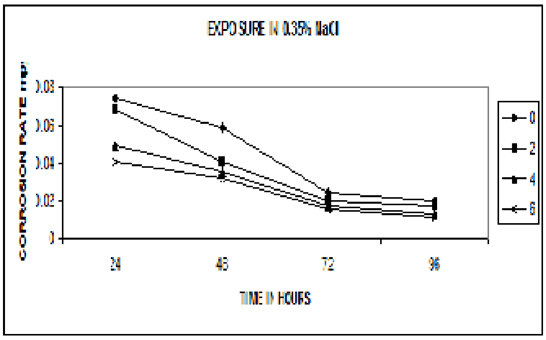


**Fig 3-** Weight loss corrosion of composite with matrix alloy in 0.3 5 3% Sodium chloride solution

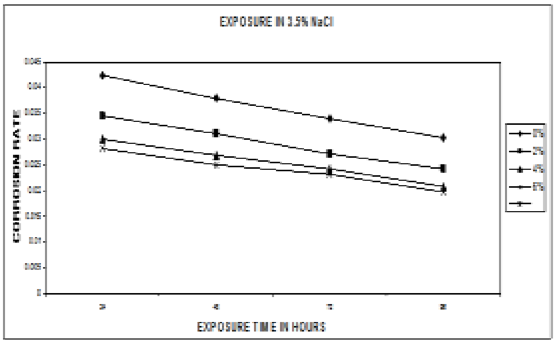


**Fig 4** - Weight loss corrosion of composite with matrix alloy in 3. 5 3% Sodium chloride solution

### 3.1 Effect of test duration

The corrosion rate mpy measurement as a function of exposure time in the static immersion test is shown in the Fig1 to 4. The trend observed in all the cases show decrease in corrosion with increase in test duration. It is clear from the graph that the resistance of the composite to corrosion increases as the exposure time increases. This eliminates the possibility of hydrogen bubbles clinging on to the surface of the specimen and forming a permanent layer affecting the corrosion process. The phenomenon of gradually decreasing corrosion rate indicates the possible passivation of the matrix alloy. De Salazar[9] explained that the protective black film consists of hydrogen hydroxy chloride, which retards the forward reaction. Castle et. al.[10] pointed out that the black film consists of aluminium hydroxide compound. This layer protects further corrosion in corrosion media. But exact chemical nature of such protective film still is not determined.

### 3.2 Effect of red mud content

From the Fig 2 to 4 it can be clearly observed that for both as cast and composite, corrosion rate decreases monotonically with increase in Red Mud content. In the present case, the corrosion rate of the composites as well as the matrix alloy is predominantly due to the formation of pits and cracks on the surface. In the case of base alloy, the sodium chloride solution used induces crack formation on the surface, which eventually leads to the formation of pits, thereby causing the loss of material. The presence of cracks and pits on the base alloy surface was observed clearly. Since there is no reinforcement provided in any form the base alloy fails to provide any sort of resistance to the acidic medium. Hence the weight loss in case of unreinforced alloy is higher than in the case of composites.

Red Mud being the ceramic remains inert and is hardly affected by sodium chloride solution during the test and is not expected to affect the corrosion mechanism of the composite. The corrosion result indicates an improvement in corrosion resistance as the percentage of Red Mud particulates increased in the composite, which shows that the Red Mud particulates directly or indirectly influence the corrosion property of the composites. B.M.Sathish et.al.[11]who obtained similar results in glass short fiber reinforced ZA-27 alloy composites reported that the corrosion resistance increases with increase in reinforcement.

Wu.Jinaxin et.al[12] in their work on corrosion of aluminium based particulate reinforced MMCs, state that the corrosion is not affected to a significant extent by the presence of Red Mud particulates in aluminium, where as the particulates definitely play a secondary role as a physical barrier as far as MMC corrosion characteristics are concerned. A particulate acts as a physical barrier to the initiation and development of corrosion pits and also modifies the microstructure of the matrix material and hence reduces the rate of corrosion.

One more reason for the decrease in corrosion rate is the intermetallic region, which is the site of corrosion forming crevice around each particulates, which may be due to formation of magnesium inter- metallic layer adjacent to the particulate during manufacture as discussed by Trzaskoma[13], Mclntyre[14] et.al. further showed that the magnesium inter-metallic compounds are more active than the alloy matrix. Pitting in the composites is associated with the particulate matrix interface, because of the higher magnesium concentration in this region. With increase in time pitting would continue to occur at random sites on the particulate matrix interface. The active nature of the crevices would cathodically protect the reminder of the matrix and restrict pit formation and propagation.

## IV. CONCLUSION

The Red Mud content in ZA-27 alloys plays a significant role in the corrosion resistance of the material. Increase in the percentage of Red Mud will be advantageous to reduce the density and increase in the strength of the alloy, but the corrosion resistance is thereby significantly reduced.

ZA-27 MMCs when reinforced with Red Mud of weight percentage from 0 to 6 percent could be successfully produced by liquid melt metallurgy technique. The rate of corrosion of both the alloy and composite decreased with increase in time duration in 3% sodium chloride solution. The corrosion rate of the composites was lower than that of the corresponding matrix alloy in 3% sodium chloride solutions from 10 to 40 days.

## ACKNOWLEDGEMENTS

Authors wish to thank the management of Sri Siddhartha Institute of technology, Tumkur and Adarsha Institute of technology, Bangalore for constant support.

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H.V.Jayaprakash. "Corrosion studies of ZA-27 / Red Mud Composites in Neutral Chloride Medium." International Journal of Engineering Research and Applications (IJERA), vol. 7, no. 9, 2017, pp. 69–72.