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Studies on Corrosion Properties of Aluminium 6013/ Red Mud Metal Matrix Composites in Sodium Chloride and Sodium Hydroxide Medium

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Abstract:
This paper deals with the development of metal matrix composites exhibiting high corrosion resistance when compared with the matrix alloy. Matrix selected is Al6013 and reinforcement selected is red mud particulates, which is a ceramic material. Liquid melt metallurgy technique using vortex method was employed for the manufacture of the metal matrix composites. Bar castings were taken and are cut into cylindrical discs of 20mm diameter and 20mm thickness. Static weight loss corrosion tests were conducted according to ASTM standard G69-80 at room temperature. Mediums used for test were made up of mixtures of sodium chloride and sodium hydroxide solutions. In all concentrations of sodium chloride and sodium hydroxide solutions corrosion rate decreases with increase in exposure time for matrix and metal matrix composites with increase in red mud content.

Key words: Composites, vortex, particulates, red mud

I. INTRODUCTION

A composite can be defined as heterogeneous system containing a matrix which may be metal or alloy and a reinforcement which may be particulates or fibres or whiskers. Both matrix and reinforcement will not react with each other. Composites are tailor made materials to suit particular requirements like reduction in density or improvement in stiffness, yield strength, ultimate tensile strength and wear resistance. The attractive physical and mechanical properties such as high specific modulus, strength and thermal stability can be obtained from MMCs. Thus, MMCs combine metallic properties with ceramic properties leading to greater strength in shear and compression and higher service temperature capabilities (1-8). Aerospace, automotive and other structural industries are showing more interest in the use of metal matrix composites over the past few decades, as a result of the availability of reinforcements and the development of various processing routes which result in reproducible micro structure and properties (9-10). The trend is now towards the safe usage of the MMCs as components in the automobile engine, working particularly at high temperature and pressure environments. Typical examples are piston, cylinder liner, brake caliper etc (11-14). Over the last two decades, metal matrix composites are of particular interest and the most popular families being represented by aluminium reinforced with ceramic particulates. Many researchers have carried out research work with aluminium 6061 as matrix and used many reinforcements like alumina, silicon carbide, quartz, albite and garnet particulates. But the studies were limited to mechanical properties only. Works related to corrosion studies are very less. The work with red mud as reinforcement for aluminium 7075matrix has been carried out by researchers with respect to mechanical properties only. P.V.Krupakara and H.R.Ravikumar (15) manufactured aluminium 6061 alloy metal matrix composites with red mud particulate reinforcement. Static weight loss corrosion test was carried out by them in sea water for a time of exposure from 24 to 96 hours. Composites exhibited improved corrosion resistance when compared to matrix alloy. Tasveer Singh (16) studied the tribological behaviour of Aluminium 6063 / redmud metal matrix composites which were manufactured by stir casting process. The researcher conclude that sliding distance has the highest influence on wear rate followed by sliding speedand applied load for Al – 6063/ 5% Red Mud metal matrix composites. Panwar N and Chauhan A (17) in their research review inform that Aluminum composites are widely used materials amongst the different category of metal matrix composite materials available. The main problem associated with the Metal Matrix Composites is their higher cost of reinforcement. To overcome this obstacle, a need arises to look for low cost reinforcements such as Red mud, Fly ash, and graphite etc. which may result in better properties of the developed composite. Further, the use of red mud as a reinforcement material will consume a waste product which otherwise can cause disposal problem and environmental hazards. M.Mamathaet al (18) studied the corrosion behaviour of aluminium 7075 / red mud particulate composites prepared by liquid melt metallurgy technique. The researchers conducted static weight loss corrosion test, open circuit potential test and potentiostat test in three different concentrated solutions od sodium chloride. In all the three types of corrosion characterization they obtained increased corrosion resistance with respect to increased percentage of reinforcement and exposure time.

II. EXPERIMENTAL PROCEDURE

Material Selection: In the present study the matrix alloy used is Al6013, which is having improved properties like casting and strength. Table 1 gives the detailed chemical composition of Al6013 alloy.

Table.I. Chemical Composition of Al6013alloy

Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
0.6	0.5	1.1	0.2	0.8	0.1	0.25	0.1	Bal

The reinforcement used is red mud particulates. Red mud is a waste obtained after the removal of aluminium from its ore. The red color is caused by the oxidized iron present, which can make up to 60% of the mass of the red mud. EDS analysis of red mud shows the presence of different metallic oxides. It is a pure ceramic material. Red mud particulates are procured from HINDALCO, Renikoot district, UP, India. Red mud particulates of size 50-80 µm are selected for the present experimental studies. The corrosion mediums used to characterize the composites are 0.03%, 0.3%, 3% sodium chloride and 0.25M, 0.5M and 1M solutions of sodium hydroxide.

III. COMPOSITE PREPARATION

Liquid melt metallurgy technique was adopted for the manufacture of metal matrix composites containing Aluminium 6061 ally and red mud particulates. This method employed by many researchers because of its simple procedure (19). The matrix material Aluminium6013 is heated to its melting temperature and a vortex is created by introducing a impeller made of aluminite coated steel rod. Aluminite will prevent the migration of ferrous ions from the impeller to join the melt. Stirring was carried out at 450 rpm so that a clear vortex is created. Uncoated red mud particulates of size 50-80µm was pre heated to 400°C in a muffle furnace and added in to the vortex of liquid melt at a rate of 100 g/m. The composite melt was thoroughly stirred and immediately degasification was carried out by the addition of degasifying tablets made up of hexachloro ethane to the melt. Castings were taken in pre heated permanent moulds made up of cast iron in the form of cylindrical rods with dimensions 30mm diameter and length 150mm. These castings are subjected to machining for the manufacture cylindrical specimens of dimension 20mm diameter and 20 mm length. Matrix alloy was also casted and machined similar to composites in order to compare the results with those of composites. In this way Aluminium 6013 matrix containing 2, 4 and 6 weight percent of red mud particulates were produced.

Specimen preparation

The cylindrical specimen samples with dimension 20mm diameter and 20mm length which were manufactured by machining are made ready for the experiment by subjecting to standard metallographic techniques to get smooth surface without out any cracks are gaps by rubbing with emery papers of numbers ranging from 240 to 600. The specimens are dipped in acetone and air diried. Scanning electron microscope was used to take out the microstructures of the specimens including matrix alloy. The weight of the samples was determined using electronic balance. Weight up to fourth decimal place was noted for all the specimens. The dimensions of the specimen were determined using slide callipers.

Corrosion test

The static weight loss corrosion behaviour of Aluminium 6013 alloy was carried out by immersing the specimens in the test solutions. For the weight loss test the quantity of corrosion medium solution taken was 200 cm^3. The specimens were immersed for time intervals up to 96 hours in steps of 24 hours. After the specified time the samples were taken out and subjected to mechanical cleanliness by using a brush such that the heavy corrosion deposits on the surface is removed. Then specimens are washed with distilled water and acetone and subjected to air drying. Then the weight of the specimens after corrosion test was determined up to fourth decimal place using the same electronic balance which was used in the beginning. The difference in weights for all the specimens in all the mediums of sodium chloride and sodium hydroxide were determined. The formula Corrosion rate = 534 W/DAT mpy given by Fontana M.G (20) was employed for the calculation of corrodion rates. Where is weight loss in gm is given by W, density of the specimen given by D in gm/cc, A is the exposed in square inch and exposure time in hours is given by T.

IV. RESULTS AND DISCUSSIONS

Red mud particulates were subjected to energy dispersive X-ray spectroscopic analysis, the spectrum is shown in Figure 1. The results exhibit that red mud contains oxides of iron, aluminium, titanium, calcium, zirconium, sodium, vanadium etc.

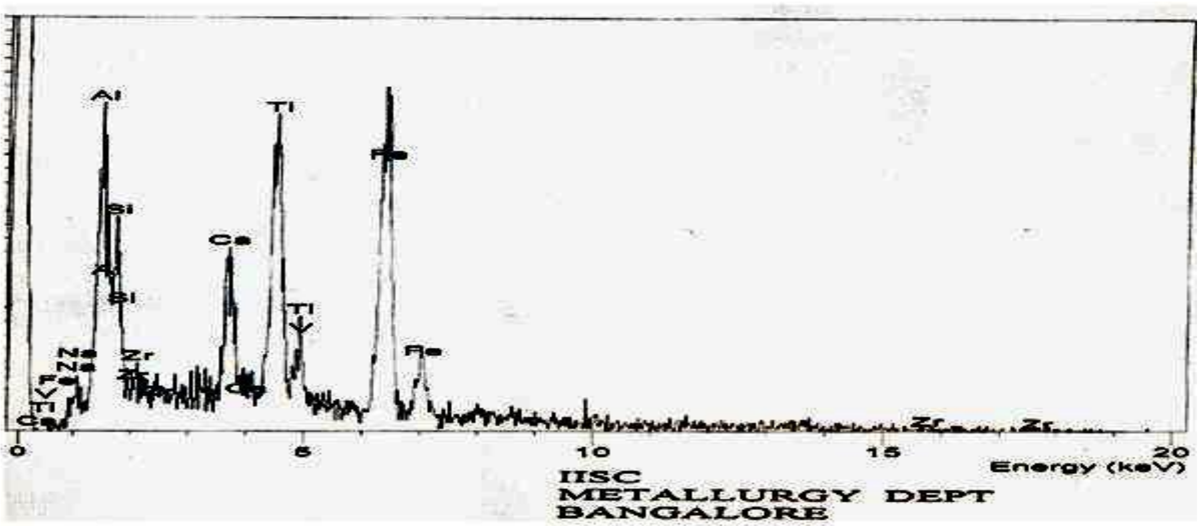

Figure.1. EDX analysis of red mud

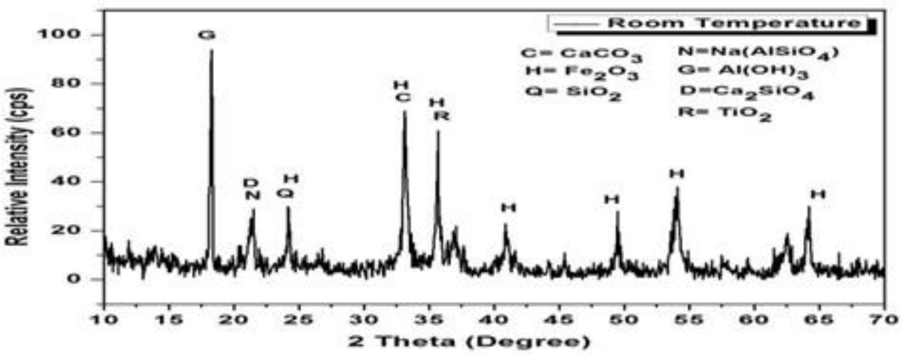

Figure.2.XRD analysis of red mud

The elemental analysis and phase characterization of red mud particulates by XRD is given in figure 2.The main components found in the XRD analysis are hematite (Fe_2O_3),Gibbsite ($Al(OH)_3$), Rutile (TiO_2), Calcite ($CaCO_3$), sodium aluminium silicate ($NaAlSiO_4$), Dicalcium silicate (Ca_2SiO_4) and quartz (SiO_2).(21) Microstructures using scanning electron microscope of aluminium 6013 alloy and its metal matrix composites containing the same alloy with 2,4 and 6% red mud particulates are shown in figures 2 to 5. In all the composites uniform distribution of red mud particulates was found..

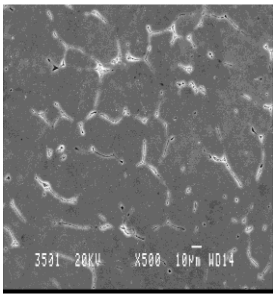

Figure.2. SEM of alloy

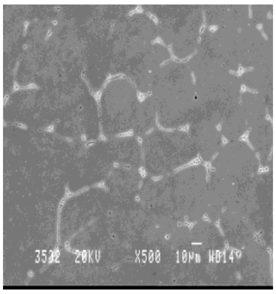

Figure.3. SEM of 2% MMC

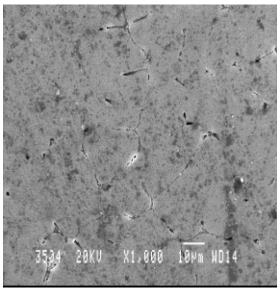

Figure.4. SEM of 4% MMC

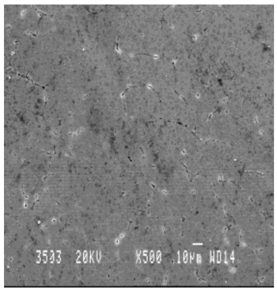

Figure.5. SEM of 6%MMC

Figures 6 to 11 are the graphs plotted by computer simulation in MS excel by taking time of exposure on x axis and corrosion rate on the y axis after the corrosion tests in different concentrations of sodium chloride and sodium hydroxide.

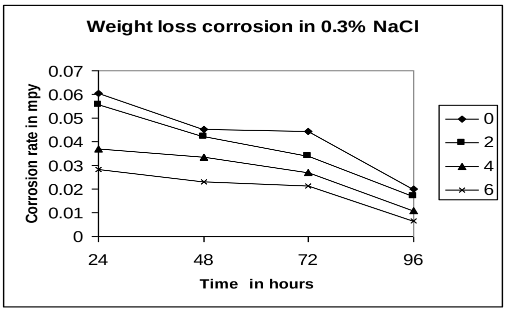

Figure.6. Results in 0.03% NaCl

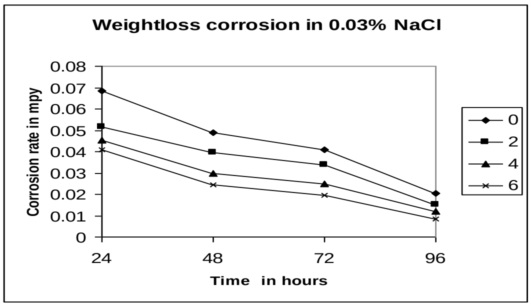

Figure.7. Results in 0.3%NaCl

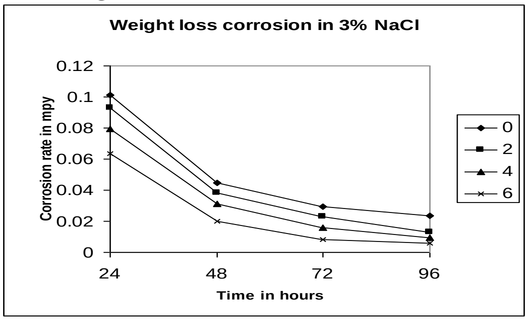

Figure.8. Results in 3%NaCl

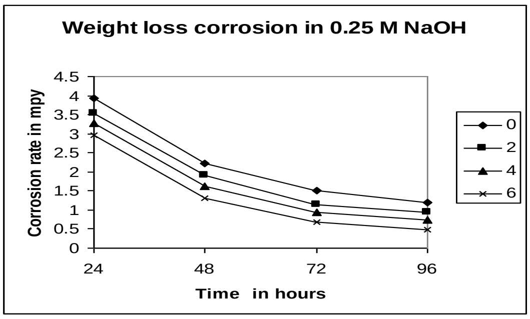

Figure.9. Results in 0.25 M NaOH

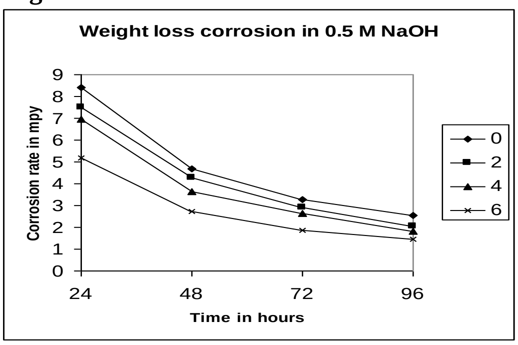

Figure.10. Results in 0.5 M NaOH

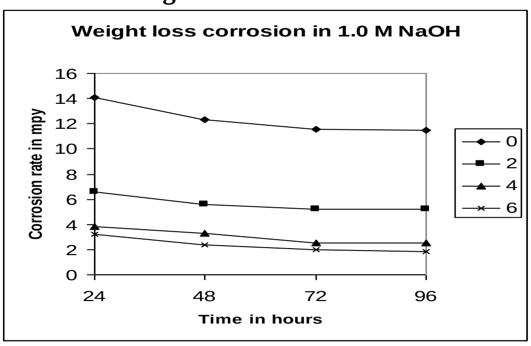

Figure.11. Results in 1 M NaOH

V. EFFECT OF EXPOSURE TIME

From the graphs it's clear that the corrosion rate is found to decrease during the exposure time. Due to the passivity exhibited by the matrix alloy the corrosion rates are decreased. A black film was developed on the specimens which is clearly visible. Black film is made up of Al $(OH)_{3,}$ which covered the surface. Thus Al $(OH)_3$ acts as a passive layer. Since the passive layer acts as a barrier between the fresh metal surface and the corrosive media, it avoids the direct contact between the specimen and the corrosive media, thus further dissolution of the metal alloy would not takes place. Corrosion rate depends on the stability, nature and thickness of the passive layer. After a specific duration, the film may be stable but it contains porosities and micro cracks through which solution may come in contact with the specimen surface and hence oxygen drifting might take place through these defects in the passive layer. Such passive layer reduces the contact between the specimen surface and corrosion media. Hence it leads to drastic reduction in corrosion rate. During weight loss corrosion test, decrease in corrosion rate with time is due to an increase in the quantity of dissolved Al^{3+} ions, which leads to the increase in the release of H_2(g).Hence, the pH of solution increases. The H_2(g) evolved also remains entrapped in the crevices or cavities. Thus it protects these regions from further corrosion. Due to the saturation of the solution with the anodic ions, the anodic reaction is slowed down. According to Trzaskoma (22) if specimen is exposed to saturated media at very high temperature and for a long time, the corrosive chemical reaction would be stopped due to exhaust of conducting media.

Effect of reinforcement: From the graphs, it is clearly observed that, as the percentage of reinforcement increases rate of corrosion decreases monotonically. During casting an interface is developed between the matrix alloy and reinforced particulates, which is mainly responsible for decrease in corrosion rate. The presence of a more conductive phase at the interface provides an easier path for the electron exchange necessary for oxygen reduction and will drive the anodic reaction to higher level. Both reinforced matrix alloy and un reinforced matrix alloy exhibit decrease in corrosion rate with increase in exposure time. Decrease in corrosion rate gradually with increase in reinforcement content and exposure time is due to the formation of the protective layer which is stable and not attacked by neutral and alkali solutions. But attacked by acid solutions (23).

Effect of concentration of corrosion media: The tests are conducted in 0.03, 0.3 and 3 percent solutions of sodium chloride and 0.025, 0.05 and 0.1 molar solution of sodium hydroxide. In these corrosion mediums the corrosion rate of matrix alloy and the composites will increase with increase in concentration of corrosion medium. The corrosion rate is very high in 0.1 normal solution of sodium hydroxide. Because it may be due to segregation of alumina particles in the matrix which is very common in as cast composites and promotes nucleation of pits which facilitates corrosion. Surface variations due to the presence of ceramic reinforcement in the matrix can also promote film flaws and hence increase pitting. (24)

VI. CONCLUSIONS

- Metal matrix composites of Aluminium 6061 matrix and red mud reinforcement were manufactured by liquid melt metallurgy technique.
- Microstructures of composites showed uniform distribution of reinforcement
- Corrosion rates decreases with increase in exposure time in all combinations of corrosion medium.
- As the reinforcement content increased in the matrix corrosion rate decreased irrespective of corrosion medium.

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