Corrosion Behaviour of Red Mud particulate reinforced Aluminium 6013 composites by Potentiodynamic Polarization

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Abstract

Metal matrix composites containing Aluminum 6013as matrix are getting considerable applications in the automotive, aerospace and other related areas. Ceramic particulates as reinforcement particles in Al-based Metal matrix composites will have a great influence on corrosion resistance. This research work gives the details of corrosion behavior of Red Mud particulate reinforced Aluminium 6013 composites in neutral medium by potentiodynamic polarization (PDP) techniques using electrochemical work station. Composites are manufactured by stir casting method. Composites of Aluminium 6013 containing red mud particulates with different weight percentage were manufactured. Aluminium 6013 alloy was also casted for comparison. Corrosion rates of composite materials were found to be decreased when compared with that of matrix alloy. Therefore composite materials are more suitable for application in marine engineering than matrix alloy.

Keywords: Aluminium -6013, Red Mud, liquid stir casting method, Vortex,

Introduction

Metal matrix composites made up of aluminium and aluminium alloys are getting importance due to their applications in various fields like automobile, aircraft and marine engineering (1-3). Common reinforcements used for the manufacture of aluminium based composite materials are quartz, silicon carbide, alumina, titanium di boride, titanium dioxide etc.(4-8). The reinforcement red mud is obtained as a waste from bauxite ore after the removal of aluminium from it. Energy dispersive X-ray spectroscopy studies of red mud reveal that it contains oxides of Titanium, Zirconium, Vanadium, Iron, Aluminium, Sodium, Calcium and Silicon. (9). XRD studies reveal that the main components present in red mud particulates are oxides of Iron, Titanium, Silicon, hydroxide of Aluminium, carbonate of Calcium, Silicates of Sodium, Aluminium and calcium (10). Therefore ceramic inert behaviour was observed in red mud particulates metal matrix composites. Krupakara et al (11) studied the behaviour of Aluminium 6061 composites reinforced with red mud particulates and in sea water collected from Arabian Sea shore of Malpe beach in Udupi district, Karnataka. Composite material was manufactured by stir casting method. The results showed that as the red mud content and time of exposure increased composites exhibited increased resistance to corrosion. Jayaprakash et al (12) manufactured composites made up of ZA-27 alloy reinforced with red mud particulates and studied the open circuit potential behavior of the composites. The

authors reported that the matrix alloy exhibits less corrosion resistance due to development of high potential when compared to the composites containing three different percentages of red mud particulates. Harjeet Nath and Abanthi Sahoo (13) characterized the red mud particulates using XRD, EDX, FTIR and BET analysis. Presence of certain compounds in red mud as found in XRD analysis was confirmed by the authors using EDX and FTIR analysis. They also studied the FESEM image of the red mud which showed that the red mud particulates are poorly crystalized with high porosity. BET analysis conducted by the same authors reveals that red mud particulates are having decent surface area.

Material selection

The matrix alloy selected in this work is Aluminium6013.It is commercially available. Research work on the corrosion behavior of this alloy reinforced with red mud particulate has not been studied so far. The composition of Aluminium 6013 alloy is given in table1.

Table 1: Composition for Aluminium 6013 alloy

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

The reinforcement used is 50-80µM size red mud particulates. It is procured from HINDALCO, Renikoot District, UP state, India. It is the waste obtained after the removal of aluminium from its ore.

The corrosion medium used to study the Potentiodynamic polarization studies were carried out in 0.035%, 0.35% and 3.5% sodium chloride solutions. Analytical grade sodium chloride was used to prepare these solutions.

Composite preparation

Stir casting method (14) was used to manufacture the metal matrix composites. Vortex in the melt of the alloy is created by introducing a mechanical stirrer. Red mud particulate with 2,4 and 6 weight percentage was added as reinforcement to manufacture composite materials. Red mud particulates are added to the vortex created in the molten aluminium 6013 alloy with the help of mechanical impeller having a coating of aluminium in order prevent the release of ferrous ion from the impeller into the molten metal. A vortex was created by rotating the mechanical stirrer at a speed of 450 rpm. The red mud particulates were added in to the melt at a rate of 120 g/m after preheating it to 400^0C in a muffle furnace. The composite melt was thoroughly stirred and subjected to degasification to remove the entrapped gas bubbles by adding degasification tablets made up of hexa chloro ethane.

Castings were produced by pouring the melt with reinforcement in permanent cast iron molds. Matrix alloy was also casted in the same way to compare the results obtained for composites.

Specimen preparation

Specimens of dimension 20 mm x 10 mm x 1mm were machined from cylindrical bar castings of matrix alloy and composites. Before the conduction of the experiments specimen were subjected to scanning electron microscopy to study the distribution of red mud particulates in the alloy. All the composites showed even distribution of the red mud particulates.

Electrochemical measurements were carried out using electrochemical work station model CHI 608E series manufactured by CH Instruments, USA which connected to cell with a reference electrode, counter electrode and a provision for connecting the manufactured specimen as working electrode. Figure 1 shows the electrochemical work station.

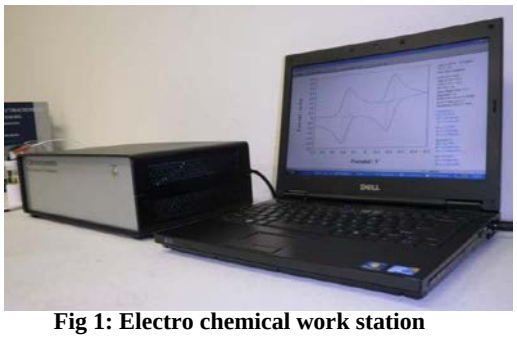

Fig 1: Electro chemical work station

The electrochemical investigations were carried out in a 100 cm^3 beaker which is used as cell containing an Ag/AgCl electrode as the reference electrode and a platinum wire as the counter electrode (CE). 1 cm^2 area of

the specimen was exposed to the corrosive environment. Figure 2 shows the cell used for the test.

Fig: 2 Cell used for the test

Results and discussion

Energy dispersive X-ray spectroscopy analysis of red mud particulates which clearly shows the presence of oxides of different metals is given in Figure 3.

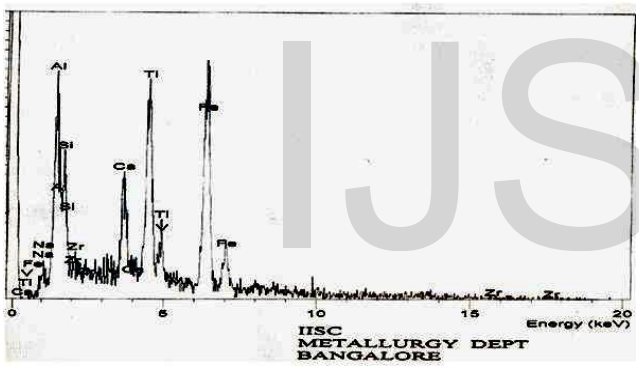

Fig 3: Energy dispersive X-ray spectroscopy analysis of red mud

The elemental analysis and phase characterization of red mud particulates by XRD is given in figure 4. The main components found in the XRD analysis are hematite (Fe2O3), Gibbsite(Al(OH)3), Rutile (TiO2), Calcite (CaCO3), sodium aluminium silicate (NaAlSiO4), Di calcium silicate(Ca2SiO4) and quartz(SiO2). (21)

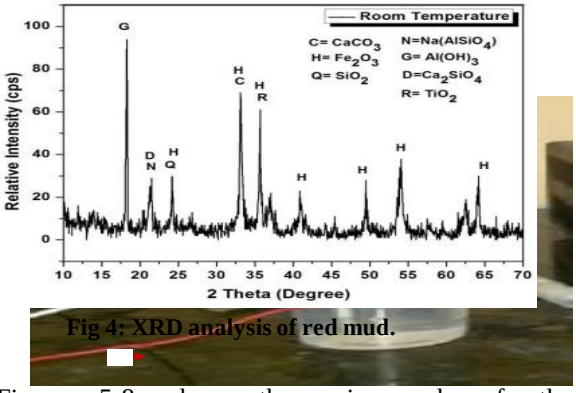

Fig 4: XRD analysis of red mud.

Figures 5-8 show the micrographs of the Aluminium 6013 matrix and Aluminium 6013/ red mud composites in order to find out the distribution of red mud particulates in the matrix alloy. From the scanning electron micrographs of the composites distribution of red mud particulates is found to be uniform.

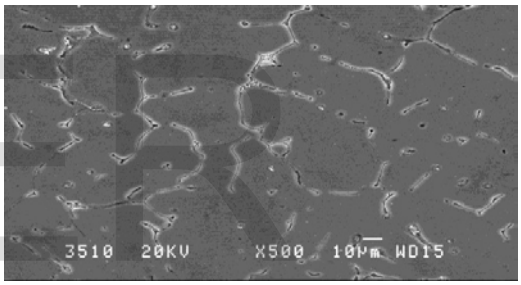

Fig 5: SEM of matrix

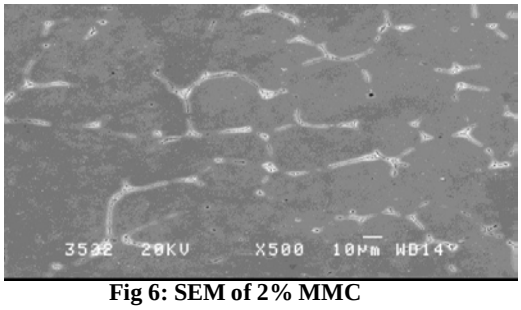

Fig 6: SEM of 2% MMC

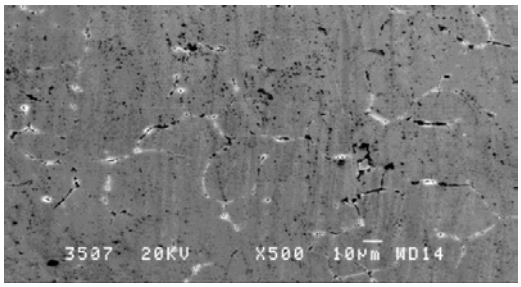

Fig 7: SEM of 4% MMC

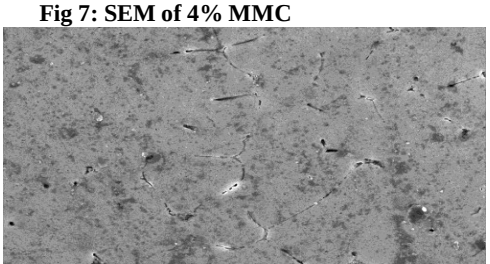

Fig 8: SEM of 6% MMC

Figures 9-11 show the results of potentiodynamic polarization studies of Aluminium 6013 / red mud composites in 0.035%, 0.35% and 3.5% sodium chloride solutions.

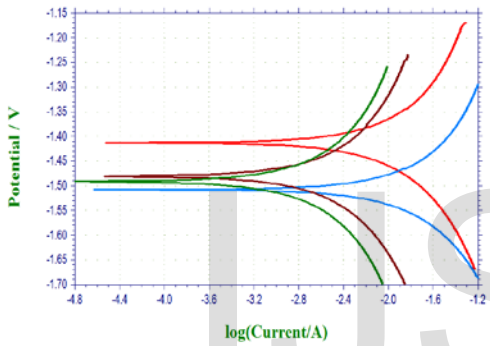

Fig 9: Tafel polarization curves in 0.035%NaCl

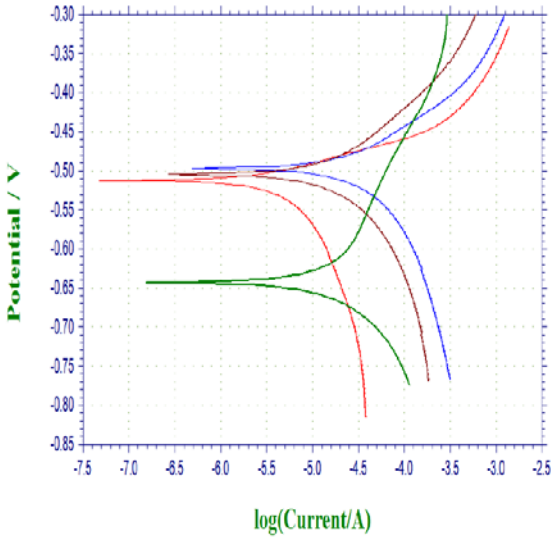

Fig 10: Tafel polarization curves in 0.35%NaCl

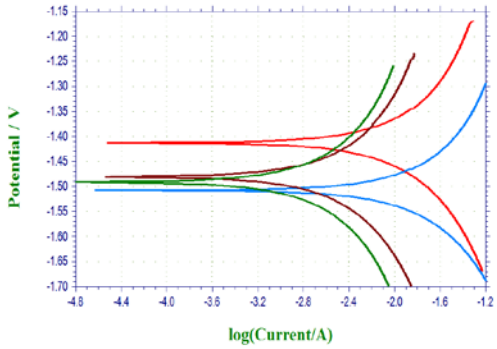

Fig 11: Tafel polarization curves in 3.5%NaCl

The point of intersection between the cathodic and anodic curve gives Icorr. The corrosion rate in mpy is calculated by the software attached to electrochemical work station.

Percentage of Red mud	0	2	4	6
Concentration of NaCl	Corrosion rate in mpy			
0.035	4.536	4.224	3.92	3.125
0.35	6.0043	5.987	5.24	3.208
3.5	9.824	6.408	5.025	4.148

Table 2: Corrosion rates in mpy

Table 2 gives the results with respect to the corrosion rates of matrix ally and its composites with red mud particulate in different concentrated solutions of sodium chloride. It is clearly observed that as the concentration of sodium chloride increases the corrosion rate increases with increase in reinforcement content. The concentration plays an important role in the corrosion studies. Due to increase in concentration the attack on the matrix and composites increases hence corrosion rate increases.

Reinforcement also plays an important role in the control of corrosion attack by sodium chloride. It is clear from the table that as the percentage of reinforcement increases the corrosion rate decreases irrespective of concentration of sodium chloride. As the reinforcement content increases the exposure of

the matrix alloy to the corrosive medium decreases hence attack on the alloy surface decreases. Red mud particulates used as reinforcement are inert in nature and not attacked by any acid, base or salt solution, hence the corrosion rate decreases. Therefore composites are more suitable than matrix alloy in saltish and marine environment.

Conclusion

- Stir casting method was employed to manufacture Aluminium 6013/ red mud particulate reinforced composites.
- Potentiodynamic polarization method was employed to test the corrosion behaviour of Aluminium 6013/ Red mud composites in comparison with Aluminium 6013 alloy in sodium chloride solutions of different concentrations.
- Results of polarization test reveals that as the concentration of sodium chloride solution increases the corrosion rate increases
- The reinforcement red mud plays a important role in the control of corrosion in composites when compared with matrix alloy.
- As the reinforcement content increases the corrosion rate decreases irrespective of concentration of sodium chloride.
- Composites are more suitable than matrix alloy in many applications.

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