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ARTICLE

Corrosion Behaviour of Red Mud Particulate Reinforced Aluminium 6013 Composites by Potentiodynamic Polarization

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ABSTRACT

Metal matrix composites containing Aluminium 6013 as matrix are getting considerable applications in the automotive, aerospace and other related fields. Ceramic particulates as reinforcement particles in Al-based metal matrix composites will have a great influence on corrosion resistance. This study gives the details of corrosion behaviour of red mud particulate reinforced Aluminium 6013 composites in neutral medium by potentiodynamic polarization 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 its alloys are getting importance due to their applications in various fields like automobile, aircraft and marine engineering [1-3]. Common reinforcements used for the manufacturing of the aluminium based composite materials are quartz, silicon carbide, alumina, titanium diboride, 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 revealed that it contains oxides of titanium, zirconium, vanadium, iron, aluminium, sodium, calcium and silicon [9]. X-ray diffraction revealed that the main components present in red mud particulates are oxides of iron, titanium, silicon, hydroxides 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 and Jayaprakash [11] studied the behaviour of Aluminium-6061 composites reinforced with red mud particulates and in sea water collected from Arabian seashore of Malpe beach in Udupi district, India. The results showed that as red mud content and time of exposure increased composites exhibited increased resistance to corrosion. Krupakara and Jayaprakash [11] manufactured composites made up of ZA-27 alloy reinforced with red mud particulates and studied the open circuit potential behaviour of composites. The authors also reported [12] that 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. Nath and Sahoo [12] characterized 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 red mud, which showed that the red mud particulates are poorly crystallized with high porosity. BET analysis conducted by the same authors revealed that red mud particulates are having decent surface area.

EXPERIMENTAL

The commercially available matrix alloy Aluminium-6013 is selected in this work. Research work on the corrosion behaviour of this alloy reinforced with red mud particulate has not been studied so far [13]. The composition of Aluminium 6013 alloy is given in Table-1.

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	0.25	0.1	Bal

The reinforcement used is 50-80 µM size red mud particulates. It is procured from HINDALCO, India as a waste obtained after the removal of aluminium from its ore. The corrosion medium used to study potentiodynamic polarization were carried out in 0.035, 0.35 and 3.5 % sodium chloride solutions. Analytical grade sodium chloride was used to prepare these solutions.

Preparation of composite: Stir casting method [14] was used to manufacture the metal matrix composites. Vortex in the melt of alloy is created by introducing a mechanical stirrer. Red mud particulate with 2, 4 and 6 weight % 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 molten metal. A vortex was created by rotating the mechanical stirrer at a speed of 450 rpm. The red mud particulates were added into the melt at a rate of 120 g/m after preheating it to 400 ºC 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 hexachloroethane.

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 × 10 mm × 1 mm were machined from cylindrical bar castings of matrix alloy and composites. Before the conduction of 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 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 manufactured specimen as working electrode.

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

RESULTS AND DISCUSSION

Energy dispersive X-ray spectroscopy analysis of red mud particulates clearly shows the presence of oxides of different metals as shown in Fig. 1. The elemental analysis and phase characterization of red mud particulates by XRD is given in Fig. 2. The main components found in XRD analysis are haematite (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) [15].

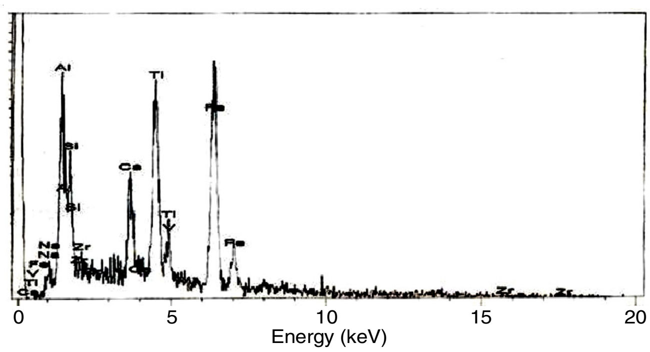

Fig. 1. Energy dispersive X-ray spectroscopy analysis of red mud

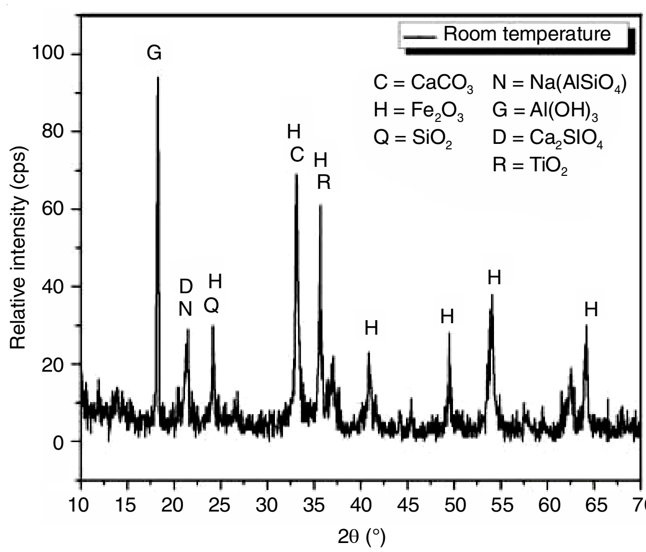

Fig. 2. XRD analysis of red mud

Fig. 3-6 show the micrographs of Aluminium 6013 matrix and Aluminium 6013/red mud composites in order to find out

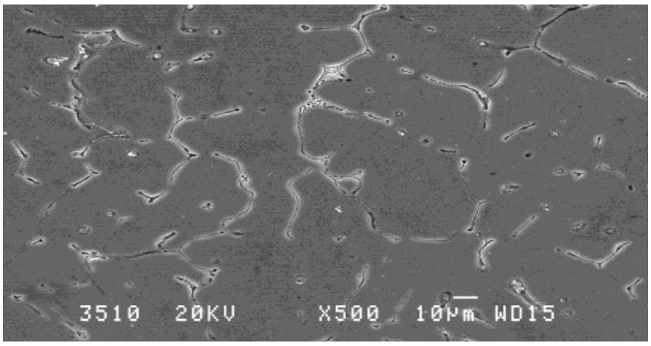

Fig. 3. SEM of matrix

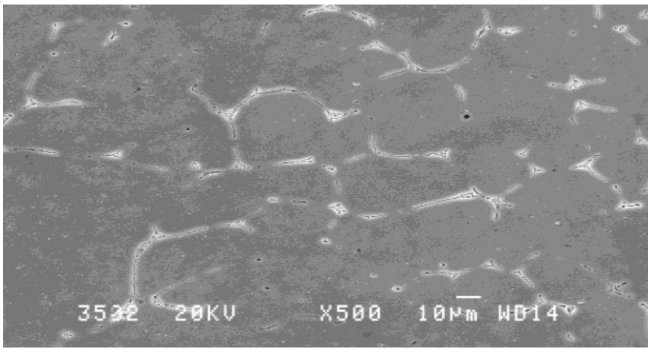

Fig. 4. SEM of 2 % MMC

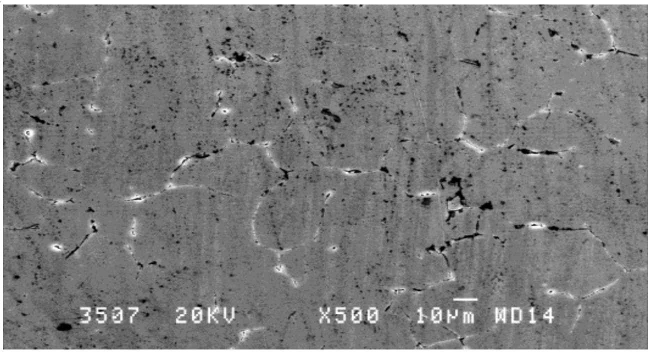

Fig. 5. SEM of 4 % MMC

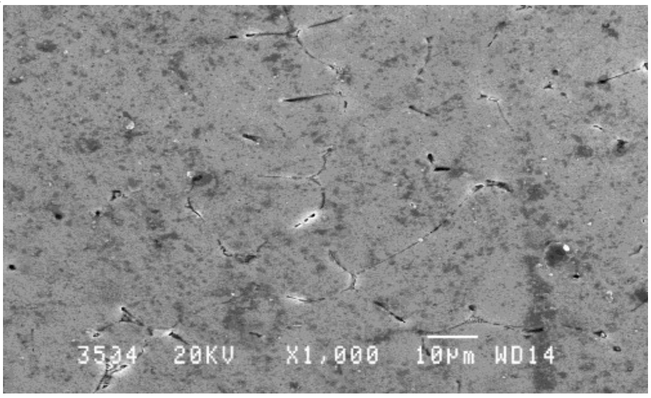

Fig. 6. SEM of 6 % MMC

the distribution of red mud particulates in matrix alloy. From the scanning electron micrographs of composites distribution of red mud particulates is found to be uniform.

Fig. 7-9 show the results of potentiodynamic polarization studies of Aluminium 6013/red mud composites in 0.035, 0.35 and 3.5 % NaCl solutions. The point of intersection between

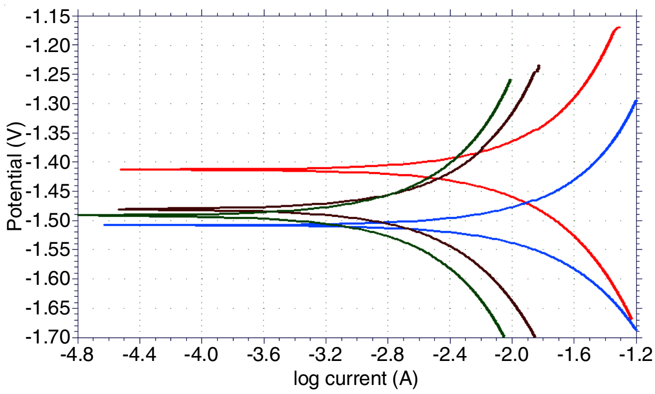

Fig. 7. Tafel polarization curves in 0.035 % NaCl

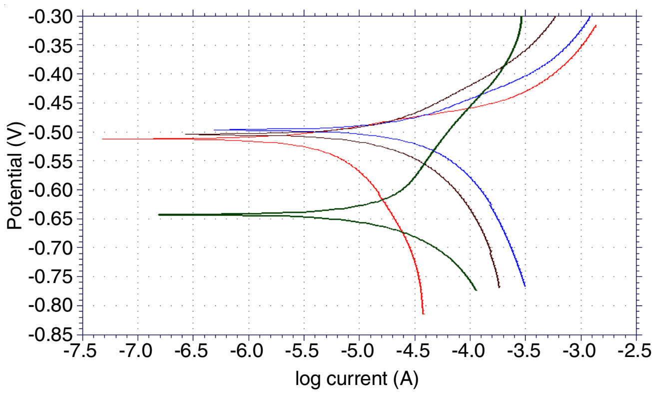

Fig. 8. Tafel polarization curves in 0.35 % NaCl

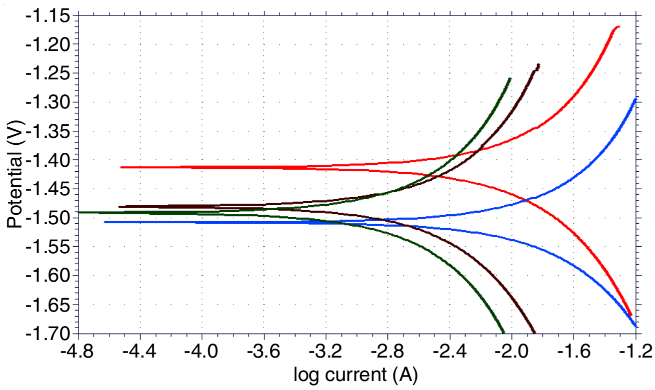

Fig. 9. Tafel polarization curves in 3.5 % NaCl

cathodic and anodic curve gives I_{corr}. The corrosion rate in mpy is calculated by the software attached to electrochemical work station.

Table-2 shows the results with respect to corrosion rates of matrix alloy and its composites with red mud particulate in different concentrated NaCl solutions. 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 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-2 that as the percentage of reinforcement increases the corrosion rate decreases irrespective of concentration of NaCl. As the reinforcement content increases the exposure of matrix

TABLE-2
CORROSION RATES OF ALUMINIUM 6013 ALLOY AND ITS COMPOSITE WITH RED MUD

Concentration of NaCl (%)	Red mud (%)			
	0	2	4	6
	Corrosion rate (mpy)			
0.035	4.5360	4.224	3.92	3.125
0.350	6.0043	5.987	5.24	3.208
3.500	9.8240	6.408	5.025	4.148

alloy to corrosive medium decreases hence attack on 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.

Conclusions

- 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 NaCl solutions of different concentrations.
- Results of polarization test revealed that as the concentration of NaCl 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.

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