Studies on potentiodynamic polarization of Aluminium 2014 / Albite metal matrix composites

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Abstract

Research paper reports the corrosion behaviour like potentiodynamic polarization conducted on aluminium 2014/ albite composite materials. Composite materials were prepared by stir casting technique using vortex method which is also called as liquid melt metallurgy technique. Composites made up of aluminium 2014 as matrix and it is added with 3, 5 and 7 weight percentages of 50-80 micron size albiote particles were casted using pre heated cast iron moulds. Matrix alloy aluminium2014 was also casted in the same way for comparison of the results. Next to machining the specimen from castings microstructural studies was done to make sure about the dispersion of reinforcement. Potentiodynamic polarization studies were done using different concentrated solutions of acid chlorides like hydrochloric acid. Electrochemical work station manufactured by CH Instruments USA, which is interfaced with personal computer and connected to a cell containing electrodes is utilized for the corrosion behaviour test. Results were drawn by the computer in the form of Tafel plots. Software loaded in the attached personal computer calculates the corrosion current and corrosion rate and displays the same. From the results it is understood that as the percentage of albite particles increase in the matrix of aluminium 2014 alloy there will be decrease in corrosion rate and increase in corrosion resistance. Therefore composite materials are more appropriate for uses in comparison to aluminium 2014 alloy in the presence of acid environment.

Key words; Aluminium 2014, Albite, Vortex, polarization, Tafel plot

Introduction

Particulate reinforced aluminium 2014 composites having required properties viz., high specific strength, enhanced fatigue resistance, elevated coefficient of thermal expansion, increased specific stiffness, high dimensional stability when compared to matrix. These characteristics of composite materials will lead to comprehensive research in automotive and aeronautical uses. In automobile industry composites are employed to manufacture piston, brake drum and cylindrical block due to their enhanced corrosion resistance and wear.[1] Gopinath et al[2] subjected hybrid composites of aluminium 6061 containing boron nitride and aluminium oxide to corrosion studies using Biologic Sp-150 workstation containing a cell to hold reference electrode, counter electrode and specimen. They report that corrosion resistance of composite materials increases with increase in reinforcement content when compared to matrix alloy. Ananda Murthy and Somit Kumar Singh[3] studied the corrosion behaviour of aluminium 6061/ titanium carbide composite materials by polarization studies using electrochemical workstation in different concentrated solutions of sodium chloride. They conclude the experimental results as corrosion resistance in composites increases with increase in reinforcement content in all concentrated solutions of sodium chloride. It is due to reinforcement particulates modifying the microstructure of matrix and also acting as physical barrier to the initiation and development of pitting corrosion. Balasubramaniam, and Tiwari [4] studied the corrosion inhibition of aluminium 6061 / SiC composite materials in 3.5% sodium chloride solution by adding inhibitors like rare earth chlorides like cerium and tantalum chlorides using techniques like linear polarization, Tafel extrapolation and electrochemical impedance spectroscopy. They conclude that composites exhibit improved uniform and pitting corrosion resistance when compared to alloy matrix. Sarapure et al[5] studied Corrosion Behaviour of SiC-Reinforced Al 6061/SiC Metal Matrix Composites Using Taguchi Technique. Composites and alloy were exposed to different concentrated solutions of sodium chloride for periods ranging from 40 to 80 days. Corrosion characteristics of the composites were statistically analysed by employing the design of experiments approach using Taguchi technique. Influence of various parameters on corrosion behaviour of composites were investigated by Signal-to-noise ratio and analysis of variance. Result of the research determines that greater corrosion resistance was obtainable by composites when compared to monolithic aluminium 6061 alloy in the chosen corrosion media. Lot of work has been done by researchers on corrosion studies of aluminium 6061 alloy. Corrosion studies of aluminium 7075 based metal matrix compounds are very few. Sudarshan Kumar et al[6] studied the corrosion behaviour of aluminium 7075/ titanium carbide composite materials by potentiodynamic polarization using 3.5% NaCl with varying the molarity of the electrolyte (1M, 2M, and 3M NaCl). Corrosion rates were calculated from corrosion current density (Icorr), by using polarization techniques with the help of Tafel extrapolation. The effect of TiC on microstructural development, hardness and corrosion behaviour was studied. It was observed that the corrosion resistance of the Al 7075-TiC composite was higher than the Al 7075-T651. The corroded surface morphology of revealed pits on the surface and the number of pits increased with increasing the concentration of NaCl. . Sambath Kumar et al[7] studied the corrosion behaviour of hybrid composites of aluminium 78075 composites containing silicon carbide and titanium carbide. They performed the corrosion test by polarization technique utilizing Tafel extrapolation method. They report that aluminium 7075 hybrid metal matrix composites exhibited better corrosion resistance than the pure Al matrix in 3.5 wt. % NaCl solution. Increasing the volume fraction of the reinforcement (SiC and TiC) particulates increased the corrosion resistance of the composites. Detail search of literature reveals that corrosion behaviour of aluminium 7075 composites with respect to static weight loss corrosion test is very less. N. Birbilis et al[8] studied corrosion associated with Al_7Cu_2Fe particles added to aluminum alloy 7075. They say that prior studies regarding either the stereology or electrochemical properties of Al_7Cu_2Fe are scarce. They report that Al_7Cu_2Fe may serve as a local cathode in the evolution of localized corrosion of AA7075-T651 and is capable of sustaining oxygen reduction reactions at rates of several hundreds of $\mu A/cm^2$ over a range of potentials typical of the open circuit potential (OCP) of AA7075-T651 in NaCl solution of various concentrations and pH. The presence of Al_7Cu_2Fe leads to the development of pitting at the particle–matrix interface. Karunanithi et al[9] studied potentiodynamic electrochemical polarisation studies on the Al 7075 alloy of different tempers and Al 7075 + TiO_2 composites in 3.5 wt.% NaCl solution. They report that corrosion potentials (E_{corr}) have shifted towards noble direction with the addition of TiO_2, and there is an increase of corrosion current density (i_{corr}) beyond 10 vol.% TiO_2 in the composites. This is attributed to the increase in particle-matrix interface areas enhancing pitting corrosion. Optical micrographs of the corroded surface of 30% TiO_2 composites exhibited maximum pitting damage. Suresh et al[10] studied the weight loss corrosion behaviour of aluminium 7075 alloy reinforced with nano alumina particles and nano silicon carbide particles separately and a hybrid composite by adding both reinforcements together. Weight-loss approach was carried out by them by immersing the samples for 96 hours in various corrosion media, such as sulfuric acid (H_2SO_4), hydrochloric acid (HCl), and 3.5% sodium chloride (Nacl). They report that hybrid composites exhibit high resistance to corrosion. With reference to the extensive literature survey it was found that so far potentiodynamic polarization studies have not been studied for the composite made up of aluminium 2014 and albite composite materials.

Experimental details

Material selection

Starting materials used are matrix or metal frame work, reinforcement or fortificzation and corrosion medium. Normally a metal or alloy will be matrix which holds the reinforcement as soon as casting and cooling are over. Matrix used in the present research is aluminium 2014 alloy which is gaining popularity since 2000. It is available in the market. Perfectly analysed composition of aluminium 2014 alloy is given in the table1 below.[11]

Table 1: Composition of Aluminium 2014 alloy

Element	Cu	Si	Mg	Cr	Mn	Al
%	4.4	0.8	0.5	0.1	0.6	Bal

The reinforced material used in the present work is albite partic0les of 50-80µM. It is also available commercially. It is a ceramic material and inert. It is not attacked by any acid, base or neutral mediums. Its chemical formula is $NaAlSi_3O_8$. Its structure is tectosilicate and has pure white colour. It will be in triclinic crystal system. It finds application as a gemstone, it is semi-precious. Geologists identify it as an important rock forming mineral and it will use by them for various purpose. The mineral is also used in industry for the manufacture of glass and ceramics. Its hardness is 6-6.5 in Moh's scale. Its specific gravity is 2.6- 2.65. It is also available commercially. It is subjected to pulverization and particulates of 50-80µM were taken and added to molten alloy after pre heating in a muffle furnace at 400^0C.

To prepare the corrosive media research grade hydrochloric acid which is available commercially is used. Solutions of 0.025, 0.05 and 0.1 molar solutions of hydrochloric acid are prepared using double distilled water. Plate 1 and 2 show the sheets of aluminium 2014 and albite crystal.

Plate 1: Aluminium 7075 alloy **Plate 2:** Red mud particulates

Composite preparation

Stir casting route using vortex technique[13] is utilized to manufacture the composite materials. Mechanical stainless steel impeller was used to create the vortex. Preheated and uncoated reinforcement albite particles of dimension varying between 50-80 μM is added into vortex. The weight percentage of albite particles added was 3-7 in steps 2%. Aluminium 2014 was heated slightly above its melting point in a furnace with a door at the bottom containing graphite crucible. Albite particles are added in to the aluminium 2014 alloy melt by forming a vortex using impeller mentioned above which is having a coating of aluminite (in order to avoid movement of ferrous ions from the stirrer material to the molten alloy). The impeller was rotated at a speed of 450 rpm in order to create the required vortex. Pre heated but uncoated albite particles with dimension 50-80μM were added in to the vortex slowly at a rate of 120g per minute. The air bubbles trapped inside the molten mixture are removed by the addition of hexachloroethane tablets. Then mixture is poured directly in gto preheated cast iron moulds to get permanent castings by opening at the bottom of the furnace. Castings are obtained in the form of cylindrical rods with dimension diameter 30mm and length 150mm. The matrix alloy was also casted under identical conditions and machined for comparing the results. Plate 3 given below shows the bottom pouring furnace used and plate 4 given below shows the stainless steel stirrer used for creating vortex.

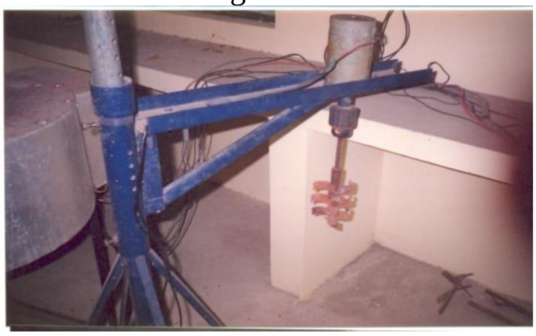

Plate 3: Bottom pouring furnace **Plate 4: M**echanical stirrer

Preparation of specimen

Composite materials and matrix alloy casted were subjected to machining in CNC lathe to get the specimens for polarization studies. Rectangular specimen with dimensions 2 cm length, 1 cm breadth and thickness of 1 mm were machined from castings of composites and alloy.

Microstructural studies

Composites and alloy after machining in to required shape and size are subjected to microstructural studies using scanning electron microscope in order toknow the distribution of reinforced particles.

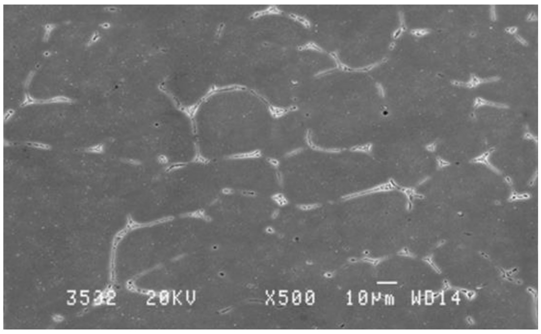

Plate 5: Microstructure of Al 2014

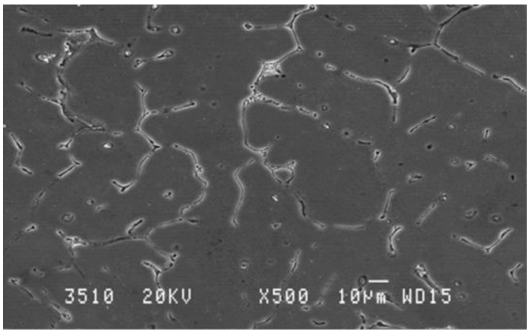

Plate 6: Microstructure of 3% composite

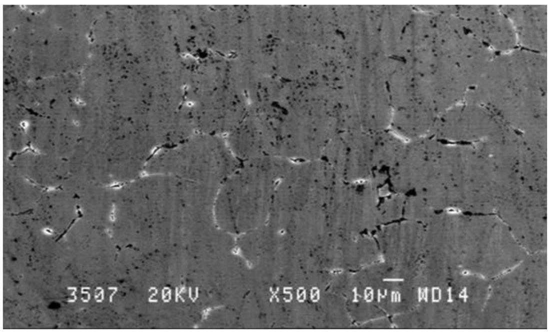

Plate 7: Microstructure of 5% composite

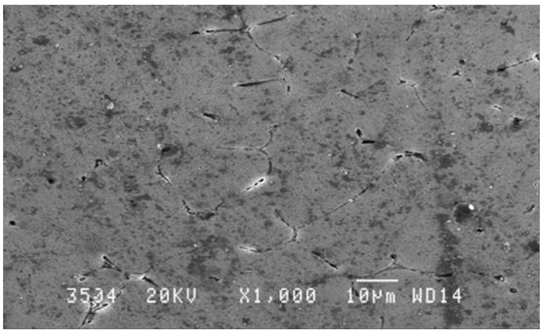

Plate 8: Microstructure of 7% composite

Plates 5 to 8 show the microstructures of the aluminium 2014 and composites of the same alloy containing 3, 5 and 7 percent of albite particulates. Uniform distribution of the reinforcemnt is observed in the microstructures.

Experimental procedure

Potentiodynamic polarization studies were carried out by electrochemical measurements using electrochemical work station model CHI 608E series manufactured by CH Instruments, USA which connected to cell containing reference electrode, counter electrode and a provision for connecting the manufactured specimen as working electrode. It is also interfaced with a personal computer to get the results in the form of Tafel plots. Software in the computer will also measure the corrosion current density and corrosion rate directly and displays next to the Tafel plots. Plates 9 given below shows the electrochemical work station. Plate 10 given below shows the cell containing the reference electrode, counter electrode and holder for working electrode which is nothing but specimen of alloy and composite materials.

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. The potentiodynamic current- potential curves were recorded by polarizing the specimen to -250 mV cathodically and +250 mV anodically with respect to open circuit potential (OCP) at scan rate of 5 mV s^{-1}.

Results and discussion

Figures 1 to 3 show the Tafel plots for matrix alloy and the composites in 0.025, 0.05 and 0.1 molar solutions of hydrochloric acid. Table 2 given below shows the corrosion rates of the alloy and composite materials manufactured in this work for the three different concentrations of hydrochloric acid.

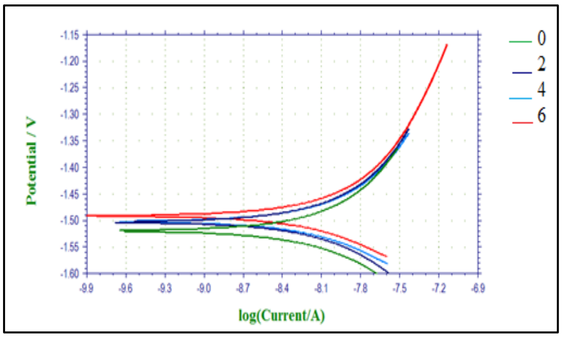

Fig 1: Polarization studies in 0.025 M HCl

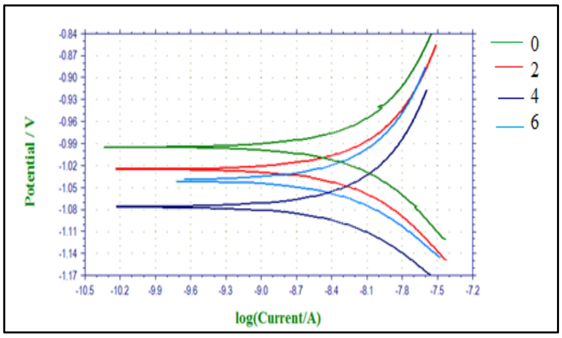

Fig 2: Polarization studies in 0.05 M HCl

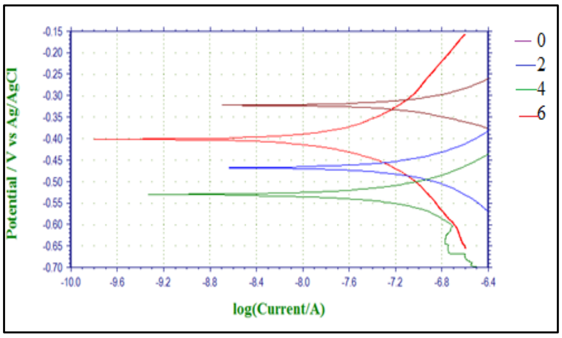

Fig 3: Polarization studies in 0.1 M HCl

Concentration of HCl	Corrosion rate in mpy			
	Alloy	3%	5%	7%
0.1 N	10.225	8.265	7.148	6.258
0.05N	8.258	7.269	6.258	5.211
0.025N	5.287	4.127	3.258	3.117

Table 2: Corrosion rates measured

It is clearly observed that as the concentration of hydrochloric acid 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 hydrochloric acid. It is clear from the table that as the percentage of reinforcement increases the corrosion rate decreases irrespective of concentration of corrodent. As the reinforcement content increases the exposure of the matrix alloy to the corrosive medium decreases hence attack on the alloy surface decreases. Albite particulates used as reinforcement are inert in nature and not attacked by acid solution, hence the corrosion rate decreases. Therefore composites are more suitable than matrix alloy in acidic environment. Many researchers have got the same results for the potentiodynamic polarization studies of the composite materials prepared by them.[14-19]

Conclusions

Stir casting method was employed to manufacture aluminium 2014/ albite particles reinforced composite materials. Potentiodynamic polarization method was employed to test the corrosion behaviour of aluminium 2014/ albite composites in comparison with aluminium 2014 alloy in hydrochloric acid solutions of different concentrations. Results of polarization test reveals that as the concentration of acid increases the corrosion rate increases. The reinforcement albite plays an 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 acid. Hence composites are more suitable than matrix alloy in many applications.

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