

Characterization of Aluminium 7075-Beryl Metal Matrix Composites by Different Corrosion Tests in Sodium Hydroxide Medium

Naddoni Sachin Govind.¹, H.V.Jayaprakash², P.V.Krupakara³

Research Scholar, Department of Chemistry, Sri Siddhartha Institute of Technology, Maralur, Tumakuru, India¹

Assistant Professor, Department of Chemistry, Sri Siddhartha Institute of Technology, Maralur, Tumakuru, India²

Vice-Principal and Professor of Chemistry, Cambridge Institute of Technology, North Campus, Bangalore, India³

ABSTRACT: Composites of Aluminium 7075 matrix containing 2 - 6 weight percentages of beryl particulates were manufactured by stir casting method like liquid metallurgy technique using vortex method. Matrix alloy is heated to a temperature slightly higher than its melting point in a bottom pouring furnace. Then beryl particulates of 50-80 micron size are added in to the vortex. Then stirred well and from the bottom the composite is directly poured into preheated cast iron moulds to get cylindrical bar castings. Aluminium 7075 was also casted in the same way without reinforcement to compare the results with composite materials. Specimens were machined from bar castings. Corrosion properties like static weight loss corrosion and potentiodynamic polarization techniques were conducted on beryl-Aluminium 7075 composites and the results are subjected to comparison with matrix alloy. After the conduction of experiments it the results showed that the Aluminium 7075- beryl composites were less prone to corrosion when compared with Aluminium 7075 alloy. Hence it was concluded that by adding beryl particulates to Aluminium 7075 alloy significantly improves corrosion resistance property when compared with that of unreinforced matrix. Hence composite materials are more suitable than matrix alloy in application where alkali medium is present.

I. INTRODUCTION

Aluminium based metal matrix composites are finding their application in many fields by replacing conventional materials.¹ Metal matrix composites containing aluminium alloys as matrix are extensively used in aircraft, automotive engineering fields.² Corrosion studies of the composite materials containing ceramic particulates will help the researchers to select a correct material for a required purpose.³ Bagesh Bihari et.al.⁴ studied the behaviour of hybrid composites of Aluminium 7075 reinforced with Alumina and Graphite in different concentrated solutions of sodium chloride. Composites containing 3% of graphite particulates and 3,6 and 9 weight percentage of alumina particulates were manufactured by the researchers using stir casting methods. Composites were subjected to potentiodynamic polarization and impedance test were performed by CH field machine. All tests were conducted in 3.5 percent sodium chloride solution. The results revealed that as the percentage of alumina particulates increase in the hybrid composites the corrosion rate decreases when compared with only Aluminium 7075 alloy. Ezhil Vannan and Paul Vizhian⁵ manufactured basalt fiber reinforced aluminium 7075 composite materials by adding 2.5, 5, 7.5 and 10% basalt fibers. Composites were subjected to weight loss corrosion in 1 M hydrochloric acid solution for a period ranging from 24 to 96 hours. Composites exhibited decreased corrosion rate as the time of exposure and the percentage reinforcement increased when compared with the matrix alloy Aluminium 7075. Experiments related to corrosion characterization of metal matrix composites of Aluminium 7075 containing different fibers and particulates have been carried out by many researchers but no significant investigation has been done on beryl particulate reinforced Aluminium 7075 alloy. This research paper focuses on the corrosion testing of Al 7075/ beryl particulate composites.

II. MATERIAL SELECTION

The raw materials selected for the corrosion testing are Aluminium 7075 alloy and beryl particulates. Aluminium 7075 alloy is commercially available in the market in the form of bar castings or ingots. Its composition is given in the table 1.

Table 1: Composition of Aluminium 7075 alloy

Element	Cu	Cr	Mn	Mg	Si	Ti	Zn	Fe	Al
Percentage	1.8	0.2	0.4	1.9	0.5	0.15	3.25	0.5	Balance

Beryl particulates which is naturally occurring ceramic material and its empirical formula is $[\text{Be}_2\text{Al}_2(\text{SiO}_3)_6]$ is selected as reinforcement. Beryl particulates exhibit density of 2.6 - 2.8 g/mm³ and shows hardness of 7.5 to 8 on Moh's scale. The shape of particulates is found to be hexagonal. Beryl particulates of size 50-80 µm are selected for the preparation of composites. Beryl particulates chemical composition is given in table 2.

Table 2: Composition of beryl particulates

Element	SiO ₂	Al ₂ O ₃	BeO	Fe ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O	MnO
Percentage	65.4	17.9	12.3	0.8	1.34	0.48	0.55	0.004	0.05

Corrosion medium selected for the experiments mentioned in the abstract are 0.025, 0.05 and 0.1 M sodium hydroxide solutions.

III. COMPOSITE PREPARATION

Composite materials are manufactured by stir casting method used by P V Krupakara.⁶ the alloy was melted in a bottom pouring surface and an impeller which is given a coating of aluminate in order to avoid the release of ions of iron to molten alloy was introduced to create the vortex. Beryl particulates were pre heated to 400°C in a muffle furnace and added to the melt at a rate of 100g/m. The weight percentage of beryl particulates added was 2-6 in steps 2%. To create the vortex impeller was turned at 450 rpm. The composite melt was thoroughly stirred. The melt was subjected to degasification by adding degasification tablets made up of hexa chloro ethane (C₂Cl₆). Cast iron moulds were used to get the cylindrical castings of the melt. To compare the results of composite materials with matrix alloy, Aluminium 7075 was also subjected to castings in the same way to compare the results.

IV. SPECIMEN PREPARATION

Cylindrical specimens of size 20 mm diameter and 20 mm length for composites and matrix alloy were machined from the cylindrical bar castings.⁷ The specimens were subjected to polishing by using emery papers containing silicon carbide to get smooth surface without any cracks which satisfies standard metallographic technique. The specimens were subjected to cleaning by dipping in acetone in order to remove oil, grease and dust particles and subjected to drying in open air. Electronic balance was used to find out the exact weight of the specimen up to fourth decimal place. A slide caliper was used to measure the dimensions of the specimens. These specimens were used for static weight loss corrosion test. Rectangular specimens of 2cm length and 1cm breadth were machined from cylindrical bar castings of matrix alloy and composites by adopting standard metallographic procedure.

V. CORROSION TESTING PROCEDURE

The static weight loss corrosion tests were conducted in open air. Specimens are weighed and dimensions are measured then submerged in the corrosive and taken out at every 24 hours of interval up to 96 hours. After the specified time of exposure and cleaning and drying of the specimen again weight was determined. Corrosion rate was calculated by knowing the weight loss and expressed in mils penetration per year (mpy). Corrosion rate was calculated using the formula given below. $CR = 534W/DAT$ mpy⁸. Where W represents difference between initial weight and final weight in grams, D is the density of the composite in gm/cm³, A is the surface area of the specimen in square inch and T is the exposure time in hours.

Electrochemical work station model CHI 608E series manufactured by CH Instruments, USA was employed to study the potentiodynamic polarization tests and it was connected to a cell with a reference electrode, counter electrode and a provision for connecting the manufactured specimen as working electrode.

The electrochemical investigations were carried out in a 100 cm³ beaker which is used as cell containing an reference electrode, counter electrode and specimen holder. Reference electrode used in these studies is silver electrode, counter electrode used is platinum electrode and composite and alloy specimen prepared for studies will be working electrode. 1 cm² area of the specimen was exposed to the corrosive environment

VI. RESULTS AND DISCUSSION

The static weight loss corrosion test results conducted in different concentrations of sodium hydroxide are given in figures 1-3. The simulation graphs were obtained by using MS office Excel by taking corrosion rate in mpy on y axis and time of exposure in hours on x axis.

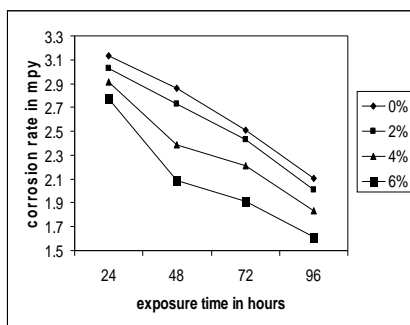


Fig 1: Weight loss in 0.025M NaOH

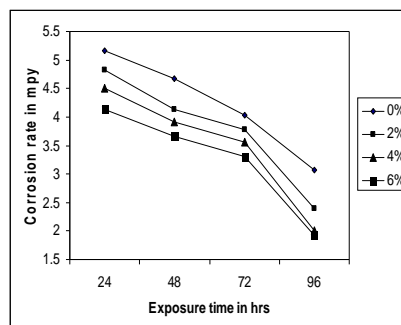


Fig 2: Weight loss in 0.05M NaOH

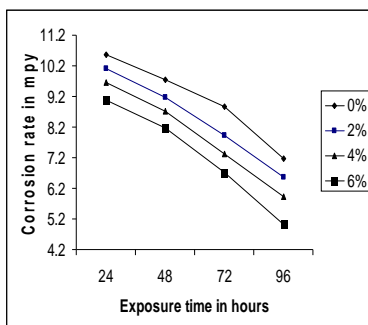


Fig 3: Weight loss in 0.1M NaOH

From the above graphs it is clearly understood that in all the concentrations of sodium hydroxide solutions the corrosion rate of matrix alloy and composites were found to decrease when the reinforcement content increased. This is due to the fact that matrix alloy's surface area exposure to corrodent decreases with increase in the reinforcement content hence corrosion rate decreases. Reinforcement content is unaffected by the corrodent because it is a ceramic material which will not react with any acid base or salt solutions. Krupakara et al⁹ got the same type of results when they subjected Al6061-Cu-Sic hybrid Composites to same test in sodium hydroxide medium. As the time of exposure increases corrosion rate decreases because there will be development of a non porous Al₂O₃ layer. It is a passive layer avoids contact between the corrodent and the surface of alloy or composite. The corrodent medium will not be able to pass through the non porous layer and attack the metal or alloy surface and decreases corrosion rate drastically after a specific duration.¹⁰ According to Trzaskoma¹¹ as the reaction proceeded; the solution became depleted in hydrogen ions, so that the reaction stopped from exhaustion of reactant. If the concentration of the corrodent solution is considered, the rate of corrosion was found to increase with increase in concentration of sodium hydroxide for the matrix alloy and composite materials. It is common because due to increase in concentration the reaction rate and reactions increase and corrosion also increases. Hence corrosion rate increases.

Figures 4-6 show the Tafel plots for the potentiodynamic polarization tests conducted in three different concentrated solutions of sodium hydroxide. The plots are obtained by the personal computer attached to it. From the plots the software itself calculates corrosion rate directly.

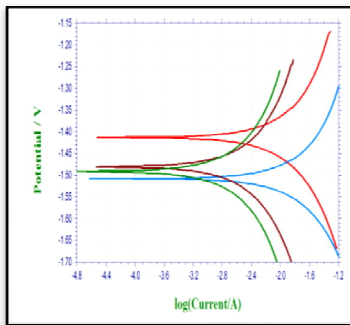


Fig 4: Tafel plots in 0.025M NaOH

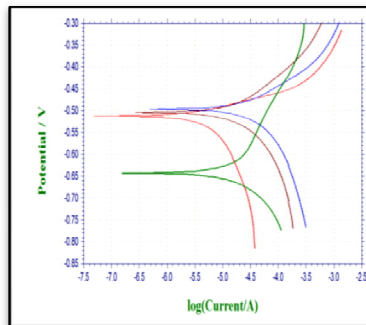


Fig 5: Tafel plots in 0.05M NaOH

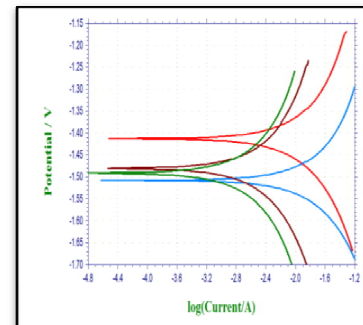


Fig 6: Tafel plots in 0.1M NaOH

Table 3 given below gives the corrosion rates of composite materials in comparison with matrix alloy in all concentrated solutions of sodium hydroxide.

Table 3: Corrosion rate in mpy for matrix and composites

Percentage of Beryl particulates	0	2	4	6
Concentration of NaOH	CR in mpy			
0.025 M	4.536	4.224	3.92	3.125
0.05 M	6.0043	5.987	5.24	3.208
0.1M	9.824	6.408	5.025	4.148

From the table it is clear that the decrease in corrosion rates of aluminium 7075/ beryl particulate reinforced metal matrix composites is due to the increase in the reinforcement content. As the reinforcement content increases the corrosion rate decreases in all concentrations of sodium hydroxide. Reinforcement content is inert material reduces the exposure of alloy surface and decreases the reaction of alloy surface with corrosive solution. Hence composite materials are used in applications where there is an alkali environment is present then the corrosion and corrosion rate decreases and the material will serve for long time.

VII. CONCLUSION

After the manufacture of composites by stir casting method like liquid melt metallurgy technique using vortex method the alloy and composites were subjected two important corrosion characterization test like static weight loss corrosion and potentiodynamic polarization experiments in three different concentrations of sodium hydroxide. In both the tests the composites exhibited decreased corrosion rate in all the concentrations of sodium hydroxide solutions. The corrosion rates of composites were found to be low when compared with the values of matrix alloy. Hence composite materials are more suitable than matrix alloy in many applications in alkali medium.

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