

## **Corrosion Characterization of Aluminium 356 Hybrid Composites in Neutral Chloride Medium**

**V. Bheema Raju**

Former Professor of Chemistry,  
Dr. Ambedkar Institute of Technology,  
Bangalore, India

**S. Kusuma**

Research Scholar, Dept. of Chemistry  
Dr. Ambedkar Institute of Technology,  
Bangalore, India

**P. V. Krupakara**

Vice Principal,  
Adarsha Institute of Technology  
Bangalore, India

**H. C. Ananda Murthy**

Associate Professor of Chemistry,  
Adama Science and Technology University,  
Adama, Ethiopia

### **ABSTRACT**

Hybrid composites are the composites which contain two different reinforcements in them. One of the reinforcements will be added in different quantities and another one will be added with same quantity. In this work hybrid composites of aluminium 356 are manufactured by adding fly ash and silicon carbide particulates. Composites are manufactured by liquid melt metallurgy technique using vortex method. Composites containing 2% fly ash and 2, 4 and 6 weight percentages of SiC particulates were manufactured. Matrix alloy was also casted in the same way for comparison. Static weight loss corrosion test and potentiodynamic polarization tests were conducted in different concentrated solutions of neutral chloride like sodium chloride. In both the tests the hybrid composites exhibited decreased corrosion rate with increase in reinforcement content. Hence hybrid composites are more suitable than the matrix alloy for applications.

**Keywords:** *Aluminium 356, Hybrid, Fly ash, Silicon carbide, polarization*

### **I. Introduction**

Designers get many advanced benefits in designing the components for automobile and aircraft industry through metal matrix composites (MMCs). These materials maintain good strength at high temperature, good structural rigidity, dimensional stability and light weight. [1-5]the trend is towards safe usage of the MMC parts in the automobile engine which work particularly at high temperature and pressure environments. [6-8]for the last two decades particles reinforced MMCs has been the most popular.

Aluminium MMCs have most popular families being represented by aluminium alloy reinforced with ceramic particulates. By the addition of second phase into matrix material enhances not only physical and mechanical properties, but also changes the corrosion behaviour significantly. In industries aluminium is used extensively with respect to their excellent fluidity, castability and mechanical properties. Aluminium composites exhibit very good tribological properties. [9] Lo et.al [10] found that aluminium is having better properties than copper, and cast iron. Many researchers have studied the aluminium matrix reinforced with different reinforcement and reported that the

composites of aluminium are more suitable for applications. [11-12]Aluminium is the matrix in the present research.

S.G.Kulakarni et al [13] studied the mechanical properties of Fly ash and  $Al_2O_3$  reinforced Aluminium 356 alloy. The reinforcement content varied from 0% to 12% in terms of 4%. They report that mechanical properties like hardness, compression strength and ultimate tensile strength were improved by the addition of reinforcement.

Hanumanthe Gowda and P.Rajendraprasad [14]added rice husk ash (RHA) and  $Al_2O_3$  to Aluminium 356 alloy and studied mechanical properties at different ageing conditions. The hybrid composites were manufactured by stir cast process. Ageing was carried out by heat treatment of the specimen at different temperature. The results reveal that ultimate tensile strength and hardness values improved significantly. Double aged specimens showed improved ultimate tensile strength and hardness when compared to those values of single aged specimens.

Sridhar Raja and BhupeshRaja [15] added 104 micron size boron carbide ( $B_4C$ ) particulates to Aluminium 356 alloy and studied corrosion behaviour by salt spray test. Composites exhibited improved corrosion resistance when compared to matrix alloy during the spray of 5percent sodium chloride solution.

Shashi Prakash Dwivedi [16]et al manufactured aluminium 356 composites containing silicon carbide particulates by two different techniques mechanical stir casting and electromagnetic stir casting. The authors report about the microstructure and mechanical properties of the composites prepared. Microstructural studies revealed that the reinforcement is distributed uniformly with less porosity in the composites manufactured by electromagnetic stir casting. Addition of silicon carbide to the matrix alloy improved the mechanical properties like tensile strength, hardness, toughness and fatigue life. Hence the authors conclude that the manufacturing methods also will have influence on the properties of composites.

B. M. Viswanathaet al[17] studied tensile and hardness properties of A356 alloy hybridcomposites reinforced with silicon carbide and graphite particulates manufactured by liquid metallurgy technique. Silicon carbide particulates addition was varied and graphite addition was constant. Authors report that the

properties mentioned above were improved with the increase in the addition of silicon carbide particulates.

## II. Experimental procedure

### A. Material Selection

The alloy selected for the work is Aluminium 356 alloy which is commercially available. Its composition is given in table 1

**TABLE 1: COMPOSITION OF ALUMINIUM 356 ALLOY**

	Si	Fe	Cu	Mn	Mg	Zn	Ti	Ot her s	Al
%	6.5-7.5	0.2	0.2	0.1	0.2 5- 0.4	0.1	0.2	0.1 5	Bal anc e

The reinforcements selected are fly ash and silicon carbide particulates. Fly ash is a waste obtained after the complete burning of coal in thermal power stations. It is procured from Raichur Thermal Power station (RTPS), Shaktinagar, Karnataka. Silicon carbide particulates are commercially available. The tests were conducted in 0.035, 0.35 and 3.5 percent sodium chloride solutions.

### B. Composite preparation

The liquid metallurgy route using vortex technique employed by P.V.Krupakara [18] was used to prepare the composites. A mechanical stirrer was used to create the vortex. The reinforcement materials fly ash and silicon carbide of size varying 50-80  $\mu m$  were preheated to 400<sup>0</sup>C in a muffle furnace. The weight percentage of fly ash used was 2 and silicon carbide particulates addition was varied from 2 to 6 in the steps of 2%. Addition of reinforcements in to the molten aluminium alloy melt was carried out by creating a vortex in the melt using a mechanical stainless steel stirrer coated with alumina (to prevent migration of ferrous ions from the stirrer material to the aluminium alloy). The stirrer was rotated at a speed of 450 rpm in order to create the necessary vortex. The reinforcement particles added in to the vortex of liquid melt at a rate of 120 g/m. The composite melt was thoroughly stirred and subsequently degassed by passing nitrogen through the melt at a rate 2-3 l/min for three to four minutes.

Castings were produced in permanent moulds in the form of cylindrical rods. [Diameter 30mm and length 150mm]

**C. Specimen preparation**

The castings were cut into 20mmx20mm pieces using an abrasive cutting wheel for static weight loss corrosion test. The matrix alloy also cast under identical conditions for comparison. For potentiodynamic polarization tests the rectangular specimens of size 20mm x 10mm x1mm were machined from matrix alloy and composites. The specimens were successively ground using 240, 320, 400 and 600 SiC paper and were polished according to standard metallographic techniques and washed in acetone and dried. The samples were weighed up to fourth decimal place using electronic balance and also the specimen dimensions were noted down using Vernier gauze.

**III. Static weight loss corrosion test**

The corrosion behaviour of aluminium alloy was studied by immersion test. The static immersion corrosion method was adopted to measure the corrosion loss. The tests were conducted in 0.035, 0.35 and 3.5 percent sodium chloride solutions.

200 ml of the prepared solution was taken in a beaker. Samples were suspended in the corrosive medium for different time intervals up to 96 hours in the steps of 24 hrs. To minimize the contamination of the aqueous solution and loss due to evaporation, the beakers were covered with parafilm during the entire test period. After the specified time the samples were cleaned mechanically by using a brush in order to remove the heavy corrosion deposits on the surface. The corresponding changes in the weights noted. At least three samples were tested and average value was taken. Corrosion rates were computed using the equation

Corrosion rate:  $534 W/DAT$  mpy

Where W is the weight loss in grams, D is density of the specimen gm/cc, A is the area of the specimen (inch<sup>2</sup>) and T is the exposure time in hours.

**IV. Potentiodynamic polarization test**

These tests are conducted in electrochemical work station model 608E manufactured by CH instruments, USA. It has a USB port or serial port for data communication with the personal computer. The graphs

are directly obtained as per requirement with the help of the software installed. Mixed potential theory forms the basis for Tafel extrapolation method used to determine corrosion rate. The Tafel plot is as an illustration of the Tafel equation. This equation is mainly used in electrochemical kinetics connecting the over potential rate to the electrochemical reaction rate. The software itself gives the values for corrosion rates.

**V. Results and Discussion**

Figures 1to 3 give the results of static weight loss corrosion test of aluminium 356 hybrid composites.

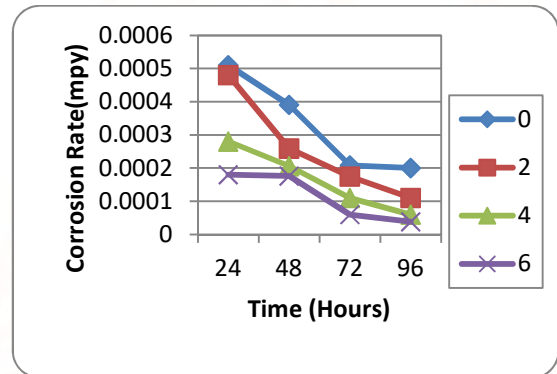


Fig 1: Static weight loss corrosion in 0.0 35% NaCl

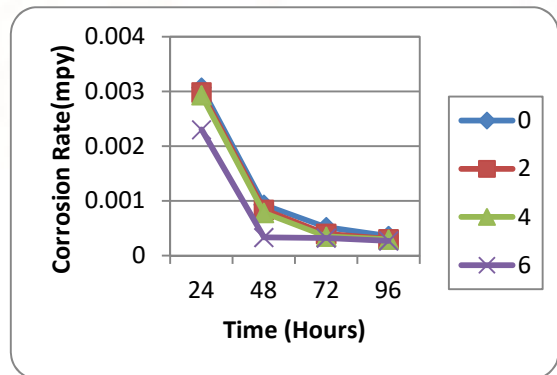


Fig 2: Static weight loss corrosion in 0.35% NaCl

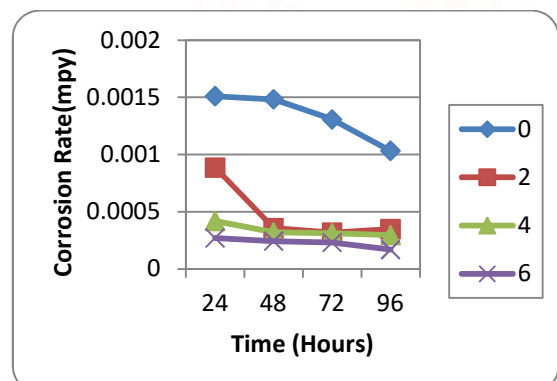


Fig 3: Static weight loss corrosion in 3.5% NaCl



From the above figures it is clearly observed that as the time of exposure increases the matrix as well as composites of Aluminium 356 exhibit decreased corrosion rate. As the exposure time increases exposed aluminium surface in matrix and composites develop a non porous layer slowly this leads to the decrease in corrosion rate. From the above figures it is also clearly understood that as the percentage of reinforcement increases the corrosion rate decreases. This is due to the fact that as reinforcement content increases, the exposure of the alloy to the corrosion medium decreases hence the corrosion rate decreases. Hanumanthe Gowda and P.Rajendraprasad<sup>19</sup> in their research studies of wear and corrosion resistance of Aluminium 356 alloy reinforced with rice husk ash and alumina particulates report that after immersing the matrix and alloy for 96 hours in 5% sodium chloride solution, 0.1 normal hydrochloric acid and sea water corrosion resistance and wear resistance of the composites increases when compared with that of matrix. The specimens containing 0-5 percent of reinforcements and aged for different period exhibited decrease in corrosion rate for composites when compared with that of matrix alloy. Hence composites are suitable than matrix alloy. As the concentration of sodium chloride increases corrosion rate increases from matrix to 6 percent hybrid composites. This is natural because as the concentration increases evolution of hydrogen increases and corrosion rate increases.

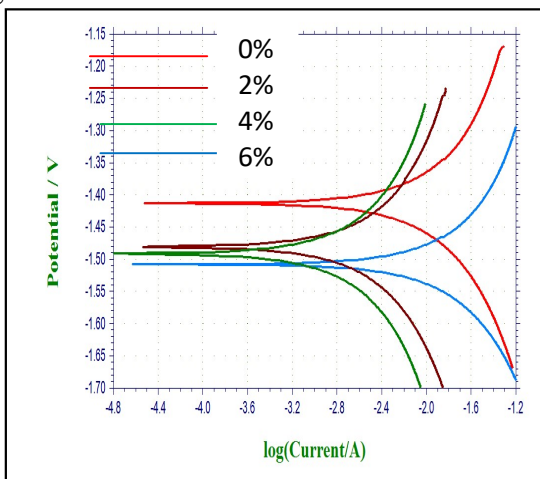


Fig 4:Tafel polarization curves in 0.035%NaCl

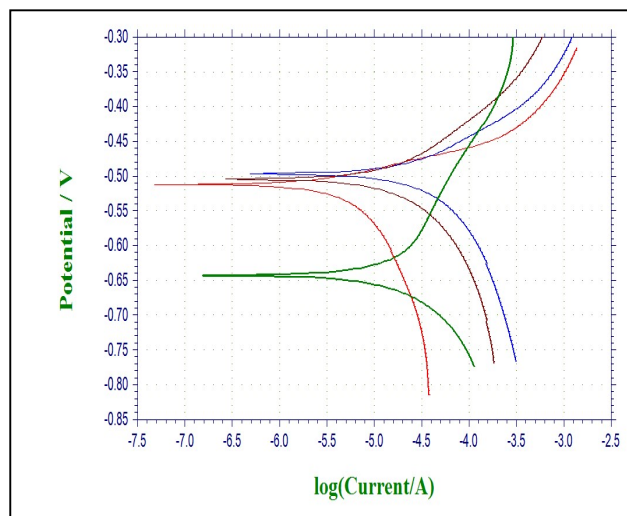


Fig5:Tafel polarization curves in 0.35%NaCl

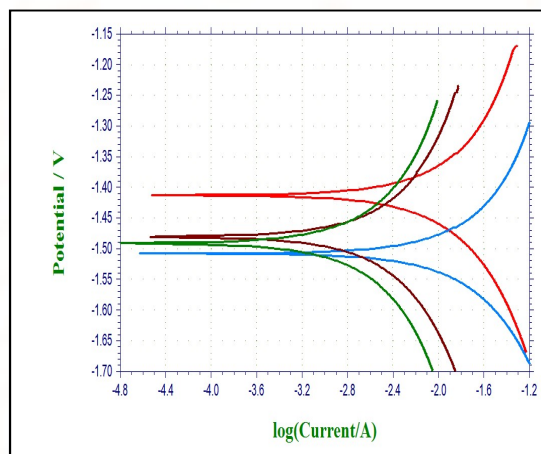


Fig6:Tafel polarization curves in 3.5%NaCl

Figures 4 to 6 are the Tafel plots for the matrix and hybrid composites in different concentrated solutions of sodium chloride solutions.

The point of intersection between the cathodic and anodic curve gives I<sub>corr</sub>. The corrosion rate in mpy is calculated by the software attached to electrochemical work station.

Table 2: Corrosion rates in mpy

Percentage of SiC	0	2	4	6
<b>Concentration of NaCl</b>	<b>Corrosionrateinmpy</b>			
<b>0.035</b>	4.236	4.024	3.79	2.925
<b>0.35</b>	5.986	5.425	4.581	3.708
<b>3.5</b>	9.824	6.408	5.025	4.148

Table 2 shows the corrosion rates in mpy for the matrix and hybrid composites in different concentrated solutions of sodium chloride. In each concentration of sodium chloride the corrosion rate decreases with increase in reinforcement content. That is as the percentage of silicon carbide increases the corrosion rate decreases. Corrosion rate increases as the concentration of the medium increases due to the increase in liberation of hydrogen gas.

This is attributed to the clean surface of Al 356 alloy reaches to the passivity rapidly when exposed to oxygen containing environment forming protective oxide film ( $\text{Al}_2\text{O}_3$ ) which is good adherence to metal surface and poor conductor for charge transfer. But this film contains flaws and increased pitting in chloride.[20]

## VI. Conclusions

Hybrid composites and matrix were manufactured by liquid metallurgy route by using vortex method. Both matrix and composites were subjected to static weight loss corrosion and potentiodynamic polarization in different concentrated solutions of sodium chloride. Composites exhibited excellent corrosion resistance when compared with that of matrix alloy in both the tests. Hence composites are more suitable than matrix alloy for applications in marine and saltish environment.

## References

- 1) B.M.Girish et.al. "Fractography , Fluidity and tensile properties of Aluminium/Haematite particle composite", Journal of Materials Engineering and performance, vol. 8(3), 1999, pp309-314
- 2) B.M.Satish et.al. "Effect of short glass fibers on the mechanical properties of cast ZA-27 alloy composites", Material and Design, vol. 17(5/6) 1996, pp245-250.
- 3) P.Reynaud "Cyclic fatigue ceramic-matrix composites at ambient and elevated temperatures". Composite Science and Technology, vol.56, 1996, pp809-814
- 4) S.C.Tjong & Z.Y.Ma, "The high temperature creep behaviour of aluminium matrix composite reinforced with SiC,  $\text{Al}_2\text{O}_3$  and  $\text{TiB}_2$  particles", Composite Science and Technology, vol.57, 1997 pp697-702.
- 5) H.Akubulut, M.Durman and F.Yilnaaz, "Higher temperature Young's Modulus of aluminium shore fire reinforced Al-Si MMCs produced by liquid infiltration", Materials Science and Technology, vol..14, pp299-305
- 6) E.Koya, Y.Hagiwara, S.Miura, T.Hayashi, T.Fujiwara, M.Oneda, "Development of aluminium powder metallurgy composites for cylinder liners", Metal matrix composites, Library of congress catalog card number 93-87522, Society of Automotive Engines, Inc, 1994, pp55-64.
- 7) M.K.Aghajanian, G.C.Atland, P.baron-Antolin, A.S.Nagelberg, "Fabrication and properties of metal matrix composites for automotive brake calipers applications", Metal Matrix composites, Library of congress catalog card number 93-87522, Society of Automotive Engines, Inc, 1994, pp77-81.
- 8) M.A.Dellis, J.P.Keusternas, F.Delannay and J.Wergia, Mater.Sci.Engg 135-253, 1991
- 9) R.J.Barnhurst and K.C.Farge in Proceedings of international symposium on Zinc-Aluminium, ZA Casting Alloys Ed. G.P.Lewis, R.J.Barnhurst and C.A.Loong, CIM, Toronto, 1986, p85.
- 10) S.H.J.Lo, S. Dionne, M.Sahoo and H.M.Hatrone, J.of Mater.Sci.27, 5681-5691 (1992)
- 11) W.Smith, Structures and Properties of Engineering alloys. 2<sup>nd</sup> edition McGraw-Hill, NewYork, 1993, p-567
- 12) N.Karni, G.B.Backay and M.Bamberger, J.Mat.Sci. Lett. 13, 541-544(1994)
- 13) N.Karni, G.B.Backay and M.Bamberger, "Investigation of mechanical properties of fly ash and  $\text{Al}_2\text{O}_3$  reinforced A356 alloy matrix composite manufactured by improved stir casting", Indian Journal of Engineering & Material Sciences, Vol23, February 2016, pp27-36
- 14) Hanumanthe Gowda and P. Rajendra Prasad, "Evaluation of Mechanical Properties of A356 Alloy Based Hybrid Composite at Different Aging Conditions", International Journal of Scientific and Research Publications, Volume 6, Issue 8, August 2016
- 15) Sridhar Raja K. S. and Bupesh Raja V. K., "Corrosion behaviour of boron carbide reinforcedaluminium metal matrix composite" ARPN Journal of Engineering and Applied Sciences, Vol. 10, No 22, December, 2015, pp10392-10394

- 16) Shashi Prakash Dwivedi, Satpal Sharma, and Raghvendra Kumar Mishra, "Comparison of Microstructure and Mechanical Properties of A356/SiC Metal Matrix Composites Produced by Two Different Melting Routes" International Journal of Manufacturing Engineering, Volume 2014 (2014), Article ID 747865, pp1-13
- 17) B. M. Viswanatha, M. Prasanna Kumar, S. Basavarajappa, and T. S. Kiran, "Mechanical property evaluation of A356/SiCp/Gr metal matrix composites", Journal of Engineering Science and Technology, Vol. 8, No. 6 (2013) 754 – 763
- 18) Krupakara, P. V, "Corrosion Characterization of Al6061/Red Mud Metal Matrix Composites" Portugaliae Electrochimica Acta, 31(3), 2013, 157-164
- 19) Hanumanthe Gowda and P. Rajendra Prasad," Evaluation of Wear and Corrosion Resistance of A356 Alloy Based Hybrid Composite at Different Aging Conditions", International Journal of Materials Science, 11(1), 2016, 57-69
- 20) Muna K. Abbass, Khairia S. Hassan, and Abbas S. Alwan International Journal of Materials, "Study of Corrosion Resistance of Aluminum Alloy 6061/SiC Composites in 3.5% NaCl Solution", 3(1), 2015, 31-35