ISSN 2349-0292
Impact Factor 2.675

GLOBAL JOURNAL OF ADVANCED ENGINEERING TECHNOLOGIES AND SCIENCES

CORROSION CHARACTERIZATION OF AL6061 /BERYL METAL MATRIX COMPOSITES IN ACID CHLORIDE MEDIUM

K. Krishnaveni*, H. R. Radha, P. V. Krupakara
[*] Department of Chemistry,Donbosco Institute of Technology, Bangalore, India
Department of Chemistry, T.John Institute of Technology, Bangalore, India
Department of Chemistry, Adarsha Institute of Technology, Bangalore, India

ABSTRACT

Metal matrix composites are getting demand now days due to their demand in different application like automobile, aircraft and marine engineering. They possess improved corrosion resistance and mechanical properties. In this work Aluminium 6061 (Al6061) alloy is used as matrix and beryl particulates are used as reinforcement. The metal matrix composites are prepared by liquid melt metallurgy technique using vortex method. Composites containing 2,4 and 6 weight percentage of beryl particulates are manufactured. Aluminium 6061 alloy was also casted in the same way for comparison.Specimensare prepared as per standard metallographic techniques. Static weight loss corrosion test of the prepared specimens is carried out in 00.025, 0.05 and 0.1 normal solutions of hydrochloric acid by immersing the specimens for a time range of 24 to 96 hours. Corrosion rates were calculated after cleaning and drying the specimen. Corrosion resistance of composites are found to be increased with increase in beryl particulate content and increase in time of exposure when compared with matrix alloy. Hence composites are more suitable than matrix alloy.

KEYWORDS: Aluminium 6061, Beryl, Vortex.

INTRODUCTION

Aluminium based metal matrix composites are finding their application in many engineering fields like aerospace, automobile and structural engineering due to their improved mechanical properties. [1]The properties like corrosion resistance and wear resistance will get improved by converting aluminium alloy in to a composite by the addition of ceramic particulates.[2] Literature survey of corrosion studies of Al6061 alloys reinforced with many ceramic particulates like beryl particulates, red mud, SiC and frit particulate are available. H.R.Radha et al[3] studies the corrosion properties of beryl particulates reinforced Al6061 alloy in sea water and obtained the results such that the composites will not undergo much corrosion in sea water when compared to alloy. Krupakara[4]studiedthe corrosion properties of Al6061 reinforced with red mud particulates in different concentrations of sodium chloride and reported that the composites show improved corrosion resistance when compared with the value of the matrix. Open circuit potential test was also carried out by him reveals that the composites are less prone to corrosion when compared with matrix. Dasappa Ramesh et al[5] reinforced Al6061 alloy with frit particulates and studied corrosion properties using electrochemical corrosion test rig in different concentrations of sodium chloride in heat treated and un heat treated condition and found that composites are less prone to corrosion when compared to Al6061 matrix. MunaK.Abbas et al[6] studied the corrosion resistance of Aluminium alloy reinforced with SiC particulates and subjected to potentiostat test in 3.5% sodium chloride solution and report that the composites show improved corrosion resistance when compared to matrix alloy Al6061. With all the above literature corrosion studies with respect Al6061 reinforced with beryl particulates is very scarce. Hence the study of the behavior of Al6061 reinforced with bery particulates with respect to corrosion has been taken up in this paper.

MATERIALS AND METHODS

Matrix selection

In the present study, liquid metallurgy technique is adopted and Al6061, which exhibits excellent casting properties and reasonable strength, is used as the base alloy Al6061alloy with good strength is suitable for mass production of lightweight metal castings. The chemical compositions of the Al6061 alloy are given in Table I.

Table 1: Chemical Composition of Al6061alloy

Mg	Si	Fe	CU	Ti	Pb	Zn	Mn	Sn	Ni	Al
0.8-1.5	10-12	1	0.7-1.5	0.2	0.1	0.5	0.5	0.1	1.5	Bal

Beryl particulates which is naturally occurring mineral and having the formula $[Be_2Al_2(SiO_3)_6]$ is used as reinforcement. They have a density of 2.6 - 2.8 g/mm3 which is almost on par with that of Al6061 and has hardness

ISSN 2349-0292
Impact Factor 2.675

of 7.5 to 8 on Mho's scale and a hexagonal structure.50-80 μm size beryl particulates are used in this study. The chemical composition of beryl particulates is given in table2.

Table 2: Composition of beryl particulates

SiO_2	Al_2O_3	BeO	Fe_2O_3	CaO	MgO	Na_2O	K_2O	MnO
65.4	17.9	12.3	0.8	1.34	0.48	0.55	0.004	0.05

Composites preparation

The liquid metallurgy route using vortex technique [7]is employed to prepare the composites. Composites containing 2,4 and 6 weight percentage of beryl particulates are manufactured. Matrix Al6061 alloy was also casted in the same way for comparison. Cylinder shaped specimen of size 20mm x 20mm were machined from bar castings for the corrosion test.

The objective of the present investigation is to understand the role of reinforcement on the static weight loss corrosion behaviour of Aluminium 6061/Beryl particulate MMCs in 0.025, 0.05 and 0.1 molar solutions of hydrochloric acid.

Corrosion test

The corrosion tests were conducted at room temperature using the conventional weight loss method. Weighed specimens were immersed in the corrodents and taken out at 24, 48, 72, and 96 h. Weight loss was calculated and converted into corrosion rate and expressed in mils penetration per year (mpy). Corrosion rate is calculated using the following formula CR=534W/DAT mpy[8]. Where W is the weight loss in grams, D is the density of the specimen (gm/cc), A is the area of the specimen (inch^2), and T is the exposure time in hours. Before corrosion test the specimens were subjected to scanning electron microscopic studies to find out the distribution of beryl particulates in Al6061 alloy.

RESULTS AND DISCUSSION

Figures 1-4 show the micrographs of matrix alloy and composites containing 2,4 and 6 weight percentage of beryl particulates. In the micrographs of composites uniform distribution of particulates is observed.

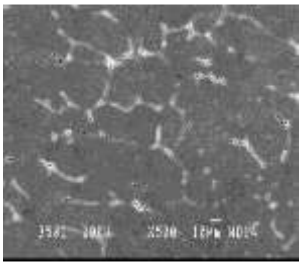

Fig.1: Matrix

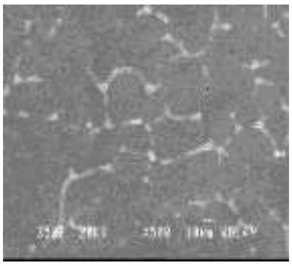

Fig.2: 2% Composite

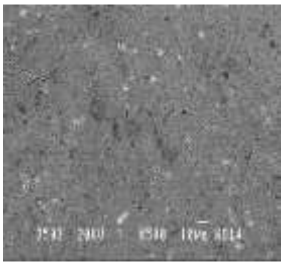

Fig.3: 4% Composite

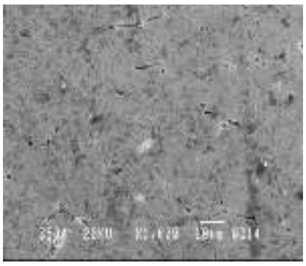

Fig.4: 6% Composite

Figures 5- 7 show the graphs of the results obtained by static weight loss corrosion test in 0.025,0.05 and 0.1 N hydrochloric acid.

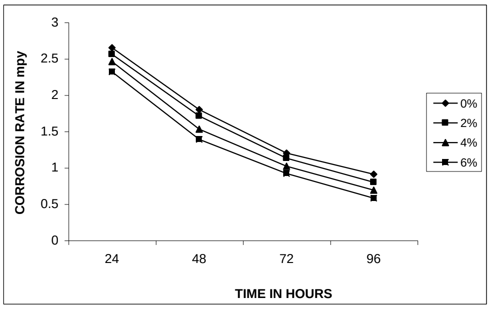

Fig. 5 static weight loss corrosion test in 0.025N HCL

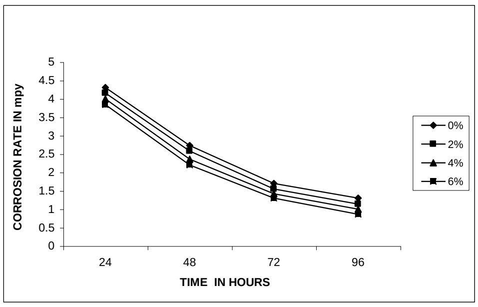

Fig 6. Static weight loss corrosion test in 0.05N HCl

 ISSN 2349-0292
Impact Factor 2.675

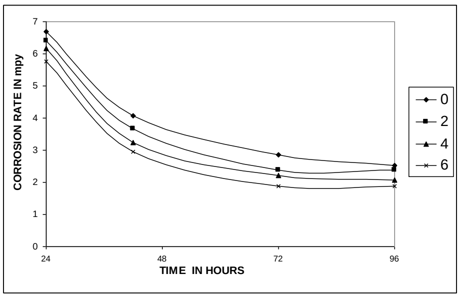

Fig.7 Static weight loss corrosion test in 0.1N HCl

From the above graphs it is clear that for each composite as well as for unreinforced aluminium 6061alloys, the corrosion rate is found to decrease during the corrosion tests. The decrease in corrosion rate is due to passivity of the matrix alloy. Visual inspection of the specimens after the corrosion tests revealed the presence of a black film, the composition of black film is $Al(OH)_3$, which covered the surface. Thus$Al(OH)_3$ acts as the passive layer. Since the passive layer acts as a barrier between the fresh metal surface and the corrosive media, it avoids the direct contact between the specimen and the corrosive media, thus further dissolution of the metal alloy would not takes place. Corrosion rate depends on the stability, nature and thickness of the passive layer. After a specific duration, the film may be stable but it contains porosities and micro cracks through which solution may come in contact with the specimens surface and hence oxygen drifting might take place through these defects in the passive layer, Such passive layer reduces the contact between the specimens surface and corrosion media hence it leads to drastic reduction in corrosion rate.According to Trzaskoma[9] if specimen is exposed to saturated media at very high temperature and for a long time, the corrosive chemical reaction would stopped due to exhaust of conducting media. From figures5 to 7, it is apparent that for all the tested specimens, there is a decrease in corrosion rate with increase in reinforcement content. The corrosion rate in the unreinforced matrix alloy is higher than those in the ceramic reinforced composites, because in alloys there is a direct contact between the alloy surface and the corrosive media, thus alloy dissolution increases, as alloy does not exhibit much resistance to the action of acid medium.

Reinforcements like beryl particulates, when it is added to the alloy matrix, it binds the matrix surface, and thus it avoids the direct contact of the alloy matrix surface with the acid media and beryl particulates being ceramic, remains inert & unaffected during the tests. Thus the reinforcement helps in protecting the metal from corrosion.

The results also show that, there is an improvement in corrosion resistance, as the reinforcement content in the composite is increased, which indicates that the concentration of reinforcement particulates, have the effect on the rate of corrosion in the composites.

However, in static corrosion test exposure of the MMCs to aggressive Cl^- environment led to pitting at the matrix-reinforcement interface. Because the interfacial region was characterized by a high dislocation density, which arises from differential thermal mismatch and the stress concentration around the particles induces allotropic transformation. The strain energy and allotropic transformation associated with dislocations may have enhanced the pit initiation process. Some beryl particulates particulate fell out of the matrix because of the extensive pit enlargement, thus rate of corrosion at the matrix-reinforcement interface increased.

From figures5-7 it can be clearly say that, for both as cast and composite, corrosion rate decreases monotonically with increase in beryl particulate content. In the present case, the corrosion of the composites as well as the matrix alloy is predominantly due to the formation of pits and cracks on the surface. In the case of base alloy, the strength of the acid used induces crack formation on the surface, which eventually leads to the formation of pits, thereby causing the loss of material. The presence of cracks and pits on the surface of base alloy surface was clearly observed. Since there is no reinforcement provided in any form, the base alloy fails to provide any sort of resistance to the acidic medium. Hence the weight loss in case of unreinforced alloy is higher than in the case of composites. Beryl particulates being a ceramic remains inert and is not affected by acidic medium during the test and is not expected to affect during the corrosion test of the composite. Thus the results indicate that there is an improvement in corrosion resistance as the percentage of beryl particulates increased in both matrix and composite.

S.Ohsaki*et. al*.[10]obtained similar results in glass fiber reinforced ZA-27 alloy composites and also reported that the corrosion resistance increases with increase in reinforcement.

Wu.Jianxin*et al*[11] in their work on corrosion characteristics of aluminium based particulate reinforced MMCs, state that the rate of corrosion is affected to a significant extent by the presence of SiC particulates in aluminium, thus the particulates definitely play a secondary role by acting as physical barrier.

As far as MMC corrosion characteristics are concerned, a particulate acts as a physical barrier to the initiation and development of corrosion pits and also they modify the microstructure of the matrix material and hence particulates reduce the rate of corrosion. One more reason for the decrease in corrosion rate is the intermetallic region, which is the site of corrosion forming crevice around each particulates. This may be due to the formation of magnesium inter-metallic layer adjacent to the particulate during manufacture as discussed by Trzaskoma.

McIntyre.*et.al.*[12] further showed that the magnesium inter-metallic compounds are more active than the alloy matrix. Pitting in the composites is associated with the particulate matrix interface, because of the higher magnesium concentration in this region. With increase in time, pitting would continue to occur at random sites, which are present at the particulate matrix interface. The active nature of the crevices would cathodically protect the reminder of the matrix and restrict pit formation and propagation.

Various researchers found that MMCs show decreased susceptibility to pitting attack when compared to non-reinforced alloys, due to the decrease in voids at the matrix/reinforcement interface. In particulate reinforced composites, increasing reinforcement volume could result in the decreases in the porosity. Thus because of the increase in the inter-particles spacing the rate of corrosion decreased.

In the present case, increase of weight loss and corrosion rate in the composites, as well as in the matrix alloy is predominantly due to the formation of pits on the surface. In the matrix, the severity of the acid used induces pits formation on the surface, which eventually leads to further corrosion, thereby causing the severe loss of material. The presence of pits on the composite and base alloy surfaces was seen clearly. However the pit formation is less on the composite surface than on the matrix alloy surface. The surface damage produced in the composites was smaller and there is no surface damage as the addition beryl particulates weight percentage increased.

CONCLUSION

- Al6061 based metal matrix composites containing 2, 4 and 6 weight percentage of beryl particulates particulates were manufactured successfully by liquid melt metallurgical technique.
- Corrosion rate of Al 6061 matrix and Al 6061 with beryl particulates metal matrix composites were found to decrease from 24 to 96 hours respectively as the percentage of beryl particulates content increased from 0 to 6 in all concentrated solutions of hydrochloric acid.
- The rate of corrosion of both the alloy and composite decreased with time duration.
- The corrosion rate of the composites was lower than that of the corresponding matrix alloy.
- The corrosion by weight loss of the composite decreased with increase in the weight percentage of the reinforcement.
- Hence composites are more suitable for applications than matrix alloy.

ACKNOWLEDGEMENTS

The authors wish to thank management and principal of T.John Institute of Technology and Don Bosco institute of Technology for constant support for the research.

REFERENCES

[1] H.N.Reddappa, K.R.Suresh, H.B.Niranjan and K.G.Satyanarayana , "Effect of cold quenching on Wear rate of al6061- beryl Composites"International Journal of Engineering Science and Technology (IJEST), Vol 3 No.10, October 2011,pp 7309-7315

[2] A.Anilkumar, C.Anilkumar, H.N.Reddappa, "Studies on mechanical, wear and corrosion properties of al6061-beryl-cerium oxide hybrid metal matrix composites"International Journal of Research in Engineering and Technology Vol. 03 issue: 06 | jun-2014,pp227-233

[3] Radha H. R.,Krupakara P. V. Sathishkumar S., Vinutha K. and Veena Devi, "Weight Loss Corrosion Studies of Al6061 / Quartz Metal Matrix Composites in Sea Water", International Journal of Innovative Research and Development, Vol3 Issue 4, April 2014, pp 133-136

[4] Krupakara, P. V, "Corrosion Characterization of Al6061/Red Mud Metal Matrix Composites" PortugaliaeElectrochimicaActa June2013, Vol.31, no. 3, 157-164

[5] Dasappa Ramesh, RageraParameshwarappaSwamy , Tumkur Krishnamurthy Chandrashekar, "Corrosion Behaviour of Al6061-Frit Particulate Metal Matrix Composites in Sodium Chloride

Solution" Journal of Minerals and Materials Characterization and Engineering, January 2013,Vol. 1, pp 15-19

[6] Muna K. Abbass, Khairia S. Hassan, and Abbas S., "Study of Corrosion Resistance of Aluminum Alloy 6061/SiC Composites in 3.5% NaCl Solution" Alwan International Journal of Materials, Mechanics and Manufacturing, February 2015, Vol. 3, No. 1, pp31-35

[7] Dr.P.V.Krupakara, H.R.Ravikumar, ""Corrosion Characterization of Aluminium 6061 / Red Mud Metal Matrix Composites in Sea Water" International Journal of advanced Research in Chemical Science (IJARCS), 2015, Vol.2, No.6, pp 1-5

[8] M.G.Fontana, Corrosion Engineering, McGraw Hill Book Company Inc., New York, 1987, 28-115.

[9] Trzskoma,"Localized Corrosion of Metal Matrix Composites. Environmental Effects on Advanced Materials", Ed. By R. H. Jones and R.E Ricker. The Minerals, Metals & Materials Society.1991, 249-265.

[10] S. Ohsaki. K. Kobayashi. M. Iino. T. Sakamoto , "Fracture toughness and stress corrosion cracking of aluminium-lithium alloys 2090 and 2091" , Corrosion Science1996, Vol.38,No.5, pp 793-802

[11] Wu Jianxin, Liu Wei, Li Pengxing and Wu Renjie, "Effect of matrix alloying elements on the corrosion resistance of C/Al composite materials", Journal of Materials Science Letters1993, Vol.12, No.19, pp1500-1501

[12] J.F. McIntyre and T.S. Dow "Intergranular Corrosion Behavior of Aluminum Alloys Exposed to Artificial Seawater in the Presence of Nitrate Anion", Corrosion, 1992, Vol. 48, No. 4, pp309-319.