



## EVALUATION OF CORROSION BEHAVIOUR OF ALUMINIUM 6061- CENOSPHERE COMPOSITES

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### ABSTRACT

One of the alarming environmental problems that require an immediate solution is associated with an infinitely increasing amount of ash produced during the burning of coal, oil, wood and other biomaterials. Among these, fly ash cenosphere utilization continues to be an important area of national concern due to India's dependence on thermal power generation for its energy supply. Alloy 6061 is one of the most widely used alloys in the 6000 series. This standard structural alloy, one of the most versatile of the heat-treatable alloys, is popular for medium to high strength requirements and has good toughness characteristics. Alloy 6061 has excellent corrosion resistance to atmospheric conditions and good corrosion resistance to seawater. This paper deals with the manufacture of cenosphere aluminium composites with varied proportions of the reinforcement phase, fly ash cenospheres – 6061 aluminium composite with features in terms of corrosion resistance have been developed. Immersion corrosion studies have been carried out with a thorough correlation between the corroded surfaces and the results indicated. The corrosion studies show that there is an increase in the corrosion pitting of the cenosphere aluminium composite.

**Key words:** Aluminium 6061 composites, fly ash cenospheres, corrosion resistance, immersion corrosion.

### 1. Introduction

Aluminum alloys are preferred engineering material for automobile, aerospace and mineral processing industries for various high performing components that are being used for varieties of applications owing to their lower weight and excellent thermal conductivity properties. Among several series of aluminum alloys, heat treatable Al6061 and Al7075 are much explored, among them Al6061 alloy are highly corrosion resistant and are of excellent extricable in nature and exhibits moderate strength and finds much applications in the fields of construction (building and high way), automotive and marine applications [1]

The composites formed out of aluminum alloys are of wide interest owing to their high strength, fracture toughness, wear resistance and stiffness. Further these composites are superior in nature for elevated temperature application when reinforced with ceramic particle [2]. In recent years, the use of fly ash as a reinforcement material in Al alloys has been reported to be desirable from both environmental and economic points of view due to its availability as a low cost waste material [3].

Zhu and Hihara [4] have reported on the corrosion performance of a continuous alumina-fibre

reinforced metal–matrix composite (MMC) and its monolithic matrix alloy (Al–2%Cu–T6) in 3.15wt% sodium chloride solution. It is stated that the MMC exhibited inferior corrosion resistance as compared to its monolithic matrix alloy. It is reported that corrosion of the MMC, have initiated along the fiber/matrix interface or in regions of plastic deformation. The built-up of acidity at localized corrosion sites on the MMC was stated to be enhanced by the formation of micro-crevices caused by fibers left in relief as a result of corrosion. It is observed that boron composites suffered from interfacial at the fiber matrix interphase due to crevice and galvanic corrosion. The later effect was attributed to aluminum boride formed at interphase during processing. Severe galvanic corrosion occurred in aluminium graphite composites because of the large potential difference established between the graphite and the matrix, whereas segregation of magnesium layer and fibers in the aluminium oxide composites caused attract to occur at the interphase. Pitting was the primary type of attack and silicon carbide composites was associated with silicon carbide particles [5]. Nunes et al [6] have studied the corrosion behavior of alumina-aluminium and SiC-Al in sodium chloride solution. Immersion and anodic polarization corrosion tests have been carried out. It is reported that composites have exhibited lower corrosion resistance when compared

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with the matrix alloy. Formations of pits in the matrix near the particle matrix interface have been observed leading to the pull out of the particle [7]. It is stated that alloy 6061 underwent pitting corrosion, the composite material exhibited two types of corrosion; 1) Pitting and crevice attack around each silicon carbide fibers and 2) crevice corrosion in surface voids or hairline fractures. The pitting and crevice corrosion around the fibers were due to the accumulation of magnesium at the fiber matrix interphase during composite manufacturing [8]. The published literature on advanced materials, such as Aluminium Fly Ash composites, is rather limited and is primarily concerned with applications of fly ash particles for synthesis of these materials. Therefore, it was thought worthwhile to study the corrosion behavior of this composite as well as present the pitting morphologies of the corroded surface. The present work is dedicated to such an investigation.

## 2. Experimental Procedure

A batch of 3.5kgs of Aluminum 6061 alloy was melted using a 6KW electric furnace. The melt was degassed using commercially available chlorine based tablets (Hexachloroethane). The molten metal was agitated by use of mechanical stirrer rotating at a speed of 300 rpm to create a fine vortex. Preheated cenospheres (preheated to 200oC for 2 hrs.) were added slowly in to the vortex while continuing the stirring process. The stirring duration was 10 min. The composites melt maintained at a temperature of 710°C was then poured in to preheated metallic moulds. The stirrer blades used were made of stainless steel and were coated with ceramic material to minimize the iron pickup by the molten metal. The amount of cenospheres was varied from 2 to 8 wt. % in steps of 2%. [9].

### 2.1 Immersion corrosion test

Immersion test were carried out as per ASTM G31 test procedure. Polished samples of Al 6061 alloy and all the composites were immersed in 3.5% NaCl solution for a total duration of 25 days. Weight loss measurements of the samples were done at the end of every 5 days. Corroded surfaces of the samples were cleaned with acetone before weighing using a electronic balance of accuracy 0.001 grams. The corresponding changes in the weights were noted. Photograph (Fig. 1.0) shows the samples immersed in NaCl solution. The corrosion rate was calculated using the following relationship.



Fig. 1 Immersion corrosion test setup

$$\text{Corrosion rate (mpy)} = 534 * \text{weight loss} / (\text{density} * \text{area of exposure} * \text{time of exposure}) \quad \text{--- (1)}$$

## 2.2 Corrosion studies

### 2.2.1 Effect of Reinforcement

From the graph (Fig 2.0) it is clearly observed that corrosion loss of Al6061 alloy increases with increase in percentage of reinforcement. A similar trend is observed by other researchers [9].

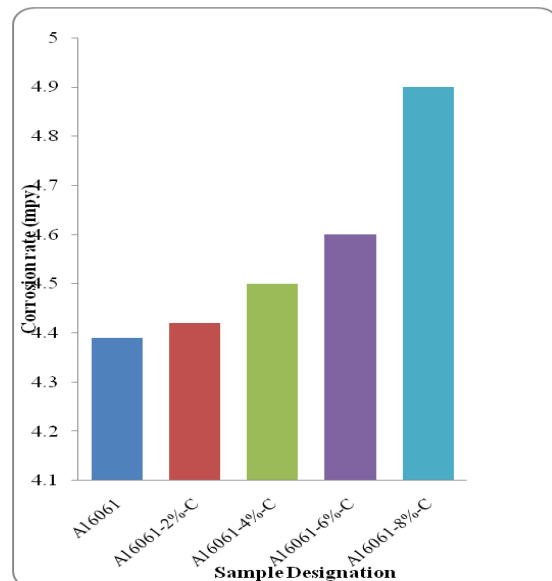


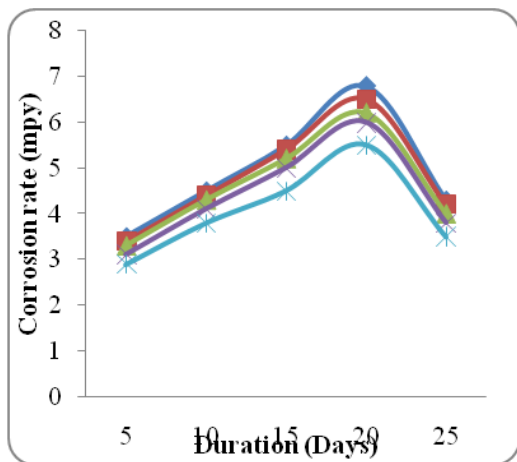
Fig. 2 Variation of corrosion rate of Al 6061 - cenosphere composites after 10 days of immersion in 3.5%NaCl solution

The increase in corrosion rate with increased incorporation of reinforcement in the matrix alloy can be attributed to the fact that corrosion occurs mainly on metals and alloys in the passive state as a result of disarrangement of passive layer by aggressive environmental elements like Cl- on the heterogeneities

of metals [11]. In case of composites introduction of reinforcement particles to the aluminium matrix releases intermetallic phases in the structure which leads to the formation of galvanic couples favorable for corrosion. Moreover factors influencing the corrosion of the composite include porosity, segregation of alloying elements to the reinforcement/matrix interface, presence of interfacial reaction products, high dislocation densities around the reinforcement phase, voids at the reinforcement/ matrix interface and electrical conductivity of the reinforcements [10]. However, these results are in accordance with other researchers [12-13].

**2.2.2 Effect of Immersion Duration**

Fig.3 shows the corrosion rate in mpy of as cast Al 6061 matrix alloy and Al 6061-cenosphere composites as a function of immersion time in number of days in 3.5%NaCl solution. It is observed that initially corrosion rate rises drastically up to 20 days, further there is a steep drop in the corrosion rate up to 25 days. It is also noted that the corrosion rate of Al 6061 matrix alloy and its composite systems varies in a narrow band.



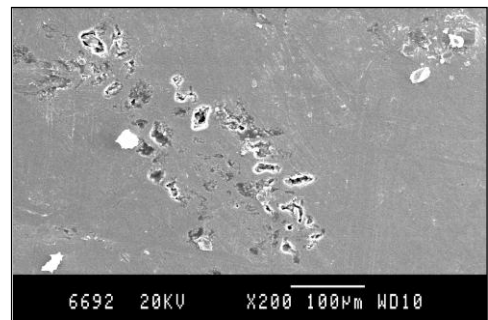
**Fig. 3 Variation of corrosion rate of Al 6061 matrix alloy and Al 6061-cenosphere composites.**

This can be attributed to the formation of a stable passive layer of Al(OH)<sub>3</sub>, which is formed over Al 6061 alloy and its composite samples leading to reduction in less corrosion rate over a period of time. Because of saturation of solution with anodic ions and formation of relatively more stable passive layer, a steady state condition is arrived after few days irrespective of the materials. The Al 6061 matrix alloy

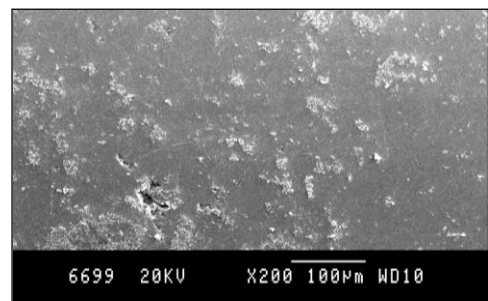
and composites exhibits more or less same corrosion rate. This can be attributed to the fact that effective area for corrosion reduces with incorporation of reinforcement particles and at the same time interface areas susceptible to pit initiation increases. These two counter phenomenon balance each other [11].

**2.2.3 Pitting Morphology**

Fig. 4 shows the SEM photographs of corroded surface of as cast Al 6061 matrix alloy (Fig. 4a) and Al 6061-cenosphere composites (Fig. 4a, 4b, 4c). It is observed that the developed composites possess large number of pits when compared with the matrix material. This may be due to fact that reinforcement has affected the corrosion by modifying the microstructure of the matrix alloy. Further, the metal loss occurs around micro particles and newly formed pits having interior smooth opening which suggests pit initiation process are rapid and also the composites favors a more generalized attack on the surface than the matrix alloy, which takes principally through the interface between the reinforcement particles with spinal formation and the aluminium matrix. A few researchers have also observed a similar trend in their studies on aluminium matrix composites [12, 13]. However, the matrix alloy contains pits which are deeper and bigger than the pits of composites. In all the composites studied, the pits are smaller and shallower than those on the unreinforced alloy. This is a clear indication that additions of cenospheres do not substantially affect pitting attack on matrix material.



**Fig. 4(a) Al 6061 alloy.**



**Fig. 4(b) Al 6061-4wt% cenosphere**

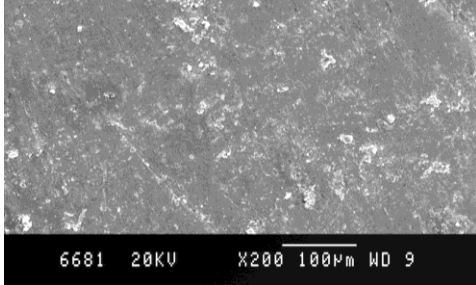


Fig. 4(c) Al 6061-4wt% cenosphere

Fig.4 SEM photographs of corroded surfaces of Al 6061 alloy and Al 6061-cenosphere composites.

### 3. Conclusions

1. Al 6061-cenosphere composites have been successfully produced by liquid metallurgy route.
2. Al 6061-cenosphere composites possess inferior corrosion resistance in 3.5%NaCl medium when compared with Al 6061 alloy.
3. It is observed from the pitting morphology studies that the pits are deeper in the reinforced composites as compared to the unreinforced counterparts.
4. The studies clearly show that the reinforcement has in particular no role to play in improvement of corrosion resistance of the composite.

### References

1. VeereshKumar G B, Rao, Selvaraj N and Bhagyashekar M S (2007), "Studies on Al6061-SiC and Al7075-Al<sub>2</sub>O<sub>3</sub> Metal Matrix Composites", *Journal of Minerals and Materials.Characterization*, Vol.9(1), 43-55.
2. "ASM Handbook of composites", Vol.21.
3. Suresh N, Venkateswaran S and Seetharamu S (2010), "Influence of cenospheres of fly ash on the mechanical properties and wear of permanent moulded eutectic Al-Si alloys", *Mater. Sci.- Poland*, Vol 28(1).
4. Metzger M and Fishman S G (1983), "Ind. Engg. – Chem. Prod. Res. Dev.", Vol.22, 296.
5. Nunes and Ramanathan L V (1995), "Corrosion Behaviour of Alumina- Aluminium and SiC-Aluminium Metal Matrix Composites", *Corrosion*, 610-617.
6. Paciej and Agarwala (1998), "Influence of processing variables on the corrosion susceptibility of metal-matrix composites", *Corrosion*, Vol.44(10), 680.
7. Zhu and Hihara (2010), "Corrosion of continuous alumina-fibre reinforced Al-2 wt.% Cu-T6 metal-matrix composite in 3.15 wt.% NaCl solution", *Corrosion Science*, Vol.52, 406-415.
8. Neil C and Garrard (1994), "The Corrosion Behaviour of Al-SiC Composites in Aerated 3.5% Sodium Chloride", *J. Corrosion Sci.*, Vol.36(5), 837 – 851.
9. Warriar and Lim (1993), "Silver coating on carbon and silicon carbide fibres", *Journal of Material Science*, Vol.28, 4868-4877.
10. Abrar Ahamed and Prashanth (2016), "Corrosion behaviour of Cenosphere Aluminium 6061 Composites", *Advanced Materials Manufacturing and characterization*, Vol.6(2).
11. Bienias, Walezake B Surowska and Sobczak J (2003), "Microstructure and corrosion behavior of aluminum fly ash composites", *Optoelectronics and Advanced Materials*, Vol.5(2), 493-502.
12. Das S, Mondal, Jha and Modi (2000), "Aluminium metal matrix composite: Present status and future prospects", *Proceeding of the third International Conference on Advances in composites*, 702-709.
13. Mondal, Saraswathi S and Das (2000), "Effect of particle reinforcement on the corrosion behavior of an Al-Si alloy-comparison with cast iron", *Proceeding of the third International Conference on Advances in composites*, Bangalore, 530- 527.
14. Trzaskoma, Mc Cafferty and Crowe (1983), "Corrosion behaviour of SiC/Al metal matrix composites, *Electrochemical Society*, Vol.130(3), 1804-1809.
15. Buarzaiga and Thorpe S J (1994), "Corrosion behavior of as-cast, silicon carbide particulate aluminium alloy metal matrix composites", *Corrosion Science*, Vol.50(3), 176-185.
16. Bhat, Surappa and Naik (1991), "Corrosion behaviour of SiC particle reinforced 6061/Al alloy composites", *Journal of Material Science*, Vol. 26(18), 49-91.