Corrosion behaviour of Cenosphere Aluminium 6061 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, and wood and other biomaterials. Among these, fly ash 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 aluminum 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.

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 fibre/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 fibres left in relief as a result of corrosion. Metzoer and S.G. Fishman have reviewed the corrosion behaviour of boron, graphite-aluminium oxide and silicon carbide containing aluminium alloy composites. Boron composites suffered from interfacial at the fibre 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 attack 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 behaviour 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 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]. W. Neal C. Garrard has studied the corrosion behaviour of Al606-T6alloy and 6061 silicon carbide composites in 3.5%NaCl. 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 fibre 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 behaviour 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 200°C 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%.

2.1 Immersion corrosion test

Immersion test were carried out as per ASTM G31 test procedure. Polished samples of all the composites were immersed in 3.5% NaCl solution for a total duration of 60 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 an electronic balance of accuracy 0.001 grams. The corresponding changes in the weights were noted. Photograph (Fig. 1) shows the samples immersed in NaCl solution.

![Immersion corrosion test setup.](image1)

3. RESULTS AND DISCUSSIONS

3.1 Corrosion studies

3.1.1 Effect of Reinforcement

From the graph (Fig 2.0) it is clearly observed that mass loss of Al6061 alloy increases with increase in percentage of reinforcement. A similar trend is observed by other researchers [9]. 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 [10]. 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 an interfacial reaction product, high dislocation densities around the reinforcement phase, voids at the reinforcement/matrix interface and electrical conductivity of the reinforcements [9]. However, these results are in accordance with other researchers [11-12]
Fig. 2 Variation of corrosion rate of Al 6061 - cenosphere composites after 10 days of immersion in 3.5%NaCl solution.

Fig. 3 Variation of corrosion rate of Al 6061 matrix alloy and Al 6061-cenosphere composites.
3.1.2 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. This can be attributed to the formation of a stable passive layer of Al(OH)3 which is formed over Al 6061 alloy and its composite samples leading to reduction in the corrosion 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 exhibit 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 phenomena may be balancing each other [11].

3.1.3 Pitting morphology

Fig. 4 shows the SEM photographs of corroded surface of as cast Al 6061 matrix alloy and Al 6061-cenosphere composites. It is observed that the developed composites possess large number of pits when compared with the matrix material. This may be due to the 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 [13, 14]. 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.

4 CONCLUSIONS

Al 6061-cenosphere composites have been successfully produced by liquid metallurgy route.

Al 6061- cenosphere composites possess inferior corrosion resistance in 3.5%NaCl medium when compared with Al 6061 alloy. Pitting morphology studies clearly shows pits deeper in the reinforced composites as compared to the unreinforced counterparts.

The study clearly shows that the reinforcement has in particular no role to play in improvement of corrosion resistance of the composite.

REFERENCES


