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Corrosion Behaviour of Al6061-Frit Particulate Metal Matrix Composites in Sodium Chloride Solution

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ABSTRACT

In this investigation, an attempt has been made to develop Al6061-Frit particulate metal matrix composites through stir casting technique using metal molds and to study the corrosion behaviour. Pre heated frit particles were added to matrix as reinforcement. Al6061 containing 2 wt% to 8 wt% in steps of 2 wt% of frit particulate composites were prepared. Corrosion tests were conducted by using Potentiostat model SEP238C where 3.5% NaCl solution was used as corrodent. The corrosion rate of metal matrix composites was lower than that of matrix material Al6061 under the corrosive atmosphere for both un-heat treated and heat treated conditions.

Keywords: Al6061 Alloy; Frit; Stir Casting; Potentiostat; Corrosion Rate (mmpy)

1. Introduction

The literature survey on metal matrix composites indicate that much published information is not available on development, and corrosion behaviour of Al6061-Frit particulate metal matrix composites. From the literature survey, it is reported by many researchers have reported that melting and casting technique is the most economical way of producing Discontinuous Reinforced Metal Matrix Composite (DRMMCs) [1-5].

Al alloy based particulate reinforced composites have a large potential for a wide number of engineering applications. Attraction in reinforcing of ceramic particles in Al alloy matrix materials is mainly due to low density, low co-efficient of thermal expansion and high strength of reinforcements and also their availability. Among available various useful aluminium alloys, Al6061 is typically characterized by several advantages and properties such as excellent casting properties, reasonable strength, fluidity, corrosion resistance, high strength to weight ratio and heat treatable. Al6061 has been commonly used as base metal for aluminium metal matrix composites (AMCs) reinforced with a variety of reinforcements [6-8].

Corrosion is the disintegration of an engineered material into its constituent atoms due to chemical reactions with its surroundings. Corrosion means in common electrochemical oxidation of metals in reaction with an oxidant such as oxygen. Formation of an oxide of iron due to oxidation of the iron atoms in solid solution is a well-known example of electrochemical corrosion (rusting). This type of damage typically produces oxides and/or salts of the original metal. Corrosion can also occur in materials other than metals and alloys, such as ceramics or polymers.

S. Samala *et al.* studied the corrosion behaviour in 3.4% NaCl-solution, which is similar to marine environment and stated that both the yield strength and tensile strength decreases with increasing corrosion rate. In acidic environment yield is directly proportional to corrosion rate and tensile strength inversely proportional corrosion rate [9].

An aggressive marine environment was simulated by preparing 3.5 wt% NaCl, NaOH and H_2SO_4 solution by K. K. Alaneme *et al.* [10] and studied the corrosion behavior of AA6063/Al_2O_3p composite in NaCl, NaOH and H_2SO_4 was investigated. They observed that Al(6063)—Al_2O_3 composites exhibited excellent corrosion resistance in NaCl medium than in the NaOH and H_2SO_4 media.

M. A. Bodude *et al.*, in their research work they have identified austempering heat-treatment is an effective technique for improving the corrosive wear resistance of ST60Mn steel in cassava juice [11].

The aim of this present research is to study the corrosion behaviour of Al6061 alloy reinforced with frit particulates. Acid medium was selected to study the corrosion behaviour of this alloy and Al6061-Frit particulate

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composites. NaCl of unit normality was selected as corrodent.

2. Materials and Methods

Al6061 was choosen as matrix material owing to its many advantages like excellent casting properties, strength, formability, and heat treatable. **Table 1** shows the chemical composition of Al6061 matrix material used in this present study.

Frit particles sizes of around 50 μm were used as reinforcement material in Al6061 matrix material. **Table 2** shows the chemical composition of frit particle reinforcement used in this present study. The frit used was developed in ceramic glass system. It has a density of 2.52 gm/cc, with hardness of 6.0 on the Mohr's scale.

2.1. Composite Production

Al6061-Frit particulate composites were prepared using liquid metallurgy route (VORTEX). Particulate MMC's are most commonly manufactured either by melt incurporation and casting technique or by powder blending and consolidation [12].

AMC's are synthesized via variety of manufacturing routes. These techniques include stir casting [13-15], liquid metal infiltration [16], Squeeze casting [17] and spray co-deposition [18]. Stir casting route is generally practiced commercially [19-21]. Its advantage lies in its simplicity, flexibility and applicability to large quantity of production. Al6061 matrix material was melted using 6 KW electrical resistance furnace. Pre heated frit particles were slowly added into the molten matrix alloy material and mixed thoroughly by means of mechanical stirrer. The melt was degassed using hexachlroetane tablet. Thoroughly mixed composite melt maintained at a temperature of 710˚C was poured into the preheated metallic mold. The proportion of frit particles was varied from 2 wt% to 8 wt% in steps of 2 wt%. However Al6061 matrix material was also casted for comparison. Castings were produced in permanent molds in the form of rectangular block. Cast Al6061 matrix material and Al6061-Frit particulate composites were machined to test standards.

Table 1. Chemical composition of Al6061 (wt %).

Si	Cu	Fe	Mn	Mg
0.809	0.355	0.155	0.027	0.8
Zn	Pb	Ti	Sn	Al
0.008	0.023	0.010	0.010	Bal

Table 2. Chemical composition of frit (wt%).

SiO2	Al_2O_3	Fe_2O_3	CaO
68.90	9.41	0.40	15.22
MgO	Na_2O	K_2O	B_2O_3
4.30	0.75	0.42	<0.05

2.2. Specimen Preparation

The cast Al6061 matrix alloy material and Al6061-Frit particulate composites were successively ground using grit emery papers and polished to metallographic standards cleaned with acetone. Rectangular specimens of 20 mm length, 10 mm breadth and 1 mm thickness were prepared by adopting standard metallographic procedure.

2.3. Heat Treatment

Al6061 matrix alloy and Al6061-Frit particulate composites were subjected to thermal treatment by solutionizing at a temperature of 530˚C followed by ice quenching. Artificial ageing was performed at a temperature of 175˚C for duration of 6 h.

2.4. Corrosion Test

All corrosion is an electrochemical process of oxidation and reduction reactions. As corrosion occurs, electrons are released by metal (oxidation) and gained by elements (reduction) in the corroding solution. Because there is a flow of electrons (current) in the corrosion reaction, it can be measured and controlled electronically. Controlled electrochemical experimental methods can be used to characterize the corrosion properties of metals and metal components in combination with various electrolyte solutions. Potentiostat model SEP238C was used to conduct the corrosion test. The electrodes are connected to an electronic instrument called Potentiostat. The electrodes used are;

1) The working electrode.
2) The reference electrode.
3) The counter electrode.

The working, reference, and counter electrodes are placed in the electrolyte solution. The experiments were conducted in 3.5% Solution of Sodium chloride (NaCl). Rectangular specimens of 20 mm length, 10 mm breadth and 1 mm thickness were prepared by adopting standard metallographic procedure [22]. They were polished and washed with liquid soap and dried in acetone. The specimens were fixed to working electrode and corrosion tests were conducted.

The **Figure 1** shows the set up of electrochemical test rig which is used for corrosion test. In the present research work corrosion rates in terms of mmpy for the Al6061 matrix alloy and developed Al6061-Frit particulate composites have been measured.

2.5. Scanning Electron Micrographs (SEM) Studies

To gain more insight on the corrosion products formed on the electrode surface were examined by Scanning Electron Microscope (SEM). The SEM micrographs of composite were obtained using the scanning electron microscope Microscopic studies to examine the morphology, particle size and micro structure were done by a JEOL 6380 LA Scanning Electron Microscope (SEM) equipped with an Energy Dispersive X-ray (EDX) detector of Oxford data reference system. Micrographs are taken at suitable accelerating voltages for the best possible resolution.

3. Results and Discussion

The scanning electron micrograph images of the corroded samples of Al 6061-Frit particulate composite is shown in **Figure 2**. From the scanning electron micrograph it is clear that uniform dispersion of particles in the matrix material. The scanning electron micrograph of corroded samples reveals pitting corrosion development.

Figure 1. Shows the set up of electrochemical corrosion test rig.

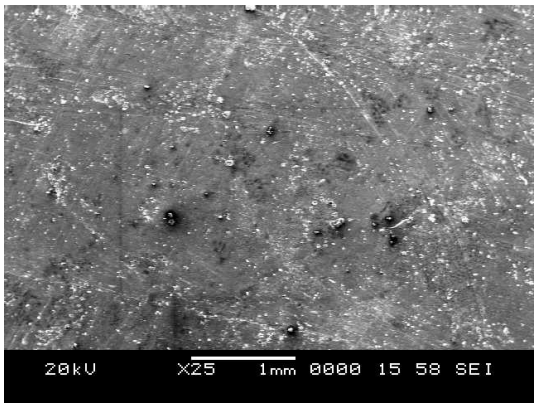

Figure 2. Scanning electron micrograph of Al6061-Frit particulate composite.

The SEM micrographs show a complete deterioration of the smoothness of the surface of matrix material [23], suggesting the penetration of chloride ions into the material surface forming corrosion spots [24].

The corrosion rate in mmpy measurement is shown in **Figure 3**. The trend observed in all specimens indicates decrease in corrosion rate. The phenomenon of gradually decreasing corrosion rate indicates the possible passivation of the matrix alloy is due formation of permanent layer, which affects the corrosion process. According to De Salazar [25] the protective black film consists of hydrogen hydroxyl chloride slows the forward reaction. Castle, *et al.* [26], reported that the black film consist of aluminium hydroxide compound, which protects further corrosion in acid media. Protective black film chemical nature is not determined still.

Figure 3 clearly indicates for both Al6061 matrix material and Al6061-Frit particulate composites the corrosion rate decreases as the weight percentage of frit particulate increases. Hard and inert ceramic frit is not expected to affect the corrosion mechanism of composites in acidic media during the test duration. The corrosion result indicates an improvement in corrosion resistance as the weight percentage of frit particulates increases, which shows the influence of frit particulates on the corrosion property. Similar result trend was reported by B. M. Girish *et al.* [27], in glass short fiber reinforced Al7075 composites. Research work by Wu Jinaxin *et al.* [28], reported that the corrosion is not affected significantly in aluminium based SiC particulate reinforced MMCs, but the inclusion of SiC particulate plays a secondary role as a physical barrier in MMCs corrosion characteristics.

The result trend is in line with the result reported by A. Jameel *et al.* [29] found that corrosion behavior of Al6061/Zircon MMCs tested by OCP method, the Zircon content plays a significant role in corrosion resistance of the material. Increase in wt% of Zircon reduces the cor-

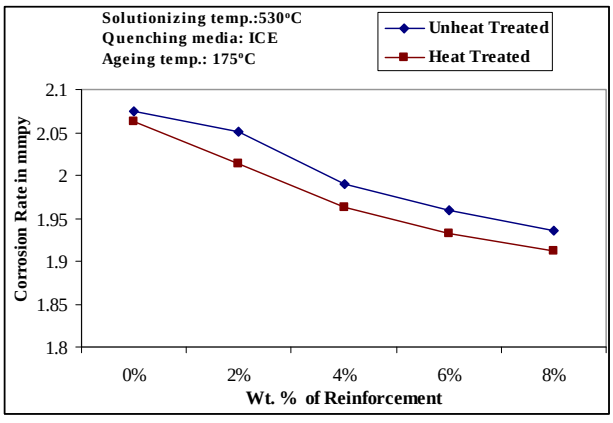

Figure 3. Shows the variations of corrosion rates Al6061 alloy and developed Al6061-Frit particulate composites.

rosion rate from 0 wt% to 7 wt% in Al6061/Zircon MMCs. In the present study, corrosion rate decreases as the wt% of reinforcement increases for both un-heat treated and heat treated composites. Further, heat treatment has improved the corrosion resistance for both matrix material and its composites in 3.5 % NaCl solution.

4. Conclusion

Based on the results of this research, the following conclusions have been drawn. The Al6061-Frit particulate reinforced composites are successfully developed using liquid metallurgy method. The frit inclusion in Al6061 matrix material plays a significant role in the corrosion resistance of the material. Increase in the weight percentage of frit increases the corrosion resistance significantly. The corrosion rate of the composites was lower than that of the corresponding matrix material in both un-heat treated and heat treated conditions.

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