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Article

Corrosion studies of Al 7075 Metal Matrix Composites Containing Beryl Particulates

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ABSTRACT

The aim of the research work was to investigate the corrosion behavior of Beryl particulate reinforced aluminum (Al) 7075 metal matrix composites (MMCs) in salt solution using weight loss and potentiodynamic polarization methods. The salt solution used is sodium chloride solution. The composites are manufactured by liquid metallurgy technique using vortex method. Al 7075/Beryl MMCs containing 2, 4, and 6 weight percentage of beryl particulates are casted. The corrosion characteristics of Al 7075/Beryl particulate composite and the unreinforced alloy were experimentally assessed. The weight loss corrosion test was carried in sodium chloride solution with 0.035%, 0.35%, and 3.5% concentrations. Potentiodynamic polarization test was carried out in 3.5% sodium chloride solution only. The results indicated that corrosion rate of MMCs was lower than that of matrix material Al 7075 under the corrosive atmosphere irrespective of exposure time and concentration of corrodent. Al 7075/Beryl composite become more corrosion resistant as the beryl content is increased. This is because of the formation of the stable oxide layer over the specimens. Scanning electron microscopy shows the degree of attack of alkaline solution on the surface of the investigated material.

Key words: Beryl, Corrosion, Metal matrix composites, Weight loss.

1. INTRODUCTION

Metal matrix composites (MMCs) are an important class of materials, which contain metal or alloy as matrix and a ceramic particulate or fiber or whiskers as reinforcements. Aluminum (Al) based MMCs exhibit enhanced corrosion resistance, wear, and mechanical properties. They provide significantly enhanced properties over metals and alloys. They are used for applications in aerospace, power utility, automotive, and military sectors [1,2]. MMCs reinforced with short fibers offer outstanding specific strength and stiffness along the fiber direction when compared to those with particulate reinforcements that have more isotropic properties. Most research on particulate reinforced MMCs has focused on their manufacturing and mechanical properties [3,4]. Relatively little research has been conducted on their corrosion behavior, and therefore, corrosion mechanisms are not well understood. Conflicting data and interpretations exist regarding fundamental issues such as corrosion initiation sites and the role of reinforcement in corrosion susceptibility [5,6]. Corrosion can affect the MMC in a variety of ways which depend on its nature and the environmental conditions prevailing. Studying corrosion resistance of Al-based materials is important especially for automotive and aircraft applications. The major advantages of Al 7075 composites compared to unreinforced materials are as follows: Greater strength, improved stiffness, reduced density, good corrosion resistance, improved high temperature properties, controlled thermal expansion coefficient, thermal/heat management, improved wear resistance, and improved damping capabilities. One of the main disadvantages in the use of MMC is the influence of reinforcement on corrosion rate. This is particularly important in aluminum alloy based composites, where a protective oxide film imparts corrosion resistance. The present work is focused on corrosion characteristics of Al 7075/SiC MMCs.

2. EXPERIMENTAL

The matrix selected is AL7075 alloy; it is an important alloy of Al available commercially. Its composition is copper 1.8%, chromium 0.2%, manganese 0.4%, magnesium 1.9%, silicon 0.5%, titanium 0.15%, zinc 3.25%, iron 0.5%, and remaining balance will be Al. Beryl particulates which are naturally occurring mineral and having the formula ($Be_2Al_2[SiO_3]_6$) is used as reinforcement. It has a density of 2.6 - 2.8 g/mm^3 which is almost on par with that of Al 7075 and has hardness of 7.5–8 on Mhos scale and a hexagonal structure. 50–80 µm size beryl particulates are used in this study. It is available commercially. Commercial beryl is finely powdered and passed through sieves of size 50–80 micrometers and used. The chemical composition of beryl particulates is silicon dioxide 65.4%, Al trioxide 17.9%, beryllium oxide 12.3%, ferric oxide 0.8%, calcium oxide 1.34%, magnesium oxide 0.48%, sodium oxide 0.55%, potassium oxide 0.004%, and manganese dioxide 0.05%.

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2.1. Preparation of Composites

The composites are prepared by liquid melt metallurgy technique used by Krupakara *et al*. [7]. Preheated and uncoated beryl particulates are added to molten Al 7075 alloy. Composites containing 2, 4, and 6 weight percentage of beryl particulates are prepared. Al 7075 alloy is also casted in the same way for comparison. Castings are taken in the form of a cylindrical bar.

2.2. Specimen Preparation

The specimen is prepared from the bar castings. Cylindrical specimen of size 20 mm × 20 mm is machined from the bar castings of the composites and the matrix alloy. Rectangular specimens of size 2 cm × 1 cm × 1 mm were also machined. All the specimens are subjected to standard metallographic techniques as done by S. Ezhil Vannan and Paul Vizhian Simson [8] before subjecting them to corrosion tests.

2.3. Experiments Conducted and Procedures

Microstructures of as-cast matrix and composites were taken using scanning electron microscopy. Weight loss corrosion tests in 0.035%, 0.35%, and 3.5% sodium chloride solutions and potentiodynamic polarization tests with Tafel plots were conducted in 3.5% sodium chloride solution to characterize the composites in comparison with matrix alloy.

The corrosion behavior of Al 7075 alloy and its composites reinforced with beryl particulates was studied by immersion test. The static samples were suspended in the corrosive medium for different time intervals up to 96 h in steps of 24 h. To minimize the contamination of the aqueous solution and loss due to evaporation, the beakers were covered with paraffin paper during the entire test period. After the specified time, the samples were cleaned mechanically using a brush to remove the heavy corrosion deposits on the surface. The corresponding changes in the weights were noted. Then, corrosion rate is calculated using the formula given below:

Corrosion rate: 534 W/DAT mpy [9]

Where w is the difference between the initial weight and final weight, i.e., weight loss, D is the density of the alloy, A is the area exposed in square inch, and T is time of exposure in hours.

Potentiodynamic polarization tests are conducted in electrochemical analyzer/workstation model 608E manufactured by CH instruments, USA. Using the instrument many electrochemical tests can be conducted. 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 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 rate in mpy.

3. RESULTS AND DISCUSSION

Before subjecting the specimens for corrosion test by weight loss method, they are subjected microstructural studies using scanning electron microscope.

Figures 1-4 show the microstructures of the matrix alloy Al 7075 and MMCs of Al 7075 with 2, 4, and 6 weight percentage reinforced preheated but uncoated beryl particulates.

The microstructures reveal that there is a uniform distribution of the reinforced beryl particulates in the alloy.

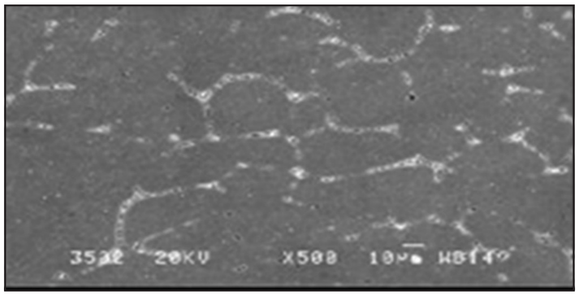

Figure 1: Microstructure of matrix.

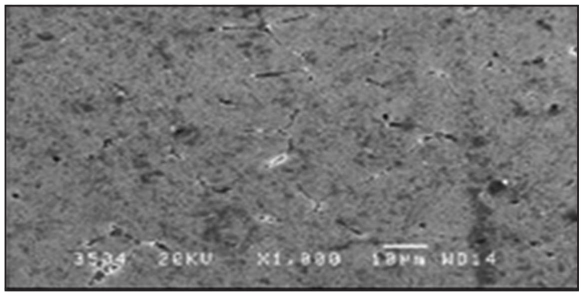

Figure 2: Microstructure of 2% composite.

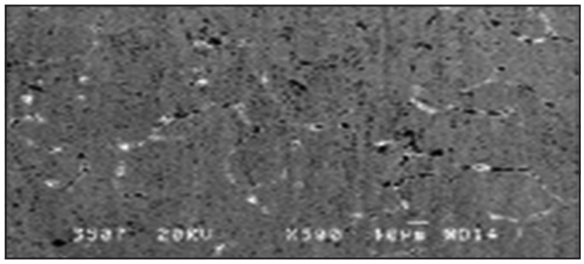

Figure 3: Microstructure of 4% composite.

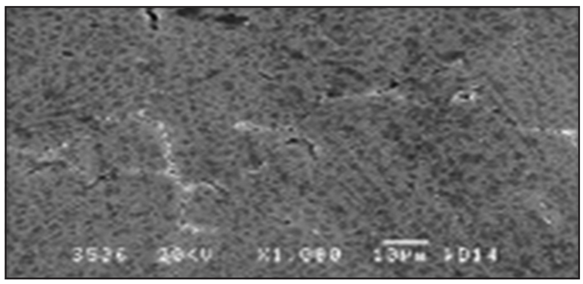

Figure 4: Microstructure of 6% composite.

3.1. Static Weight Loss Corrosion Test

The results of weight loss corrosion tests in different concentrated solution mixtures of sodium hydroxide and sodium chloride are given in Figures 5-7.

3.2. Effect of Test Duration on the Rate of Corrosion

The graphs presented from 5 to 7 shows that for each composite as well as for unreinforced Al 6061 alloys, the corrosion rate is found to decrease during the corrosion tests. The decrease in corrosion rate is due to the 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 a passive layer. Since the passive layer acts as a barrier between the fresh metal surface and the corrosive

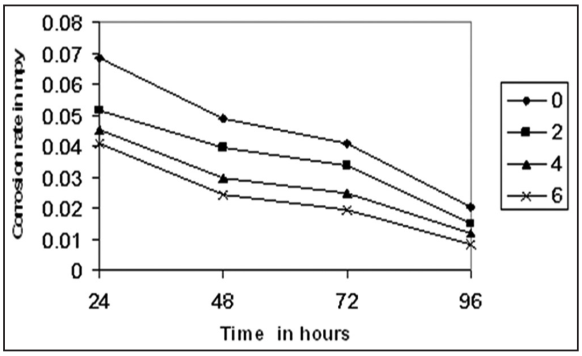

Figure 5: Weight loss in 0.035% NaCl.

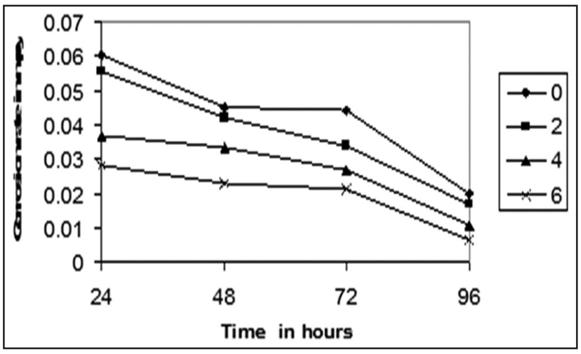

Figure 6: Weight loss corrosion test in 0.35% NaCl.

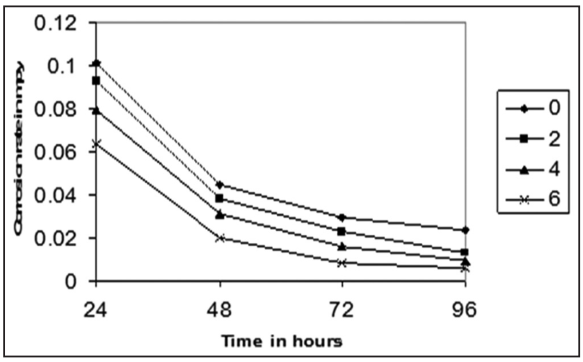

Figure 7: Weight loss corrosion test in 3.5% NaCl.

media, it avoids the direct contact between the specimen and the corrosive media, thus further dissolution of the metal alloy would not takes place [10].

3.3. Effect of Addition of Reinforcement

From graphs 5 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.

Ohsaki *et al*. obtained similar results in glass fiber reinforced ZA-27 alloy composites and also reported that the corrosion resistance increases with increase in reinforcement [11].

3.4. Potentiodynamic Polarization Test

This test was carried out in 3.5% sodium chloride solution only. Figures 8-11 show the Tafel plots for the matrix alloy Al 7075 and its composites containing 2, 4, and 6 weight percentage of beryl particulates.

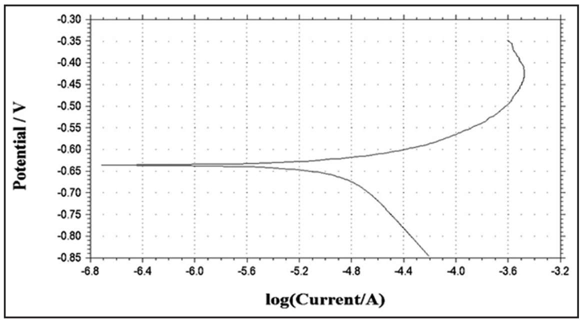

Figure 8: Tafel plot for matrix in 3.5% NaCl.

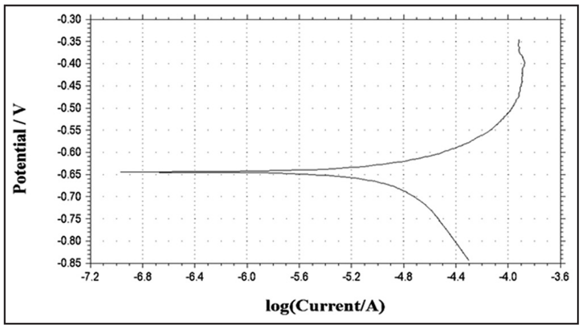

Figure 9: Tafel plot for 2% composite in 3.5% NaCl.

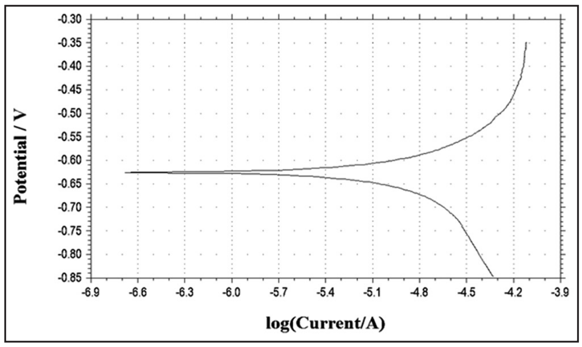

Figure 10: Tafel plot for 4% composite in 3.5% NaCl.

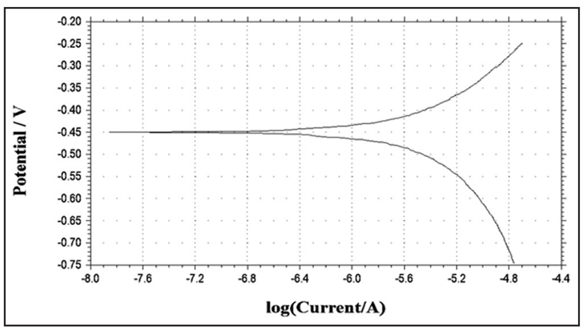

Figure 11: Tafel plot for 6% composite in 3.5% NaCl.

The results obtained for corrosion rates are given in Table 1.

The concentration had a marked effect on the corrosion rate of all the samples. With the increase in reinforcement content, the corrosion rate is decreased. It is well known that the chemical reaction depends on the concentration of solution, area of the reaction surfaces, etc.

Table 1: CR for matrix and composites in 3.5% NaCl solution

Specimen	CR (mpy)
Matrix	9.824
Al7075+2% Beryl	6.408
Al7075+4% Beryl	5.025
Al7075+2% Beryl	4.148

CR: Corrosion rates

From values, it is observed that corrosion rate of Al 7075/beryl MMCs decrease with increase in red mud content and that the rates of MMCs were less than that of the matrix alloy. This trend is attributed to the fact that red mud particulates are ceramic in nature and hence remains inert in aggressive chloride media. Beryl particulates also reduce the active exposure area of MMCs to the corrosive media.

4. CONCLUSION

Al 7075/Beryl composites were manufactured by adding 2, 4, and 6 weight percentage of beryl particulates. In the static weight loss corrosion test and potentiodynamic polarization test conducted for the composites showed improved corrosion resistance when compared with that of matrix alloy. Hence, composites are suitable than matrix for marine applications where the presence of salt will be more.

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***Bibliographical Sketch**

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