Corrosion Studies of Aluminium 6061 / Beryl Particulate Composites in Mixture of Sodium Hydroxide and Sodium Chloride Solutions

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Abstract

The aim of the research work was to investigate the corrosion behaviour of beryl particulate reinforced aluminium 6061 metal matrix composites (MMCs) in a mixture of alkaline and salt solution using weight loss method. The mixture alkali and salt solution used is mixture of sodium hydroxide and sodium chloride solutions. The composites are manufactured by liquid metallurgy technique using vortex method. Aluminium 6061 / beryl particulates MMCs containing 2, 4 and 6 weight percentage of beryl particulates are casted. The corrosion characteristics of Aluminium 6061 / beryl particulate composite and the unreinforced alloy were experimentally assessed. The corrosion test was carried out at different concentrations of mixture of sodium hydroxide and sodium chloride solution at a concentration of 0.025M, 0.05M and 0.1 M solutions for different exposure time. The results indicated that corrosion rate of metal matrix composites was lower than that of matrix material Aluminium 6061 under the corrosive atmosphere irrespective of exposure time and concentration of corrodent. Aluminium 6061 /beryl particulates composite become more corrosion resistant as the beryl content is increased. This is because of the formation of stable layer over the specimens. Scanning Electron Microscopy (SEM) show the degree of attack of alkaline solution on the surface of the investigated material.
Keywords: Beryl particulates, Corrosion loss, Metal Matrix Composite (MMCs), Weight loss

I. INTRODUCTION

Metal matrix composites are important class of materials, which contain metal or alloy as matrix and a ceramic particulate or fiber or whiskers as reinforcements. Aluminium based Metal Matrix Composites 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 behaviour, 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. Corrosion can affect the metal matrix composite 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 Aluminium 6061 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 capabilities5-6. One of the main disadvantages in the use of metal matrix composite 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 Aluminium 6061 /beryl metal matrix composites.

II. MATERIALS SELECTION AND METHODS

The material selected for the present research work is popularly used Aluminium 6061 alloy which is commercially available. Its composition is given in table 1.

Table - 1
Composition of Aluminium 6061 alloy

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, a naturally occurring mineral having the formula $(Be_3Al_2(SiO_3)_6)$ was used as the reinforcing material, while Al6061 alloy has been used as the matrix. The beryl particles used were of 45 - 60 µm size. They have a density of 2.6 - 2.8 g/mm3 which is almost on par with that of Al6061 and has hardness of 7.5 to 8 on Mho's scale and a hexagonal structure$^{7-8}$ [15,16].

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*

The mediums used for corrosion testing are 0.025M, 0.05M and 0.1 M solution mixtures of sodium hydroxide and sodium chloride. The method used for corrosion characterization is static weight loss corrosion method as per ASTM standards G69-80.The composites are prepared by liquid melt metallurgy technique used by Krupakaraet al^{9}. Pre heated and uncoated beryl particulates are added to molten aluminium 6061 alloy. Composites containing 2, 4 and 6 weight percentage of beryl particulates are prepared. Aluminium 6061 alloy is also casted in the same way for comparison. Castings are taken in the form of cylindrical bar. The specimen are prepared from the bar castings. Cylindrical specimen of size 20 mm x 20mm are machined from the bar castings of the composites and the matrix alloy. All the specimens are subjected to standard metallographic techniques as done by S. EzhilVannan and Paul Vizhian Simson^{10} before subjecting them to static weight loss corrosion tests.

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

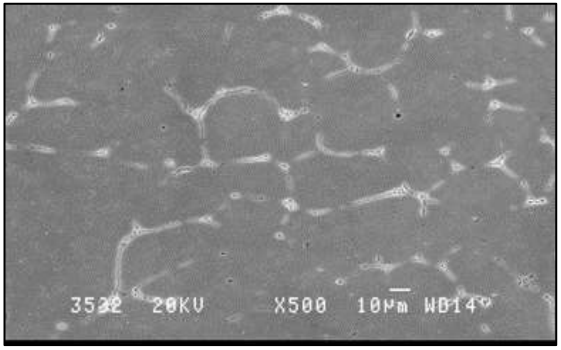

Fig. 1: Microstructure of Matrix

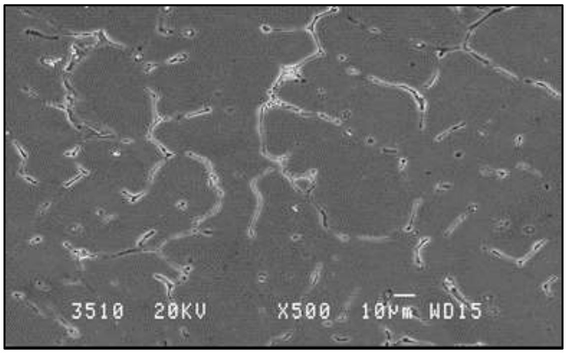

Fig. 2: Microstructure of 2 % composite

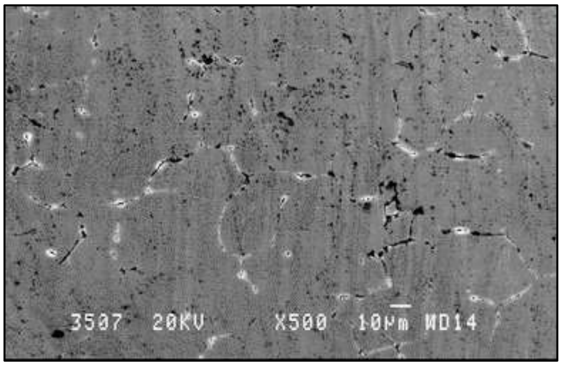

Fig. 3: Microstructure of 4% composite

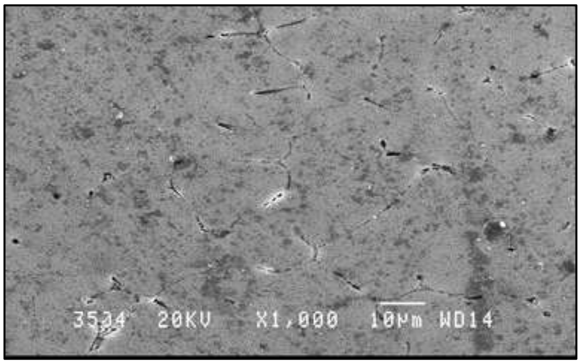

Fig. 4: Microstructure of 6% composite

Figures 1-4 show the microstructures of Aluminium 6061 matrix alloy and the composites prepared as per above mentioned procedures. In the figures 2 to 4 uniform distribution of beryl particulates is observed.

III. RESULTS AND DISCUSSION

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

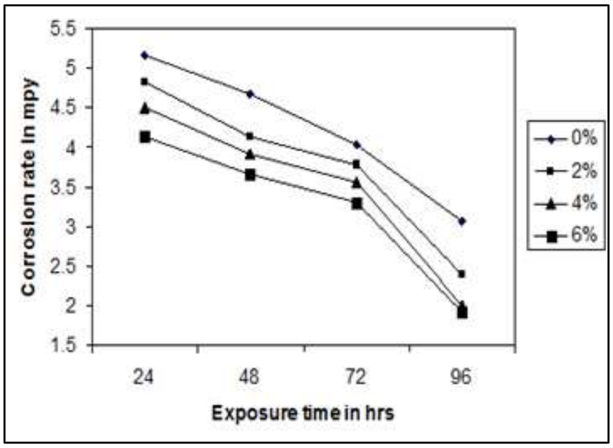

Fig. 5: Results of the test in 0.025M mixture

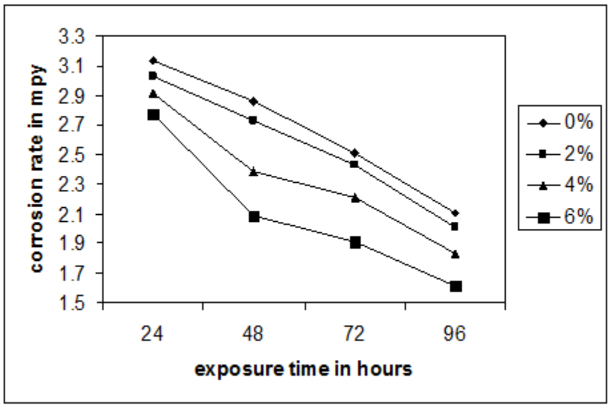

Fig. 6: Results of the test in 0.05M mixture

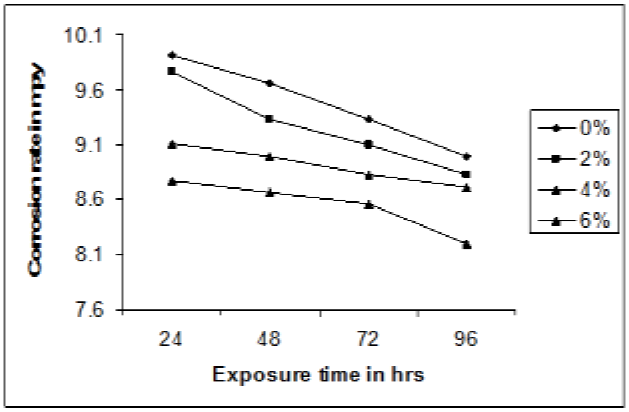

Fig. 7: Results of the test in 0.1M mixture

Figures 5-7 show the results obtained for the static weight loss corrosion test of Aluminium 6061 / beryl particulates composites and the matrix alloy in 0.025M, 0.05M and 0.1m solution mixtures respectively for different times of exposure. The results can be discussed under the topic effect of time of exposure and effect of beryl particulates content.

IV. EFFECT OF TIME OF EXPOSURE

The trend observed in all the cases show decrease in corrosion with increase in test duration. It is clear from the graphs that the resistance of the composite to corrosion increases as the exposure time increases. This eliminates the possibility of hydrogen bubbles clinging on to the surface of the specimen and forming a permanent layer affecting the corrosion process. The phenomenon of gradually decreasing corrosion rate indicates the possible passivation of the matrix alloy. De Salazar[11] explained that the protective black film consists of hydrogen hydroxy chloride, which retards the forward reaction. Castle et. al.[12] pointed out that the black film consists of aluminium hydroxide compound. This layer protects further corrosion in acid media. But exact chemical nature of such protective film still is not determined.

From the Fig 6 to 8 it can be clearly observed that for both as cast and composite, corrosion rate decreases monotonically with increase in beryl particulates content. In the present case, the corrosion rate 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 corrosion medium 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 base alloy surface was observed clearly. 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 the ceramic remains inert and is hardly affected by any medium during the test and is not expected to affect the corrosion mechanism of the composite. The corrosion result indicates an improvement in corrosion resistance as the percentage of beryl particulates increased in the composite, which shows that the beryl particulates directly or indirectly influence the corrosion property of the composites. Krupakara P.V.[13]who obtained similar results in red mud particulates reinforced Aluminium 6061 alloy composites reported that the corrosion resistance increases with increase in reinforcement.

Wu.Jinaxin et.al[14] in their work on corrosion of aluminium based particulate reinforced MMCs; state that the corrosion is not affected to a significant extent by the presence of beryl particulates in aluminium, whereas the particulates definitely play a secondary role as a 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 modifies the microstructure of the matrix material and hence reduces 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, which may be due to formation of magnesium inter- metallic layer adjacent to the particulate during manufacture as discussed by J.F.Mclyntyre et al[15] 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 on the particulate matrix interface. The active nature of the crevices would cathodically protect the reminder of the matrix and restrict pit formation and propagation.

V. CONCLUSIONS

The beryl particulates content in Aluminium 6061 alloys plays a significant role in the corrosion resistance of the material. Increase in the percentage of beryl particulates will be advantageous to reduce the density and increase in the strength of the alloy, but the corrosion resistance is thereby significantly increased.

Aluminium 6061 MMCs when reinforced with beryl particulates of weight percentage from 0 to 6 percent could be successfully produced by liquid melt metallurgy technique.

The rate of corrosion of both the alloy and composite decreased with increase in time duration in all concentrations of sodium hydroxide and sodium chloride solutions.

The corrosion rate of the composites was lower than that of the corresponding matrix alloy in concentrations of sodium hydroxide and sodium chloride solution.

The composites are more suitable than alloy in applications related to alkaline medium and marine medium

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