Weight Loss Corrosion Studies of Al7075 Metal Matrix Composites Containing Beryl Particulates

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Abstract: **This paper deals with the high corrosion resistance developed by the metal matrix composites when compared with that of matrix alloy. Matrix selected is Al7075 and reinforcement selected is Beryl particulates. The composites are prepared using liquid melt metallurgy technique using vortex method. Preheated but uncoated beryl particulates are added to the melt. Metal matrix composites containing 2, 4 and 6 weight percentage of beryl are prepared. Matrix was also casted in the same way for comparison. Corrosion tests were conducted at room temperature (23⁰ C) using conventional weight loss method according to ASTM G69-80. The corrodents used for the tests were 0.025, 0.05 and 0.1 molar solutions of sodium hydroxide and 0.25 M moisture of sodium chloride and sodium hydroxide.. Corrosion rates were calculated using the formula 534DAT/W. In each case the corrosion rate in all corrodents decreases with increase in exposure time for matrix and metal matrix composites. Hence the composites are more suitable for the use in saltish or marine environment.**

Keywords: **Weight Loss Corrosion, Al7075 Metal Matrix, Beryl Particulates**

1. Introduction

Metal matrix composites are engineering combination of two or more materials (one of which will be metal or alloy) where tailored properties are achieved by systematic combination of different constituents [1]. Composites are metal systems consisting of a mixture of two or more constituent's insoluble in each other and differing in form and material composition [2]. They are heterogeneous materials consisting of two or more phase, which are in intimate contact with each other on a microscopic scale. They are also homogeneous material in sense that any part of it will have the same physical properties on a microscopic scale [3]. The present research work involves the above mentioned metal matrix composites where aluminium 7075 is reinforced with beryl particulates particles.

Table 1: Composition (%) of Aluminium 7075 alloy

Element	Cu	Cr	Mn	Mg	Si	Ti	Zn	Fe	Al
Percentage	1.8	0.2	0.4	1.9	0.5	0.15	3.25	0.5	Bal

2. Experimental Procedure

Material selection
The matrix selected is AL7075 alloy; it is an important alloy of Aluminum available commercially. Its composition is given in table 1

Beryl particulates which is naturally occurring mineral and having the formula [$Be_2Al_2(SiO_3)_6$] is used as reinforcement. They have a density of 2.6 - 2.8 g/mm3 which is almost on par with that of Aluminium 7075 and has hardness of 7.5 to 8 on Mho's scale and a hexagonal structure.50-80 μm size beryl particulates are used in this study. The chemical composition of beryl particulates is given in table2.

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

Preparation of composites
The liquid metallurgy route using vortex technique [4] is employed to prepare the composites. A mechanical stirrer was used to create the vortex. The reinforcement material used was beryl particulates particulates of size varying 50-80 μm. The weight percentage of beryl particulates used was 2-6 weight percentages in steps 2%. Addition of beryl particulates in to the molten aluminium 7075 alloy melt is carried out by creating a vortex in the melt using a mechanical stainless steel stirrer coated with aluminite (to prevent migration of ferrous ions from the stirrer material to the zinc alloy). The stirrer was rotated at a speed of 450 rpm in order to create the necessary vortex. The beryl particulates particles were pre heated to 200°C and added in to the vortex of liquid melt at a rate of 120 g/m[5]. The composite melt was thoroughly stirred and subsequently degassed by passing

nitrogen through the melt at a rate 2-3 l/min for three to four minutes. Castings were produced in permanent moulds
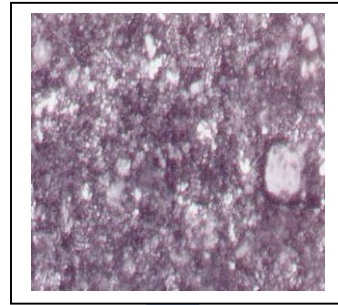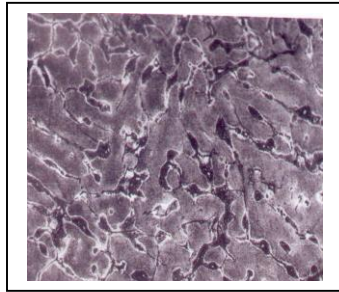
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Microstructure

Fig 1- Microstructure of aluminium 7075-matrix   Fig 2- microstructure of aluminium 7075/6% Beryl particulates

Fig 1 shows the micrograph of unreinforced aluminium 7075 alloy. Here the large, columnar aluminium -rich dendrites appear white. The small, very dark spots are interdendritic shrinkage micro-porosities, characteristic of long freezing range alloys[6]. It is noted that the branches of Aluminium rich dendrites are enclosed in a gray, zinc-rich skin. The coring effects revealed by colour variations in these dendrites are also typical of a long freezing-range alloy.

The microstructures composites show negligible solid solubility of beryl particulates in either the Aluminium or zinc-rich phases

Fig 2 is the microstructure of aluminium 7075/6% beryl particulates composite taken at 100μM. The grain size of the composites is slightly lower than matrix alloy

The structures reveal that the relatively colder particle chills the metal and unitized nucleation. The dendrites grow away from the particle, due to the restriction caused by the particle to solute enrichment. Thus the grains grow outwards from the particle and the last remaining eutectic liquid solidifies around the particles.

3. Specimen preparation

The cylindrical castings were cut into 20x20mm pieces using an abrasive cutting wheel. The matrix alloy was also casted under identical conditions for comparison. The samples were successively ground using 240, 320, 400 and 600 SiC paper and were polished according to standard metallographic techniques and dipped in acetone and dried. The samples

were weighed to fourth decimal place using electronic balance and the specimen dimensions were noted down using Vernier gauge.

4. Corrosion test

The corrosion behaviour of Aluminium 7075 alloy was studied by immersion test. The static Samples were suspended in the corrosive medium for different time intervals up to 96 hours in steps of 24 hours. 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 by using a brush in order to remove the heavy corrosion deposits on the surface. The corresponding changes in the weights were noted.

Corrosion rates were computed using the equation

Corrosion rate = 534 W/DAT mpy ……..(1)

Where W is the weight loss in gm, D is density of the specimen in gm/cc, A is the area of the specimen (inch^2) and T is the exposure time in hours.

5. Results And Discussions

Fig 1-4 are the computer simulation graphs of the results of weight loss corrosion in 0.025, 0.05 and 0.1 normal solutions of sodium hydroxide, 0.25 M equimolar solutions of sodium chloride and sodium hydroxide respectively.
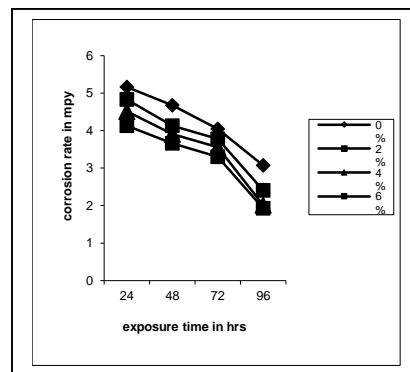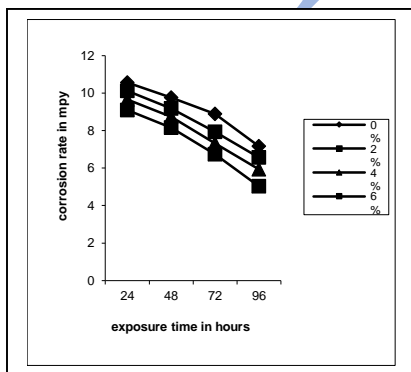
Fig 1 – Weight loss corrosion in
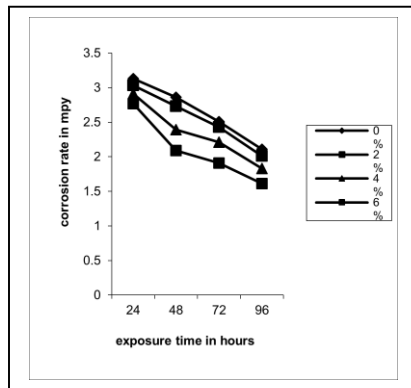0.025 N NaOH

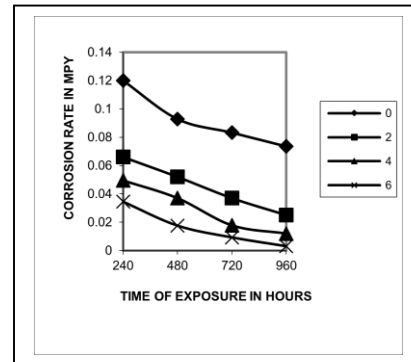Fig 2- Weight loss corrosion in
0.05N NaOH

Fig 3 – Weight loss corrosion in
0.1 N NaOH

Fig 4- Weight loss corrosion in
0.25 M equimolar solutions of NaCl-NaOH

6. Effect Of Test Duration

The corrosion rate mpy measurement as a function of exposure time in the static immersion test is shown in the Fig1 to 4. The trend observed in all the cases show decrease in corrosion with increase in test duration. It is clear from the graph 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. W.Smith [9] explained that the protective black film consists of hydrogen hydroxy chloride, which retards the forward reaction. R.J.Barnhurst et. al.[10] pointed out that the black film consists of Aluminium hydroxide compound. This layer protects further corrosion in corrosion media. But exact chemical nature of such protective film still is not determined.

7. Effect Of Beryl Particulates Content

From the Fig 1 to 4 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 sodium chloride solution used induces crack formation on the surface, which eventually lead 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[7-9].

Beryl particulates being the ceramic remains inert and is hardly affected by sodium chloride solution 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 particulates increased in the composite, which shows that the beryl particulates particulates directly or indirectly influence the corrosion property of the composites[10-14]. B.M.Sathish et.al. [15] who obtained similar results in glass short fiber reinforced ALUMINIUM 7075 alloy composites reported that the corrosion resistance increases with increase in reinforcement.

Wu.Jinaxin et.al [16] 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 particulates in Aluminium , where as 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 Trzaskoma[17], Mclntyre[18] et.al. 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.

8. Conclusions

The beryl particulates content in aluminium 7075 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 reduced.

Aluminium 7075 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 0.025, 0.05 and 0.1 normal solutions of sodium hydroxide, 0.25 M equimolar solutions of sodium chloride and sodium hydroxide.

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