Influence of heat treatment on corrosion rate of aluminium A356 reinforced with mica and titanium di oxide

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Abstract

Composite material plays important role in the field of engineering and has vast applications in the aerospace, marine industries, automobiles, recreational etc. Researchers are always engaged in identifying the hidden parameters of the composites. In this present study, aluminium A356 alloy is proportionally mixed with the reinforcements like titanium di oxide (TiO_2) and mica by using vortex method. The matrix A356 is mixed with equal proportions of TiO_2 and mica (1 wt%, 2 wt%, 3 wt%, 4 wt% and 5 wt%) and different castings formed are subjected to various heat treatment process. Once the different ageing conditions are achieved, the specimens are studied for the corrosion behavior. Results suggest that the specimen with double ageing (4 h) is having greater resistance to corrosion. The density of the prepared casting decreased with increase in reinforcement.

Keywords Composites · A356 · Mica · TiO_2 · Ageing conditions and corrosion resistance

1 Introduction

Researchers are always identifying materials with many advantages like density, corrosion resistance, long life, very economical, good strength etc. A monolithic material does not always provide such needy performance. Hence a need for hybrid materials is explored around the world through research and development. A composite material fills this demand with its high strength to weight ratio, low density, machinability and other various properties.

In this present study, aluminium A356 is the matrix material and reinforced with mica and TiO_2 with equal weight percentage. A356 belong to a group of hypo eutectic Al–Si alloy and has a wide field of application in automotive and avionics industries [1]. Alloy A356.0 has great elongation higher strength and considerably higher ductility than 356.0. Impurities less and hence have wide application in airframe casting, machine parts, truck

chasses [2]. Titanium dioxide, also known as titanium is the naturally occurring oxide of titanium. It has a wide range of applications, from paint to sunscreen to food coloring. Mica is a complex aluminosilicate mineral. Mica is plate or sheet like structure. Mica has high toughness, good physical, thermal, mechanical properties. Many investigations on composites are done by researchers.

Mohan Vanarotti et al. studied the synthesis and characterization of aluminium alloy A356 and silicon carbide and reveals reasonable increase in hardness and decrease of ductility with increasing silicon carbide [3].

Maninder singh et al. studied the performance of aluminium based metal matrix composites with SiO_2 and TiO_2 as reinforced particles and concludes that the addition of reinforcements increases the hardness and wear resistance [4].

Sharath Kumar et al. investigated the wear loss in aluminium, silicon carbide and mica hybrid composites and

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suggests when the mica is added, it reduces the wear loss and increases the wear resistance of the material [5].

2 Aim of the present study

In this present investigation, aluminium A356 alloy based hybrid composite is been prepared by using TiO_2 and mica particles as reinforcement for equal proportions (1 wt%, 2 wt%, 3 wt%, 4 wt% and 5 wt%) by stir casting method and investigated for the corrosion resistance which are highly important criteria for the hybrid material to survive in marine applications [6].

3 Processing of MMC's

In this process, the specimens were prepared using stir casting technique. Aluminium A356 alloy was taken as the matrix material. Titanium and Mica were chosen as the reinforcement to form the hybrid composite material. Initially A356 alloy was heated to 700 °C so as to obtain the molten material in an electric furnace. The prepared mica and TiO_2 particles having mesh size in the range 100–250 μ was preheated to a temperature of 450 °C for at least 1 h to remove the moisture content and absorbed gases in the particles. Degassing of molten metal was evacuated by adding hexachloro- ethane tablets. Liquid metal temperature was maintained at 700 °C with sufficient viscosity. The liquid metal was stirred at a speed of 500 rpm for 10–15 min with the help of impeller to create sufficient vortex [7]. The stir speed chosen is high enough to get a sufficient vortex for proper mixing of the reinforcement particles with the liquid metal. At the same time, stir speed is low enough to avoid the gas and air entrapment in the molten metal. The 1% weight preheated particles were incorporated laterally into the vortex of the molten metal. 1% magnesium was added to the molten metal to increase the wettability of the particles with the molten material. Stirring speed was maintained at 500 rpm for next 15 min to ensure the proper mixing [8]. After this stage, the molten mixture was drained into the mould. To accomplish the uniform solidification of the molten metal, the mould was preheated to 250 °C for 30 min [9]. Thus, particles are incorporated successfully to form hybrid composite material by using the stir casting technique [10]. Later 2 wt%, 3 wt%, 4 wt% and 5 wt% by equal weight proportions of mica and TiO_2 were replaced to prepare the test specimen and tested for different aging condition.

4 Heat treatment process

The heat treatment steps for the MMCs are as follows,

1. *Solutionizing* Solutionizing at 540 °C for 6 h followed by quenching into water at room temperature was executed on the prepared specimens.
2. *Single Ageing* once quenching is done, the specimens are heated to a temperature of 140 °C for about 12 h is carried out.
3. *Double Ageing 1* In this process, the specimens are heated to a temperature of 190 °C for about 2 h is carried out.
4. *Double Ageing 2* In this process, the specimens are heated to a temperature of 190 °C for about 4 h is carried out [11].

5 Corrosion test

Corrosion test was carried out by dipping the specimens in the prepared solutions in separate trays. Solutions, each with 0.1 normal HCL, 5% NaCl and Sea Water were taken and the specimens were dipped into it for duration of 96 h (ASTM B117). The specimens were later rinsed with water and weighed in a electronic weighing scale [12].

Figure 1, 2 and 3 shows the corrosion behavior of the as-cast samples and it is observed that the corrosion resistance has increased as there in increase in reinforcement. Small amount of corrosion is evidenced in HCl but corrosion rate in Sea water and NaCl in negligible. This may be due to resistance to corrosion by the hard reinforcement material.

The above Figs. 4, 5 and 6 shows that the corrosion resistance has increased as there in increase in reinforcement and at different ageing conditions. Small amount of corrosion is evidenced in HCl and corrosion rate in Sea water and NaCl in negligible. Double ageing (4 h) has exhibited substantial improvement than the base alloy [13]. This may be attributed to increased precipitate in grain boundary distribution during heat treatment and ageing and finer grain size after stretching resulting in increased inter-granular corrosion resistance [14]. The same can be evidenced in the digital photographs of various aged conditions in various solutions. Pitting corrosion is very predominant in as-cast condition and is least in double aged with strain/stretching condition [15, 16]. Figures 7, 8 and 9 shows the micrograph images,

Fig. 1 Corrosion rate verses samples with different reinforcement in 0.1 normal HCl

Fig. 2 Corrosion rate verses samples with different reinforcement in 5% NaCl

Fig. 3 Corrosion rate verses samples with different reinforcement in sea water

Fig. 4 Corrosion rate verses different samples at different ageing conditions with 0.1 normal HCl

Fig. 5 Corrosion rate verses different samples at different ageing conditions with 5% NaCl

where the corrosion causes pitting on the surface of the specimens.

6 Conclusions

1. Resistance to corrosion has increased as there is an increase in reinforcement and at different ageing conditions. Corrosion is evidenced in HCl but very minimum in Sea water and NaCl. Double ageing (4 h) has exhibited substantial corrosion resistance compared to as-cast.
2. This improvement in resistance to corrosion may be attributed to increased precipitate in grain boundary distribution during heat treatment/ageing and finer grain size after stretching resulting in increased inter-granular corrosion resistance.

Fig. 6 Corrosion rate verses different samples at different ageing conditions with sea water

Fig. 7 Pitting corrosion on the flat surface of single aged specimen tested with 0.1 normal HCl, 5% NaCl and sea water for 96 h

Fig. 8 Pitting corrosion on the flat surface of double aged specimen tested with 0.1 normal HCl, 5% NaCl and sea water for 96 h

Fig. 9 Pitting corrosion on the flat surface of double aged with strain/stretching specimen tested with 0.1 normal HCl, 5% NaCl and sea water for 96 h

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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