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RESEARCH ARTICLE

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INFLUENCE OF HEAT TREATMENT ON TRIBOLOGICAL PROPERTIES AND CORROSION RESISTANCE OF ALUMINIUM A356 ALLOY REINFORCED WITH MICA AND TITANIUM DI OXIDE HYBRID COMPOSITE AT DIFFERENT AGING CONDITIONS

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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 (1wt%, 2wt%, 3wt%, 4wt% and 5wt %) and different castings formed are subjected to various heat treatment process. Once the different aging conditions are satisfied, the specimens are studied for the wear and corrosion behavior. Results suggest that the specimen with double aged with strain is having greater resistance to wear and corrosion. The density of the prepared casting decreased with increase in reinforcement.

Key words: composites, A356, Mica, TiO_2, Aging conditions, Wear 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 of alumino-silicate 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].

S.Sharath kumar et al investigated the wear loss in aluminium, silicon carbide and mica hybrid composites and 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 (1wt%, 2wt%, 3wt%, 4wt% and 5wt %) by stir casting method and investigated for the wear and corrosion resistance which are highly important criteria for the hybrid material to survive in marine applications.

3. Material Selection

Author O.P Khanna (2007) published that, for the selection of suitable materials of experiments several factors like availability, economic requirement, fabrication, service has to be considered. The matrix material A356 and reinforcements like TiO_2 and Mica are selected based on the above factors and on the comprehensive survey from the literatures.

3.1 Matrix Material

For the present experimental investigation, Aluminium A356.0 was used as a matrix material whose chemical composition (in wt %) is listed in table 2.1. A356 alloy has good cast ability, mach inability, weld ability, heat treatable and corrosion resistance properties. The main chemical composition is silica with up to 7.5% wt % which provides greater hardness.

Table: 3.1 Chemical Composition of the Aluminium A356 Alloy

Chemical Compositions	Si	Fe	Cu	Mn	Mg	Zn	Ti	Others	Aluminium A356
Percentages (%)	6.5-7.5	0.20	0.20	0.10	0.25-0.45	0.10	0.20	0.15	Remainder

3.2 Selected Reinforcement Material

3.2.1 Titanium Di Oxide (TiO_2)

The purpose of selecting Titanium dioxide is due its low density, easily blend with Aluminium Alloys to improve mechanical property and low cost.

3.2.2 Mica

Mica is one of the naturally obtained mineral which when added as the reinforcement is considered to change the machinability of the material prepared. Some of the characteristics of the mica are high chemical resistance, elasticity, machinability and flexibility. The chemical, physical and mechanical properties are mentioned in the below tables.

Table 3.2: Chemical Composition of Mica

Compositions	%Composition
Silica	45.57
Alumina	33.10
Potassium Oxide	9.87
Ferric Oxide	2.48
Sodium Oxide	0.62
Titanium oxide	Traces
Calcium Oxide	0.21
Manesia	0.38
Phosphorus	0.03
Sulphur	0.01
Graphitic Carbon	0.44
Moisture at 100º	0.25
Loss on ignition	2.74

Table 3.3: Physical composition of mica

Physical Properties	Range
Density	2.6-3.2(gm/cc)
Melting Point	600ºC-1200ºC
Thermal Conductivity	Very Low

Table 3.4: Mechanical Properties of Mica

Mechanical Properties	Range
UTS	1750(kgf/cm^2)
Shear Strength	2200-2700(kgf/cm^2)
Modulus of Elasticity	1400-2100(kgf/cm^2)

4. Methodology

The materials selected based on the literature review and other properties, the experimental procedure is carried out accordingly and are as follows.

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 700ºC so as to obtain the molten material in an electric furnace. The prepared mica and TiO_2 particles having mesh size in the range 100-250µ was preheated to a temperature of 450ºC for at least 1hr 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 minutes with the help of impeller to create sufficient vortex. 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 in to 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 minutes to ensure the proper mixing. After this stage, the molten mixture was drained in to the mould. To accomplish the uniform solidification of the molten metal, the mould was preheated to 250°C for 30 minutes. Thus, particles are incorporated successfully to form hybrid composite material by using the stir casting technique. 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.

5. Heat Treatment Procedure

i) Solutionizing: Solutionizing at 540°C for 6 hrs followed by quenching in to water at room temperature was executed on the prepared specimens.

ii) Stretching and straining: This is a particular condition where, instantaneously after the heat treatment and quenching, before precipitation starts and the hybrid composite material become harder. One set of prepared samples is permanently deformed by 8 % to 10 % by applying external force (before 5 Hrs).

iii) Single Aging: once quenching is done, the specimens are heated to a temperature of 140ºC for about 12hrs is carried out.

iv) Double Aging: In this process, the specimens are heated to a temperature of 200ºC for about 12 hrs is carried out.

6. Results and Discussion

Once the cast is solidified, it is machined to obtain the ASTM standards for the purpose of testing. The various prepared specimens were also solutionized and heat treated. The final hybrid composite was then investigated for their microstructure, density, and wear and corrosion resistance.

6.1 Microstructure Analysis

The microscopic analysis is used to check the uniform distribution of reinforcement in the matrix material. Higher microscopic magnification can help to determine the various distribution of reinforcement. Some qualitative evidences of particle distribution of combined mica and TiO_2 quality of bonding between two particles and matrix are obtained. Pre microscopic analysis, the prepared specimen was grinded, polished by using emery papers, washed with water and finally etched with Keller's reagent. Thus the specimens are ready for their investigation through the microscope.

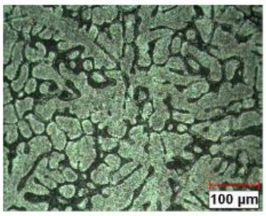


Fig. 5(a) As Cast (3% TiO_2 and 3% Mica)

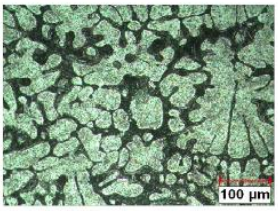


Fig. 5(b) Single Age (3% TiO_2 and 3% Mica)

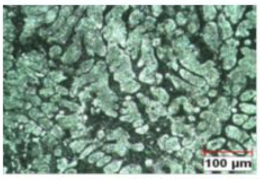


Fig. 5(c) Double aged(3% TiO_2 and 3% Mica)

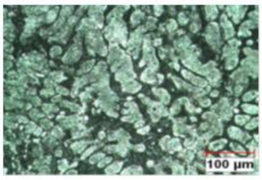


Fig. 5(d) Double aged with strain(3% TiO_2 and 3% Mica)

The figures 5(a) represents the microscopic view of the as cast specimen with 3% Mica particles and 3% TiO_2. Figure 5(b) and 5(c) represents the microstructure of the aged hybrid composite. Figure 5(d) shows the microstructure of 3% Mica particles and 3% TiO_2. This analysis demonstrated the uniform distribution of spherodized particles of mica in double aged with strain compared to dendrite structure observed in as cast specimen, double aged with strain and single aged with strain specimens.

6.2 Density Measurement

A materials density is the mass per unit volume and is essentially a measurement of how tightly matter is compacted. The principle of density is measured by Greek scientist Archimedes equation

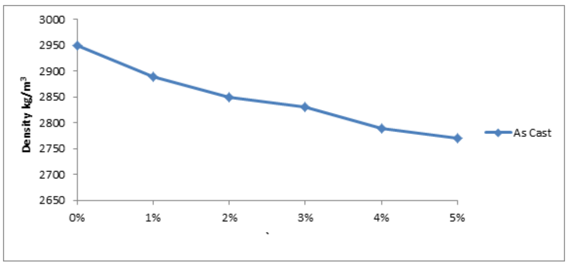
$$\rho mmc = \frac{m}{m-m1} * \rho w \qquad [6]$$

Where,

'm' is the mass of the composite in air (Kg)

m $_1$ is the mass of the same composite in distilled water (Kg)

ρ_w is the density of distilled water (Kg/m^3)



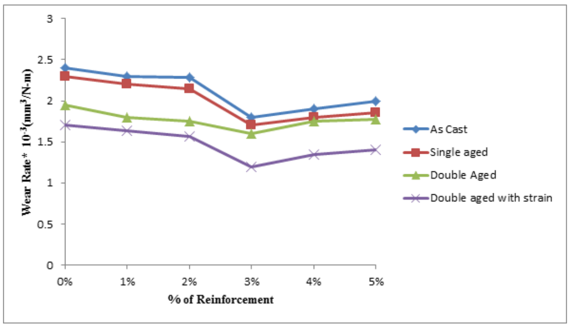
Graph 1: Density of A356 alloy hybrid composite

From Graph 1, it is observed that the density of A356 Alloy hybrid composite material reduces when the percentage of reinforcement Mica and TiO_2 increases. The presence of higher porosity may be due to solidification nature and due to the agglomeration of TiO_2 particles. The presence of voids in matrix, low interface bonding between reinforcement and matrix and development of fracture of reinforcement leads to lower density with increase in reinforcement.

6.3 Wear Resistance

The wear rate of as-cast and various aging samples are investigated by conducting the dry sliding wear tests. The pin-on-disc testing machine has been used for this investigation. The aim of the investigation is to find the dry sliding wear characteristics of aluminium alloy and its composites. Test samples were taken from the castings, machined to pins of size 10mm diameter and 30mm height, polished and subjected to wear tests. The counterpart disc was made of high carbon EN32 steel having a hardness of HRC62 and the radius of the sliding track on the disc surface was 57mm. All the wear tests were conducted at room temperature for 20 minutes with a load of 1Kg and at 600 RPM. The wear rates of the composite specimens were analyzed as a function of the volume worn out (Volume loss method), sliding distance and applied load. The wear rate is estimated from the following equation.

$$\textit{Volume Rate Wear} = \frac{\textit{Volume of the material removed}}{\textit{Normal load} * \textit{Sliding distance}} \qquad [7]$$



Graph 2: Evaluation of wear rate for different specimens

From the graph 2 it can be observed that, with the increase of reinforcement, there is decrease in the wear rate of the composites. This is due to the drastic enhancement in hardness and great bonding among the matrix and the reinforcement particles. The wear loss is greatly reduced with aging and the lowest wear rate is observed in double aging with strain specimens which is associated with higher hardness.

6.4 Corrosion Test

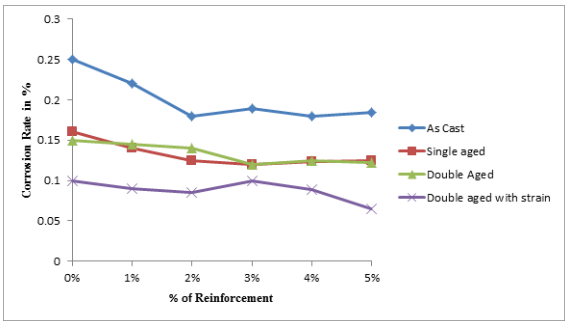
Various solutions were prepared and stored in vessels. The prepared specimens were dipped in these solutions to investigate the corrosion rate. The solutions are prepared by using 5% NaCl , Sea water and 0.1 normal HCL. The samples were soaked in to it for a period of 96 hours. After this the specimens are cleaned with H_2O and rinsed with acetone and weight is checked in an electronic weighing machine. Following formula can be used to calculate the percentage of corrosion rate.

$$\% \, Corrosion \, Rate = \frac{Wi - Wa}{Wi} * 100 \quad [8]$$

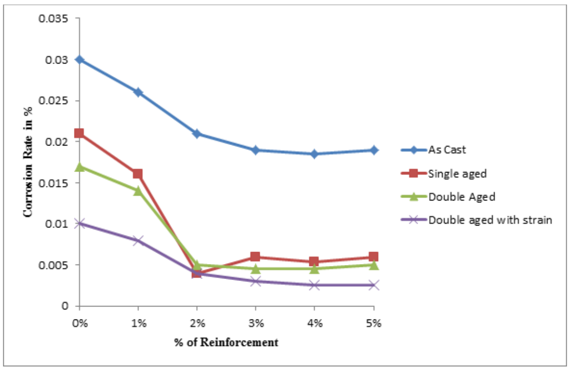
Where,

W_i = Weight before corrosion

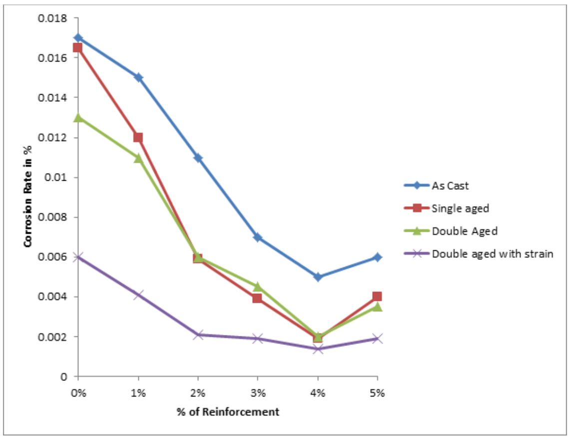
W_a= Weight after corrosion



Graph 3: Evaluation of corrosion rate for specimens dipped in 0.1 normal HCL



Graph 4: Evaluation of corrosion rate for specimens dipped in 5% NaCl



Graph 5: Evaluation of corrosion rate for specimens dipped in sea water

From the graph 3, 4 and 6, it is noticeable that the corrosion rate of the A356 hybrid composite material is much lower when compared to that of its parent metal. With the increases in wt% of TiO_2 and mica content the corrosion resistance has improved. This is due to the inclusion of reinforcement, which makes A356 alloy into stronger and resistant to corrosion. Also stabilized material has been resulted from the heat treatment and aging and hence there is an appreciable reduction in corrosion resistance. It is also evidence that the corrosion rate in NaCl and sea water is lesser than HCL.

7. Conclusion

The aluminium A356 alloy was successfully produced by vortex or stir casting method for different weight percentage of reinforcement for as cast, single aging, double aging and double aging with strain. After the conduction of the experiments, following conclusions have been drawn:

i. From stir casting method, Mica and TiO_2 particulates can be successfully introduced in the aluminium A356 matrix alloy material to fabricate hybrid composite materials.

ii. From the microstructure analysis, it is noted that the reinforcement particles are uniformly and evenly distributed in the matrix.

iii. The bonding between the matrix and reinforcement is denser in double aged strain specimen due to the nucleation of precipitates.

iv. There is a decrease in density of the hybrid composite when the reinforcement are increased.

v. There is a decrease in the corrosion loss due to the increase in the reinforcement. Thus the corrosion resistance of the hybrid composites is highly influenced by the heat treatment.

vi. There is a decrease in the wear loss due to the increase in the reinforcement. Thus the wear resistance of the hybrid composites is highly influenced by the heat treatment.

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