Characterization of As Cast and Heat Treated Aluminium 6061/Zircon sand/Graphite Particulate Hybrid Composites

Gopi K.R, Mohandas K.N, Reddappa H.N, M.R. Ramesh

***Abstrct**: The present investigation has been focused on the development of hybrid composite involving aluminium matrix reinforced with particulates of Zircon sand and graphite (produced by stir casting technique), the cast composites were tested for hardness, wear characteristics and the obtained properties were correlated with the microstructure. The results of the present investigation indicate that there is a considerable improvement in the hardness valves, microstructure and resistance for wear.*

Keywords: Aluminium 6061, Zircon sand, Graphite

I. INTRODUCTION

Conventional monolithic materials have limitations in achieving good combination of strength, stiffness, toughness and density. To overcome these shortcomings and to meet the ever increasing demand of modern day technology, composites are most promising materials of recent interest.

Metal matrix composites (MMCs) possess many advantages over monolithic materials, including higher specific strength, good wear resistance, higher thermal conductivity than ceramic materials, lower coefficient of thermal expansion compared to unreinforced alloys. There has been an increasing interest in composites containing low density and low cost reinforcements.

Now a days the particulate reinforced aluminium matrix composite are gaining importance because of their low cost with advantages like isotropic properties and the possibility of secondary processing facilitating fabrication of secondary components. Cast aluminium matrix particle reinforced composites have higher specific strength, specific modulus and good wear resistance as compared to unreinforced alloys. The excellent mechanical properties of these materials and the relatively low production cost make them very attractive for a variety of applications in automotive and aerospace industries. Some of the Al matrix composites such as those reinforced with SiO_2, B_4C, Al_2O_3 or SiC are now commercially available in a variety of structural forms.

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Amongst the various aluminium-ceramic combinations limited studies are done on aluminum–zircon composite as zircon is not readily wetted by liquid aluminum and there is a significant difference between their density values.

However, wetting characteristics of the liquid metal with the solid surface may quickly be altered by an appropriate alloying element addition. Despite having disadvantages in synthesizing aluminium-zircon composites, zircon was found to be a promising candidate due to its high hardness, high modulus of elasticity and excellent thermal stability. Excellent thermal stability is important since fabrication processes undergo enormous changes in temperature and large volumetric changes due to phase transformation can cause de-bonding at the interfaces and graphite which has a good lubricating property.

The present investigation, an attempt is made to develop the hybrid composite involving aluminium matrix reinforced with particulates of zircon sand and graphite (produced by stir casting technique), the cast composites were tested for hardness property, dry sliding wear properties and microstructure.

II. EXPERIMENTAL PROCEDURE

The details of the experiments carried out on Al6061 alloy subjected to refinement (Zircon and Graphite) and with T6 heat treatment has been highlighted under the following headings.

- Preparation of Composites
- Melting and casting
- Heat Treatment Process

A. *Preparation of Composites*

Matrix Material

The base matrix chosen in the present study is the aluminium 6061 because it is one of the most extensively used of the 6000 series aluminium alloys. Alloy 6061 is an aluminum alloy containing copper, magnesium, manganese and some minor alloying elements. They have high strength to weight ratio, good formability, age hardenability and other appropriate properties. Among Al alloys, Al 6061 has high machinability, high hardness property and also light weight. But some of the mechanical properties such as low wear resistance have limited application of these materials.

Al6061 is used in consumer products and military applications. The aircraft and aerospace industry uses aluminium alloys because it is much lighter than steel and every kilogram of weight reduction results in greater fuel savings and higher payloads.

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The car industry has increased its use of aluminum over the years as the price of gasoline has increased and the need to reduce vehicle weight has been of paramount importance. Today, much of aluminum use is to reduce the weight of the item being produced.

Reinforcing Material

Zircon Sand

Zircon was found to be a promising candidate due to its high hardness, high modulus of elasticity and excellent thermal stability. Excellent thermal stability is important since fabrication processes undergo enormous changes in temperature and large volumetric changes due to phase transformation can cause debonding at the interfaces.

Graphite

The most important graphite properties:
High thermal resistance
Low friction and self-lubrication
High electrical conductivity
High thermal conductivity
Low wettability by liquid metals

B. Melting and casting

1) Production of the metal matrix composite (MMC) through stir casting technique.
2) The Al6061 alloy melts at a temperature of 756^{0}C in a graphite crucible in melting furnace and degassing was carried out using hexachloroethane degassing tablets.
3) The stirring device was a stainless steel rod, which was equipped with four stirring blades, each 1 mm thick. The blades were mounted radial on the rotating rod, being angled 5° to the radial horizontal rotational plane
4) The addition of zircon sand and graphite will be added on the percentage weight of the aluminium alloy.
5) The mixture starts from 2% by weight and will go on up to 10% by weight, with the increment of 2% per trial.
6) The molten alloy was stirred at 400 rpm for up to 1 min until a vortex is formed. Preheated Zircon sand and graphite particles at 200^{0}C was added into the formed vortex slowly and steadily while continuing stirring for 3-5 min in a maneuvering way to ensure the complete insertion of particles.
7) The molten metal will be poured into preheated finger mould die.

Fig 1: Electrical furnace

C. Heat treatment process

The Aluminum composites were heat treated and tempered to T6 condition, i.e. the samples were heated at 530^{o}C for 3 hours and then immediately quenched in water at room temperature and finally were artificially aged in the furnace at 180^{o}C for 5 hours and then air cooled to room temperature.

III. EXPERIMENTAL DETAILS

A. Hardness Test

Hardness is the property of a material that enables it to resist plastic deformation, usually by penetration. However, the term hardness may also refer to resistance to bending, scratching, abrasion or cutting. Hardness is not an intrinsic material property dictated by precise definitions in terms of fundamental units of mass, length and time. A hardness property value is the result of a defined measurement procedure. This deformation may be in the form of scratching and mechanical indention or cutting. Indenters in the form of spheres and cones are frequently used.
Hardness of the material was found out on Brinell hardness testing machine. The testing machine is the most widely used method to determine hardness. Brinell hardness was carried out as follows:

1) The specimen or the area or location must be selected and polished so as to give a reliable indication of the properties of the material.
2) The specimen was placed on the anvil so that the surface is normal to the direction of applied load.
3) The anvil is raised by means of elevating screw.
4) Now, raise the anvil, the pointer comes to the red dot on the dial. [i.e., it indicates the application of minor load (10 kg) acting on the indenter. This is done to ensure the perfect seating and loading of the specimen].
5) Apply the major load (60 kg) with a 5 mm diameter steel ball indenter and wait for 30 seconds duration, to ensure the complete acting of the load on the specimen by the indenter.
6) Remove the load after 30 seconds, measure the indentation by using travelling microscope and find out the BHN using formula.
7) The indentations were taken at three points on each specimen. Figure 2 shows the hardness tester and the hardness specimen.

The BHN is calculated according to the formula given below

$$BHN=2P/ (\Pi D (D-\sqrt{(D^2-d^2)})$$

Where,
P (Load Applied) = 60 Kg
D (Dia Of Ball Indenter) = 5mm
d (Dia Of Indentation)

Fig 2: Brinell hardness testing setup

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B. *Wear test (Dry sliding wear)*

1) The figure 3 shows the Pin on Disc Sliding Wear testing apparatus. The disc is rotated by means of an electric motor and the loads of 1kg, 1.5kg and 2kg has been applied and the wear is calculated which is the measure of weight loss of the specimens.
2) The velocity of the disc has been set to 400 rpm and 800 rpm and the wear loss in micrometers of the pin has been tabulated for 10 minutes constant. The track diameter of rotation has been kept at 130 mm of the disc.
3) Weight loss was considered for wear analysis (i.e. the difference between the initial and final weight). Formulae used for finding weight loss and wear rate is as shown below

Weight loss (W_L) = Initial weight – Final weight = $W_1 - W_2$ grams

Fig 3: Pin on disc setup

C. *Microstructure examination*

The study of Microstructure forms important part of the experiment. Microstructure will help in characterization of composition structure and properties of the material. Steps involving in the preparation of specimen for microstructure examination are given below.

1) Sectioning: The specimen is prepared by sectioning for the required dimension by fixing to the hand wise and the cutting of the material by using a hack saw blade. The specimen was section using suitable abrasive wheel cutter. Sharp edges, burrs and any intervening deformed material was removed by rough grinding using an abrasive belt grinder.
2) Grinding: The surface is prepared for the microstructure by removing the irregularity. The surface is prepared by polishing the specimen for microstructure was carried out using 80, 120, 220, 400, 800, 1000, 1200, 2500 and 3000 grade water proof emery paper for a period of 5mins for each paper.
3) Polishing: The specimens were then polished by using diamond paste on a mescaline cloth.
4) Etching: Etching is a process of cleaning the top surface. Etching is carried out for a period of ten seconds. Samples were etched to reveal the grain structure using Keller's reagent. 100ml of Keller's reagent was prepared by adding HNO3 2.5ml, HCL 1.5ml, HF 1ml and H_2O 95ml, after etching samples were washed and dried thoroughly.

IV. RESULTS AND DISCUSSIONS

Comparison of before heat treated and after heat treated (HT) specimens with respect to as cast and varying percentage of zircon from 2 to 10% and with graphite 2% constant.

A. *Hardness test*

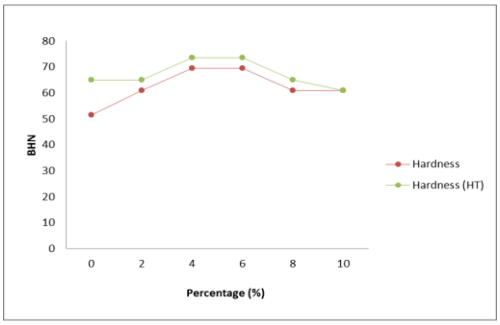

Figure: With 2% Graphite and 2-10% Zircon

The figure indicates that maximum value of BHN is observed in heat treated specimen compared with as casted specimen.

B. *Wear Test (400 rpm)*

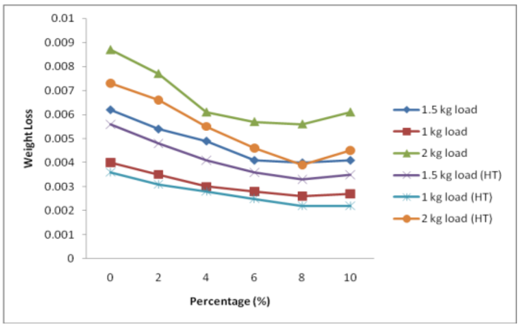

Figure: 2% Graphite and 2-10% Zircon at 400 rpm

The maximum wear rate is seen in the as cast specimen compared to heat treated alloys.

C. *Wear Test (800 rpm)*

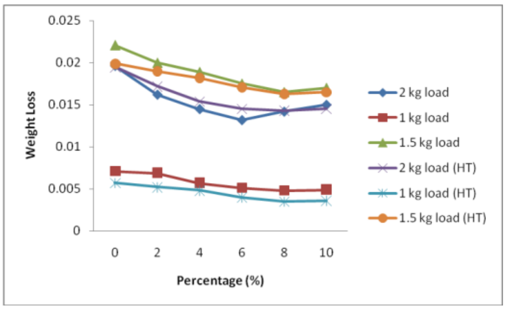

Figure: 2% Graphite and 2-10% Zircon at 800 rpm

The maximum wear rate is seen in the as cast specimen compared to heat treated alloys.

D. *Microstructure*

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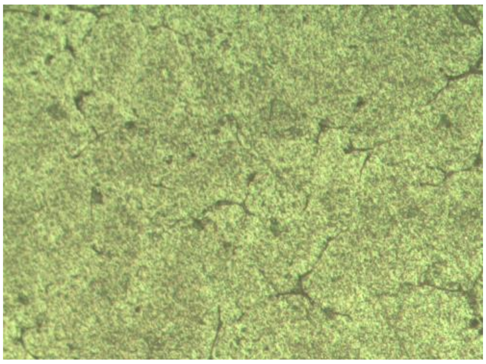
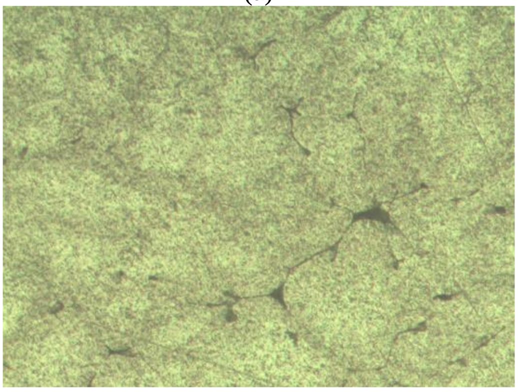
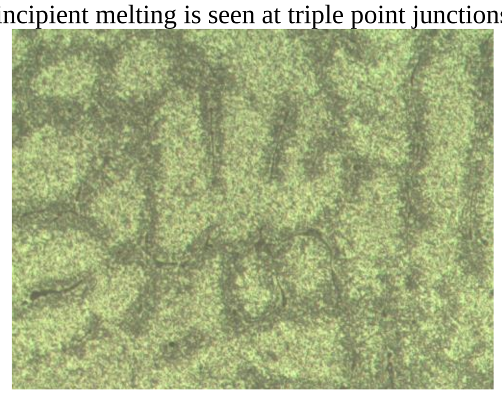


(a)



(b)

Figure: Microstructure of as cast Al6061 alloy. (a) Microstructure consists of fine grains of aluminium solid solution with a fine dispersion of intermetallic precipitates. (b) Microstructure consists of fine grains of aluminium solid solution with a fine dispersion of intermetallic precipitates. Some incipient melting is seen at triple point junctions.



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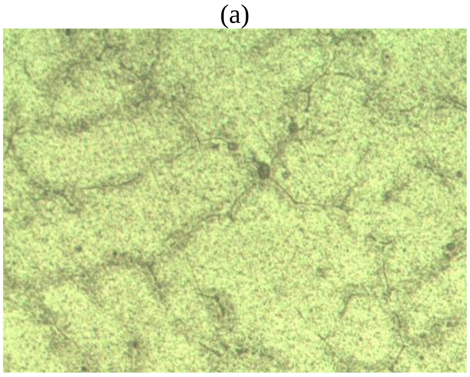
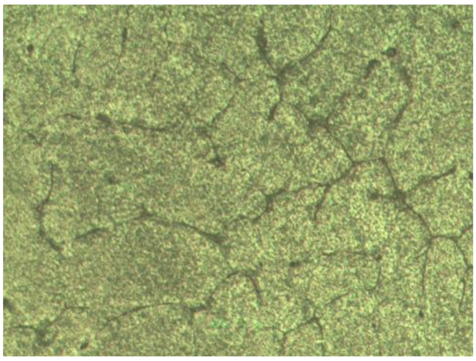
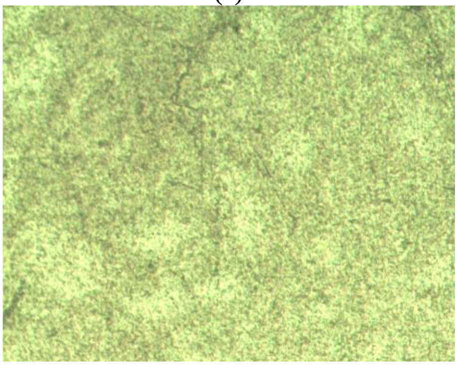


(b)

Figure: Microstructure of Al6061+2% Zircon sand+2% Graphite. (a) Microstructure consists of fine dendrites of aluminium solid solution. Some coring (micro-segregation) is seen. (b) Microstructure consists of fine dendrites of aluminium solid solution. Microsegregation is slightly reduced, through some remnance of coring (micro-segregation) is seen.

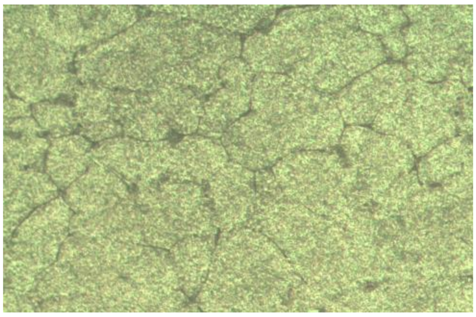


(a)



(b)

Figure: Microstructure of Al6061+4% Zircon sand+2% Graphite. (a) Microstructure consists of fine grains of aluminium solid solution. (b) Microstructure consists of alumnium solid solution. The structure is fairly homogeneous. Grain boundaries are barely revealed



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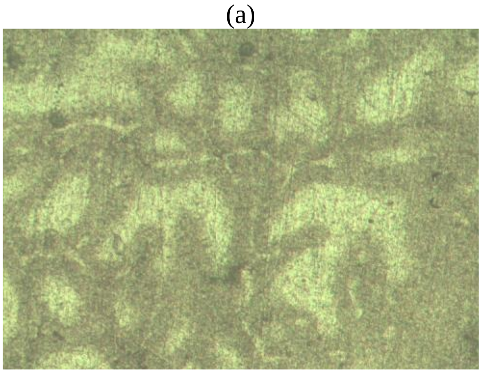

(b)

Figure: Microstructure of Al6061+6% Zircon sand+2% Graphite. (a) Microstructure consists of fine grains of aluminium solid solution. (b) Microstructure consists of fine grains of aluminium solid solution. Some coring (micro-segregation) is seen at the grain boundaries.

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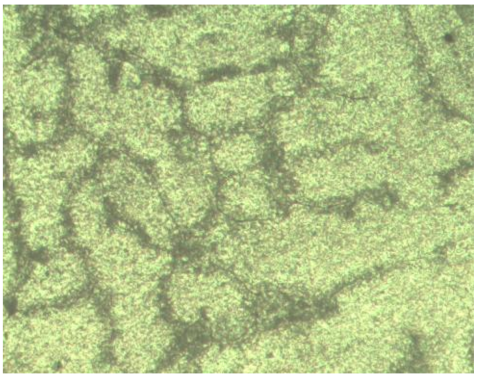

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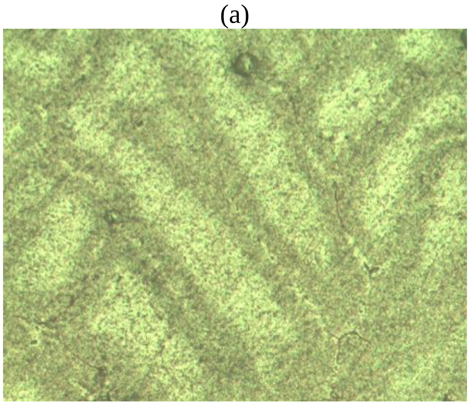
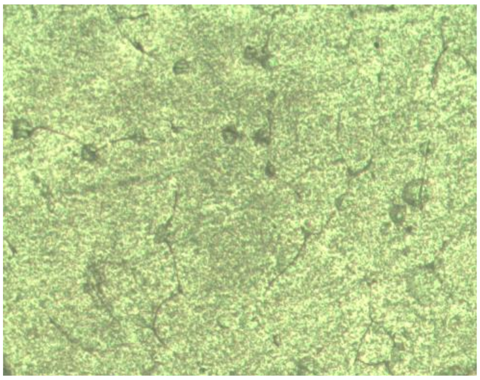
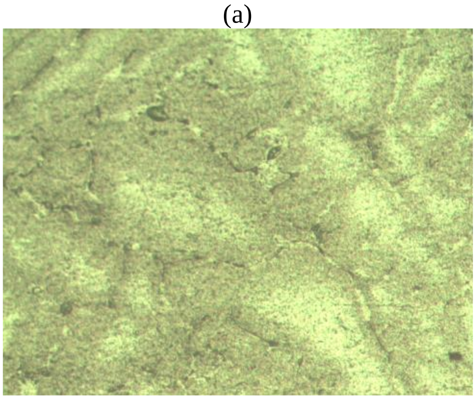


(b)

Figure: Microstructure of Al6061+8% Zircon sand+2% Graphite. (a) Microstructure consists of fine dendrites of aluminium solid solution. Some coring (micro-segregation) is seen. (b) Microstructure consists of fine dendrites of aluminium solid solution. Microsegregation is slightly reduced, through some remnance of coring (micro-segregation) is seen.



(a)



(b)

Figure: Microstructure of Al6061+10% Zircon sand+2% Graphite. (a) Microstructure consists of fine grains of aluminium solid solution. (b) Some coring (micro-segregation) is seen at the grain boundaries. (b) Microstructure consists of fine grains of aluminium solid solution. Some coring (micro-segregation) is seen at the grain boundaries.

V. CONCLUSION

A. Hardness properties

Hardness gets improved with addition of zircon and graphite and along with heat treatment. The maximum hardness value of 73.5 BHN is observed in 4 and 6% zircon with constant addition of 2% graphite. An increase of 13% is seen when compared with heat treated as cast condition. This indicates that addition of reinforcements has an influence on the mechanical properties of the Al6061 alloy.

B. Wear behavior

There was a considerable improvement in the resistance for wear with addition of zircon and graphite and along with and T6 heat treatment. There was an average of 35% improvement in the resistance for wear at 400 rpm. There was an average of 28% to 30% improvement in the resistance for wear at 800 rpm.

When compared to untreated composites, the heat treated composites showed reasonable improvement in their properties.

C. Microstructure

In the as-cast specimen coarse acicular intermetallic particles are seen and it is distributed along primary aluminum dendrite boundaries. The grain structure gets reduced and a closed structure is observed when the alloy is subjected to combination of addition of different percentage of zircon and graphite and with T6 Heat treatment.

VI. ACKNOWLEDGMENT

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