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Fabrication and Characterization of Metal Matrix Composites using Al6063, Graphite and Cenosphere

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Abstract

The advantageous properties like wear, hardness, toughness, etc has bought a great fame to the composite materials as a major engineering material. Aluminium has been used in various applications of automobile and aerospace industries since ages, Hence Aluminium of different grades are been used in the manufacturing of many metal matrix composites with varying composition of the reinforcement. Focusing on the various advantages and applications of Aluminum this project uses Aluminium 6063 as a matrix material with Graphite and Cenosphere as the reinforcement materials. Cenosphere being light weighted material due to its less density stir casting method has been used in casting of composites. Machining of the prepared composite specimens is done according to the ASTM standards. For obtaining the better mechanical properties the machined composite material are subjected to the hardening process using the method of quenching. Three different quenching techniques like air, water and ice quenching are been adopted in the project. Testing like compression, shear, wear, and hardness are carried out for each set of specimens in order to know the mechanical properties of the prepared composite material. In order to know the uniform distribution of the reinforcements test like SEM is carried out. Finally all the calculated properties are studied and tabulated.

Introduction

The failure of homogeneous materials to withstand the stresses in different engineering applications and the experimentation with material properties in order to achieve materials with high strengths and enhanced properties lead to the discovery of an epic idea of mixing of materials. The materials to be added during the mixing process are selected based on the properties of materials and type of the parent material. The materials prepared by this technique came to be known as composite materials.

Aluminium has been the centre of attraction in metal matrix composites because of the unique combination of its low density, high strength, good mechanical properties, good corrosion resistance and good machinability properties. Aluminium 6063 is one of the most widely used materials in the aerospace and automobile industries due to its excellent mechanical properties and less density. Hence Al6063 has been used as basic matrix material. Graphite has been used as a primary reinforcement to increase the wear resistance of the prepared composite. And also due to excellent toughness, Graphite is being used as one of the majorly used reinforcement to increase the strength of the composite. The excellent heat conducting property of graphite makes it a perfect reinforcement material for increasing the thermal property of the composite material. But using graphite above 1% usually declines the mechanical properties. Hence to compensate the reduction in mechanical properties, a second reinforcement cenosphere has been added.

Experimental

The flowchart in Fig. 1 depicts the methodology followed. Using stir casting technique the composite materials are prepared. Graphite used as a primary reinforcement is kept constant to 4% and the cenosphere which is added as second reinforcement is varied as 2%, 4%, and 6% respectively. Hence four cases of composites are studied as shown below.

A - Casted Aluminium 6063.
B - Al6063 + 4% Graphite + 6% Cenosphere.
C - Al6063 + 4% Graphite + 4% Cenosphere.
D - Al6063 + 4% Graphite + 2% Cenosphere.

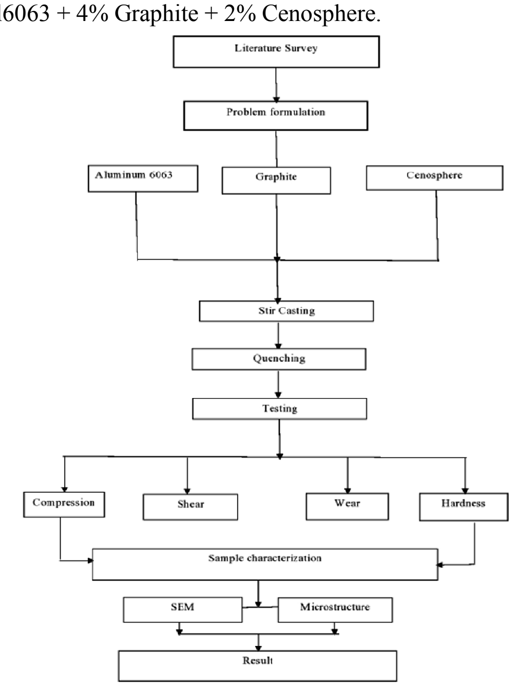

Figure 1: Methodology

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Stir casting technique

Cenosphere due to its less density property requires stir casting technique for its uniform distribution in the prepared composite materials. Al6063 is melted by keeping the temperature of the electric furnace at 680°C. The weighed reinforcements are preheated and added in the molten aluminium. Now a stirrer is rotated at about 450 rpm to mix the poured reinforcements in the matrix material. The die is preheated before pouring in order to avoid casting defects. Fig. 2 illustrates the steps involved in stir casting. In the Fig. 2 we can see the melting up of the Al6063 and stirring of the added reinforcements in the molten metal. The subsequent images of Fig. 2 illustrate the slag removal and pouring the molten metal into the dies.

Figure 2: Steps in stir casting

Compression Test

For compression test ASTM standard E9-89a is selected. The most common specimen for ASTM E9-89a has a cylindrical cross section. The composite specimen selected for the compression test is shown in Fig. 3. In order to avoid buckling l/d ratio is maintained less than 1. L= Length (18 mm); D= Diameter (17mm).

Figure 3: Compression test specimen

Compression test is the capacity of a material or structure to withstand loads tending to reduce size. The compression test is carried on universal testing machine.

Hardness test

Hardness is a measure of how resistant solid matter is to various kinds of permanent shape change when a compressive force is applied.

Figure 4: Hardness test

Brinell hardness test is carried out in order to know the hardness number of the composite specimens. Fig. 4 shows the hardness test being carried out where using the indenter the indentation on the surface of the specimen is done. Later the diameter of the indentation is measured and using the formula brinell hardness number will be calculated.

Wear test

The wear test is carried out on disc on pinion setup. The specimen is a cylindrical section of 8mm diameter and 50mm length. The prepared specimen for wear test has been shown in Fig 5.

Figure 5: Wear test specimen

Shear test

Double shear test is conducted on the universal testing machine. Fig 6 shows the test on UTM where continuous load is being applied unless the specimen breaks due to shear stresses. The peak load at which specimen breaks are noted for the calculation of maximum shear strength of the specimen.

Diameter of the specimen- 10mm

$$\text{Area of the specimen} = \frac{\pi}{4} d^2$$

$$= \frac{\pi}{4} * (10)^2 = 78.53$$

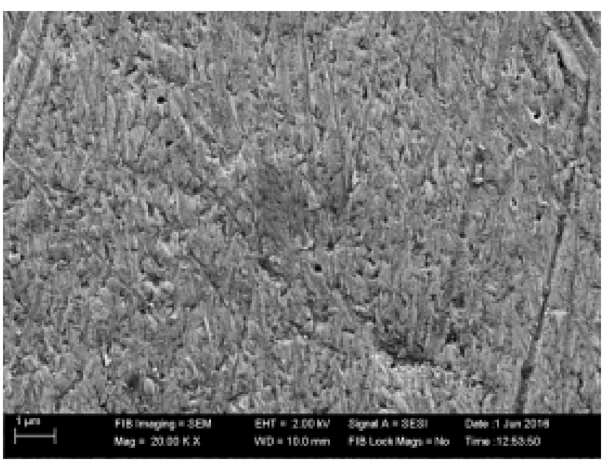
$$\text{Maximum shear strength} = \frac{Peak\ load}{2A}$$

Figure 6: Shear test on UTM

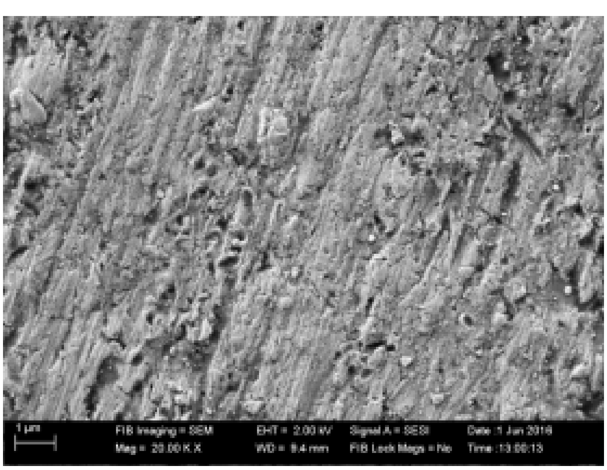
Results and Discussion

SEM Characterization

For the characterization of the prepared composite materials Scanning electron microscope test is done in order to confirm the uniform distribution of the reinforcements added. For each prepared type of composite specimen the scanning electron microscope test has been carried out in 20000X resolution. Figure 7 (a-d) depicts the SEM images for each case of prepared composite specimen.



(a)



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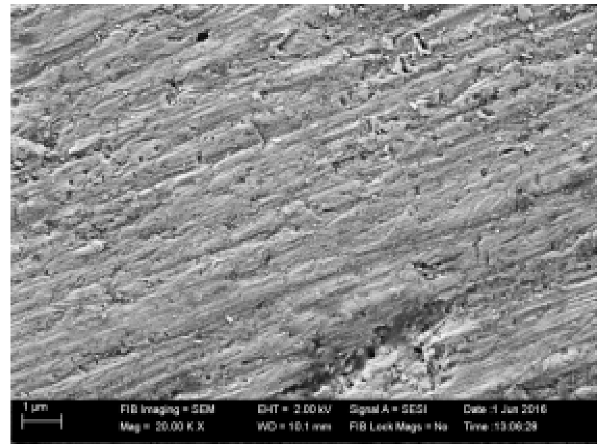

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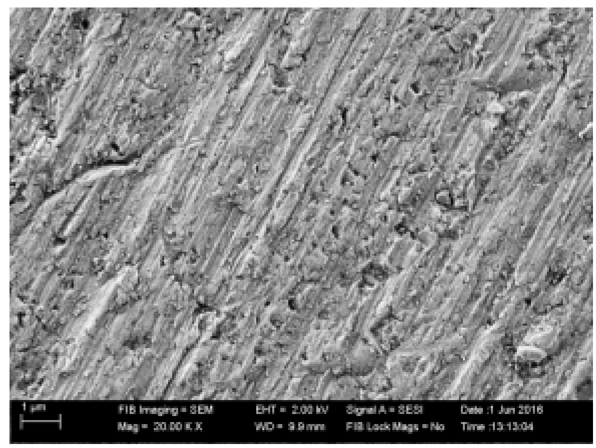

(d)

Figure 7: SEM of (a) Al6063; (b) Al6063+ 4%G+ 6%C; (c) Al6063+ 4%G+ 4%C; (d) Al6063 +4% G+ 2%C

Compression test results

Table1: Compression test results

Type of quenching	Specimen A Ultimate stress (in kN/mm^2)	Specimen B Ultimate stress (in kN/mm^2)	Specimen C Ultimate stress (in kN/mm^2)	Specimen D Ultimate stress (in kN/mm^2)
Ascasted	0.356	0.473	0.416	0.626
Water.	0.683	0.533	0.542	0.571
Ice.	0.553	0.421	0.410	0.435
Air.	0.4365	0.4435	0.592	0.691

The maximum compressive strength is 0.691 N/mm^2 obtained by the air quenched specimen D i.e. 4% graphite and 2% cenosphere.

Brinell hardness test results

Table 2: Brinell hardness test results

	A (in N/mm^2)	B (in N/mm^2)	C (in N/mm^2)	D (in N/mm^2)
Ascasted.	50.41	41.92	59.6	47.75
Ice quenched.	43.85	65.62	76.25	72.54
Water quenched.	35.72	41.92	47.67	41.92
Air quenched.	47.58	45.58	49.68	43.65

The specimen C made up of 4% graphite and 4% cenosphere showed the maximum hardness. And of all the specimens, the specimens with ice quenching showed an increase in the hardness property.

Wear test results

Table 3: Wear test results at 1kg load

Type of quenching.	Specimens			
	A	B	C	D
Ascasted	$5.292*10^{-9}$	$1.71*10^{-8}$	$5.25*10^{-8}$	$2.14*10^{-7}$
Water	$1.12*10^{-8}$	$2.07*10^{-8}$	$1.43*10^{-8}$	$3.62*10^{-8}$
Air	$1.08*10^{-8}$	$4.95*10^{-9}$	$1.79*10^{-8}$	$1.97*10^{-8}$
Ice	$6.59*10^{-8}$	$1.76*10^{-8}$	$5.14*10^{-8}$	$4.52*10^{-8}$

Specimen D (4% graphite and 2% cenosphere) showed the maximum wear rate in the unquenched form i.e. upto 2.14 X 10^{-7}. Also the ice, water, and air quenching process have decreased the wear rate when compared to the unquenched specimens.

Shear test results

Table 4: Shear test results

	A (N/mm^2)	B (N/mm^2)	C (N/mm^2)	D (N/mm^2)
Ascasted	123	117.085	113.135	111.61
Ice quenched	105.69	155.55	119.69	118.29
Water quenched	113.51	124.15	114.28	112.313
Air quenched	108.49	120.10	105.30	117

The maximum shear strength is $155N/mm^2$ seen in specimen B with the composition 4% graphite and 6% cenosphere.

Conclusions

The mechanical properties such as compression, hardness, wear and shear are characterized and studied experimentally, the key followings of the present work are as follows-

1. Fabrication of metal matrix composites with graphite and cenosphere as reinforcement into the Al 6063 matrix has been done successfully.
2. The specimen C made up of 4% graphite and 4% cenosphere showed the maximum hardness. And of all the specimens, the specimens with ice quenching showed an increase in the hardness property.
3. The maximum shear strength is seen in specimen B with the composition 4% graphite and 6% cenosphere.
4. Specimen D (4% graphite and 2% cenosphere) showed the maximum wear rate in the unquenched form i.e. upto 2.14 X 10^{-7}. Also the ice, water, and air quenching process have decreased the wear rate when compared to the unquenched specimens.
5. The maximum compressive strength is obtained by the air quenched specimen D i.e. 4% graphite and 2% cenosphere.

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