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Fabrication of LM6/B_4C/Gr Hybrid Aluminium Metal Matrix Composite

Sarath S Nair
M. Tech. Student
ICET, Muvattupuzha, India

Faisal M H
Assistant Professor
ICET, Muvattupuzha, India

Abstract

This work deals with fabricating or producing aluminum based metal matrix composite and then studying its mechanical properties such as tensile strength, hardness and wear behavior of produced test specimen. In this conditions Aluminum Alloy (LM6) –Boron Carbide and graphite metal matrix composite were fabricated by liquid metallurgy technique with different particulate weight fraction (Gr 2% and B4C 3 %, 5%). Mechanical properties such as hardness test and compression strength are determined and tribological behavior of the composite is studied using wear test. The composite were characterized by Hardness and tensile strength tests. With the increase the amount of boron carbide, the density of the composite decreased whereas the hardness is increased. The tensile strength of the composite was increased with increase in the weight percentage of the boron carbide and Gr in the composite.
Keywords: Hybrid Metal Matrix Composite, Tribological, LM6, Boron Carbide, Graphite

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I. INTRODUCTION

Aluminum is the familiar matrix for the metal matrix composites (MMCs). The Al alloys are quite useful due to their low density, good corrosion resistance, high Thermal and electrical conductivity, and high damping capacity. They offer a large variety of mechanical properties depending on the chemical composition of the Al-matrix. There are two principal classifications, namely casting alloys and wrought alloys. About 85% of aluminum is used for wrought products. Aluminum alloys are used extensively in aircraft due to their high strength-to-weight ratio. On the other hand, pure aluminum metal is much too soft for such uses, and it does not have the high tensile strength that is needed for airplanes and helicopters. Copper is one of the best alloying elements since the beginning of the aluminum metal matrix composites. In the cast alloys the basic structures consists of dentritic in nature and possesses aluminum solid solution, with a variety of particles at the grain boundaries or inter dendritic spaces, forming brittle components with eutectics in nature. Most alloying elements can improve the modulus of elasticity of aluminum, but the increase is not remarkable for the aluminum-copper alloys. The modulus of elasticity at room temperature is of the order of 70-75 G Pa and practically the same in tension and in compression. It changes regularly with temperature from a value of 76-78 G Pa at 70 K to a value of the order of 60 G Pa at 500 K. The Poisson ratio is of the order of 0.32-0.34. The Poisson ratio increases with increasing temperature. Many of the cast alloys and of the aluminum-copper-nickel alloys are used for high-temperature applications, where creep resistance is important[1].

Aluminum metal matrix composites provide both light weight, courtesy of the aluminum matrix, and enhanced strength, stiffness and wear resistance through the reinforcement which is added to produce the composite, although this is achieved at the expense of ductility. While commonly used reinforcements include SiC and Al_2O_3, the more recently used B_4C is both the lightest and the hardest of the three, making it a viable choice with respect to the reduced weight criterion. Additionally, the capacity of boron for high neutron capture has created much interest in using B_4C reinforced aluminum composites in strategic applications. The enhanced elevated-temperature strength and favorable neutron absorption characteristics of Al-B_4C composites are strong points which justify investigating their suitability for use in both current and emerging applications. Aluminum/graphite composites have been used as self-lubricating materials due to the superior lubricating effect of graphite during sliding. The greatest challenge in introducing aluminum graphite composites in industrial components is the negative effect of graphite on mechanical properties of composites[2].

II. SCOPE AND OBJECTIVE

A. Scope

Aluminum/graphite composites have been used as self-lubricating materials due to the superior lubricating effect of graphite during sliding. The greatest challenge in introducing aluminum graphite composites in industrial components is the negative effect of graphite on mechanical properties of composites. There are many approaches to reducing the damaging effect of graphite particles on the deterioration of mechanical properties. For example, using hybrid aluminum metal matrix composites containing ceramic particles and graphite particles shows better tribological behavior compared to aluminum alloys or Al/Gr composites. In these hybrid composites, graphite acts as a solid lubricant and ceramic particles have load bearing ability, which leads to decrease in wear rate.

B. Objectives

- Fabrication of a hybrid aluminium metal matrix composite to improve the characteristics of self lubricating composites.
- Evaluation of wear characteristics and other mechanical properties of hybrid aluminium metal matrix composite.

III. METHODOLOGY

A. Literature Review

1) Procurement of Materials
- LM6, boron carbide, graphite

2) Casting of hybrid aluminium composite

3) Specimen Preparation
- Specimens were prepared with desired composition.
- They are machined to the required dimensions.

4) Tests
- To determine mechanical properties tensile test and hardness test were done.
- Wear is determined using pin on disc testing.

IV. MATERIALS AND METHODOLOGY

A. LM 6

LM6 alloy was used in this study

Table – 1
Properties of LM6

Density(Kg/m^3)	*2680*
Elastic Modulus(Gpa)	*71*
Poisons Ratio	*0.33*

B. Boron Carbide

Table – 2
Properties of Boron Carbide

Density(Kg/m^3)	*2550*
Elastic Modulus(Gpa)	*460*
Poisons Ratio	*0.17*
Melting Point(^oC)	*2763*
Thermal conductivity(W/mk)	*90*

C. Graphite

Table – 3
Properties of Graphite

Density(Kg/m^3)	*1950*
Elastic Modulus(Gpa)	*12*
Poisons Ratio	*0.21*
Melting Point(^oC)	*3800*
Thermal conductivity(W/mk)	*90*

D. Stir Casting

This is the layout of the stir casting apparatus. It consist of cylindrical shaped graphite crucible is used for fabrication of AMCs, as it withstands high temperature which is much more than required temperature [680°C].Along that graphite will not react with aluminum at these temperature. This crucible is placed in muffle which is made up of high ceramic alumina.

Stir casting process starts with placing empty crucible in the muffle. At first heater temperature is set to 500°C and then it is gradually increased up to 900°C.High temperature of the muffle helps to melt aluminum alloy quickly, reduces oxidation level, enhance the wetability of the reinforcement particles in the matrix metal. Aluminum alloy LM6 is used as matrix material. Required quantity of aluminum alloy is cut from the raw material which is in the form of rectangular pieces. Aluminum alloy is cleaned to remove dust particles, weighed and then poured in the crucible for melting. Powder of boron carbide (B_4C) and graphite are used as reinforcement [3].

Fig. 1: Stir Casting Setup

It consists of two processes:

1) *Process 1: (LM 6, B_4C 3% AND GR 2%): sample 1*
   - Total 500 g
   - 16g of B_4C
   - 10g of Gr
2) *Process 2: (LM 6, B_4C 5% AND GR 2%): sample 2*
   - Total 500 g
   - 26g of B_4C
   - 10g of Gr

Fig. 2: Casting

Fig. 3: Casted Specimens

Fig. 4: Test Specimens

V. RESULTS AND DISCUSSIONS

Mechanical testing plays an important role in evaluating fundamental properties of engineering materials as well as in developing new materials and in controlling the quality of materials for use in design and construction. If a material is to be used as part of an engineering structure that will be subjected to a load, it is important to know that the material is strong enough and rigid enough to withstand the loads that it will experience in service. As a result engineers have developed a number of experimental techniques for mechanical testing of engineering materials subjected to tension, compression, bending or torsion loading.

A. Tensile Test

1) Sample 1

a) Output Data

- Yield stress : 130 N/mm^2
- Tensile strength : 168 N/mm^2
- Elongation : 2.9%

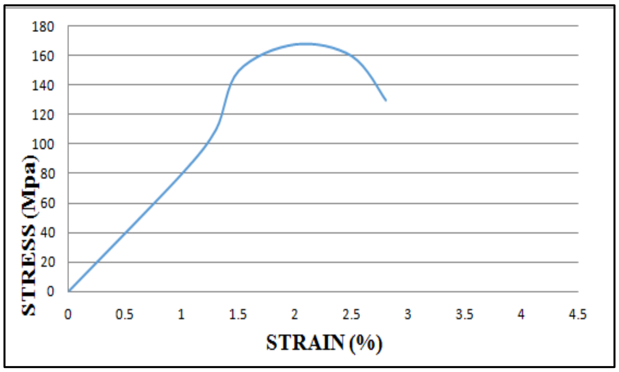

Fig. 5: Sample 1 Output Graph

2) Sample 2

a) Output Data

- Yield stress : 140 N/mm^2
- Tensile strength : 175 N/mm^2
- Elongation : 2.2%

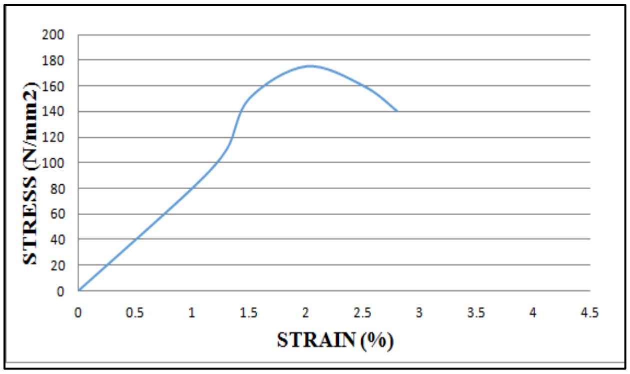

Fig. 6: Sample 2 Output Graph

B. Hardness Test

Rock well hardness test was done according to ASTM E18:2014. Specimen size is 22 mm diameter and 27 mm length.

Table – 4
Hardness Test

Sl. No	*Sample Id*	*Observed values, HRB*			*Average, HRB*
		1	*2*	*3*	
1	*Sample 1*	*80*	*79*	*80*	*80*
2	*Sample 2*	*93*	*92*	*93*	*93*

C. Wear Test

As outlined by ASTM G99-04, pin-on-disk testing consists of a rotating disk in contact with a fixed pin with a spherical top. A schematic is shown below.

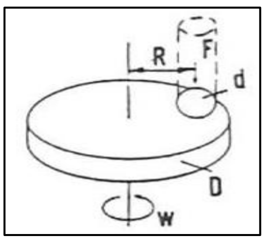

Fig. 7: Layout of Wear Test

F: Applied normal load
R: Radius of the wear track that is produced
d: Diameter of the spherical top of the pin
D: Diameter of the disk
w: Rotational speed

Table - 5
Specifications

Parameter	*Units*
Pin size	*3, 6, 10 & 12 mm diameter*
Disc Size	*165 x 8 mm*
Disc Rotation Speed	*0 – 2950 RPM*
Wear Track dia. Mean	*50 – 100 mm*
Load	*1 – 200 N (any steps possible)*
Sliding Speed Range	*0 to 10 m/s*
Frictional Force	*0 – 200 N*
Wear Measurement	*0 – 2000 micrometer (1 µm LC)*
Temperature	*ambient to 300 deg C*
Power	*230V, 50 Hz S phase*

Table – 6
Wear Test

Sl. No.	*Material*	*Wear in microns*	*COF*	*Frictional Force (Average) N*
1	*Sample 1*	*117*	*0.4586*	*9*
2	*Sample 2*	*105*	*0.3807*	*7.5*

- Load : 20 n
- RPM : 300
- Sliding Velocity : 1.885 m/s
- Time Duration : 20 mins

VI. CONCLUSIONS

1) Specimens were prepared with varying percentages of B_4C.
2) AMC's are far much superior to aluminium alloys due to enhanced properties and ability to possess functional properties by variety of reinforcements.
3) With the stir casting technique setup attached with mechanical stirrer assembly, it is possible to develop MMC with uniform distribution of reinforced particulates on aluminum matrix.
4) With the increase the amount of boron carbide, the density of the composite decreased whereas the hardness is increased.
5) The tensile strength of the composite was increased with increase in the weight percentage of the boron carbide and Gr in the composite.

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