ISSN: 2348 - 2117

International Journal of Engineering Technology and Computer Research (IJETCR)
Available Online at www.ijetcr.org
Volume 3; Issue 5; September-October-2015; Page No. 113-117

Study on the Influence of Graphite on Mechanical Properties of Al6061-hBN-Gr Hybrid MMC's

Lokesh K M[1], Mr. B M Nagesh[2], Mr. Nagesh D[3]

[1]IV Sem. M. Tech. Dept of Mechanical Engg, Sir M VIT,

E-mail: klokeshm56@gmail.com

[2] Associate Professor, Dept of Mechanical Engg, Sir M VIT,

[3] Assistant Professor, Dept of Mechanical Engg, SJCIT,

Abstract

This paper deals with the fabrication and mechanical investigation of Aluminium 6061, hexa Boron Nitride (hBN), and Graphite (Gr) hybrid metal matrix composites. Al6061 is the matrix metal having properties like good toughness, excellent corrosion resistance, good weldability and brazability. Boron nitride has excellent thermal and chemical stability and also high hardness. Graphite is a self-lubricating reinforcement that enhances the antifriction properties. Here, the fabrication is done by stir casting which involves mixing of the required quantities of reinforcements into stirred molten Al6061. After solidification, the specimens are prepared as per ASTM standards to determine various mechanical properties like tensile, density and hardness. The microstructure of the composite is observed by optical microscope (OM).

Keywords: Aluminium 6061, hexa Boron Nitride, Graphite, Stir casting, Mechanical properties.

1. INTRODUCTION

The use of aluminium metal matrix composites has increased in the recent years replacing many conventional metals like steel, iron etc. in the fields of automobile, aerospace, marine, high speed trains etc. because of their superior properties such as low density, high wear resistance, stiffness, reliability, toughness, good combination of strength to weight ratio. Improvement of mechanical properties of aluminium can be achieved by reinforcing aluminium with proper material and through creating composite material. The most effective improvement of these properties is through creating hybrid composite with two or more reinforcements. By adding boron nitride mechanical properties of matrix are changed, but in that case problem of machinability occurs. To improve machinability, graphite is added.

Ramesh et al. [1] conducted a "comparative study of the mechanical properties of Al6061-Albite and Al6061-Gr composites" by stir casting technique by varying the reinforcements from 0% to 4% by wt. He subjected the composites to a list of tests and concluded the following: the ultimate tensile strength (UTS), Young's modulus and hardness increased with the increase of albite particles but with reduced ductility and also there was only a marginal increase in its compressive strength. But with the increase of graphite particles there was reduction in its hardness, ductility, UTS, compressive strength and Young's modulus.

Muthazhagn et al. [2] studiedthe "mechanical properties of Al6061-B_4C-Graphite hybrid MMC's" by varying the percentage of both B_4C and Graphite by 5%,10% and 15% and concluded that the hardness of the composite is increased with increasing of B_4C particles in Al6061 matrix. The hardness of the composite is decreased with increasing of graphite particles in aluminium matrix. Addition of B_4C and Graphite decreased the tensile strength of the composite.

A AnandhaMoorthy et al. [3] studied the "tribological characteristics of AA2218-hBN-fly ash composites" by maintaining the percentage of hBN at 4% and varying the percentage of fly ash by 5,10 and 15 wt %. His studies concluded that density of the composite was reduced and the accumulation of both fly ash and hBN particles into the matrix improved the wear resistance of the aluminium composite.

DrRajanna S et al. [4] conducted "Evaluation of mechanical response of graphite reinforced metal matrix composite" by vortex method. The graphite content was varied from 0% to 3% in steps of 0.5% by wt. It was seen that the hardness decreased by about 24% when the graphite content was increased from 0% to 3% whereas

Corresponding author: Lokesh K M

the ultimate tensile strength increased with increasing the graphite content.

In this work a hybrid composite of Al6061-hexa Boron Nitride-Graphite is developed and the physical and mechanical properties of the composites are evaluated and compared with the physical and mechanical properties of the un-reinforced Al6061 alloy. Al6061 is selected as the base metal matrix and hexa Boron Nitride (hBN) of 7-11 µm and Graphite (Gr) of 260µm are selected as the reinforcements. The hexa Boron Nitride is maintained constant at 2 % weight for all the compositions and the Graphite is varied from 2 % weight to 6 % weight in the increments of 2 % weight.

2. EXPERIMENTAL DETAILS

2.1 Materials

In this work for preparing metal matrix composite, aluminum 6061 (Al6061) is used as base material. Hexa Boron Nitride and Graphite in the powder form are used as the reinforcements. Aluminum alloy is cut into small ingots so that it can be easily placed in the crucible for melting.

2.1.1 Aluminum 6061

One of the most popular matrix materials that are used in case of metal matrix composites is Al6061. Because of good corrosion resistance, good electrical and thermal conductivity, low density, good mach inability etc Al6061 is quiet attractive. Many mechanical properties of this alloy can be enhanced when it is reinforced by other particles. The common reinforcements used with this alloy are aluminum oxide, silicon carbide, silicon dioxide, graphite, boron nitride, boron carbide etc.

2.1.2 Boron Nitride (hBN)

Boron nitride has excellent thermal and chemical stability and also high hardness. The particle size of hexa boron nitride used in this study is 7-11 microns. The grade of hexa boron nitride used is HCV grade. HCV grade is a basic grade of boron nitride and this serves as a starting block for the production of many advanced materials.

2.1.3 Graphite (Gr)

Graphite is a self-lubricating reinforcement that enhances the antifriction properties due to the graphite's lamellar structure. The addition of graphite to the matrix improves the machinability of the composite. The particle size of graphite used in this study is 260 microns.

2.2 Composite Preparation

Stir casting method is used for the preparation of composite. In this process the Al6061 bars are cut into small ingots using a chisel and hammer. These ingots are placed in a clay graphite crucible and the crucible is kept in the electrical resistance furnace. The ingots are melted for 5 to 6 hours at a temperature of 800 ºC. The gaseous impurities present in the molten metal that would cause porosity in the castings are liberated by the addition of degassing tablet (hexachloro ethane) into the molten metal and the slag is removed from the molten metal. The Gr and hBN particles are pre-heated at a temperature of 400 ºC for about one hour to increase the surface reaction. These pre-heated particles are then added into the melt and stirred continuously in order to achieve uniform distribution of particles in the matrix. The size of the graphite and hexa boron nitride particles used is 260 microns and 7-11 microns respectively. Magnesium of 0.5 % weight was added into the melt in order to reduce the non-wetting behavior of the hBN particles that would cause low interfacial bonding with the matrix.After the mixing of the reinforcements with the matrix, the crucible is taken out of the furnace and the molten metal is poured into the metal mould and allowed to solidify. After the solidification, the casted specimen is removed from the mould.

Composition A = Al6061-2%hBN-2%Gr
Composition B = Al6061-2%hBN-4%Gr
Composition C = Al6061-2%hBN-6%Gr

2.3 Testing of composites

For the micro structural analysis, optical microscope was used and the specimens were polished by different grades of emery paper, alumina paste and diamond paste and etched with the Keller's reagent. The density test was conducted by water displacement method to find the densities of different composition and the base metal. Brinell hardness test was conducted to determine the hardness of the composites and base metal. The tensile test was conducted on a Universal Testing Machine (UTM) to determine the tensile strength and the percentage elongation. The specimens were prepared as per ASTM E8 standard for tensile test.

3. RESULTS AND DISCUSSION

3.1 Micro structural Study

The study of microstructure helps in the analysis of the distribution of distinct phases in the Al6061 metal matrix phase. The microstructure was observed by using optical microscope.

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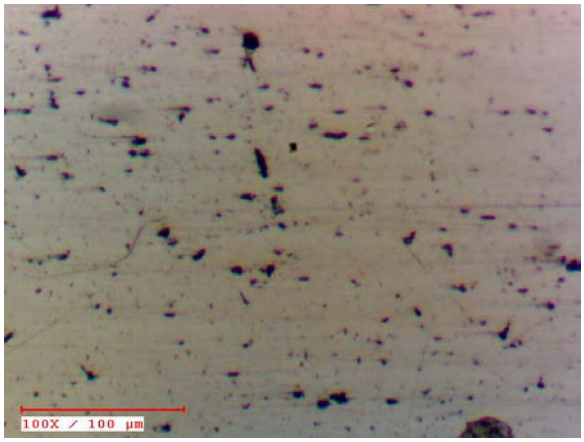

Figure 3.1: Microstructure of Al6061

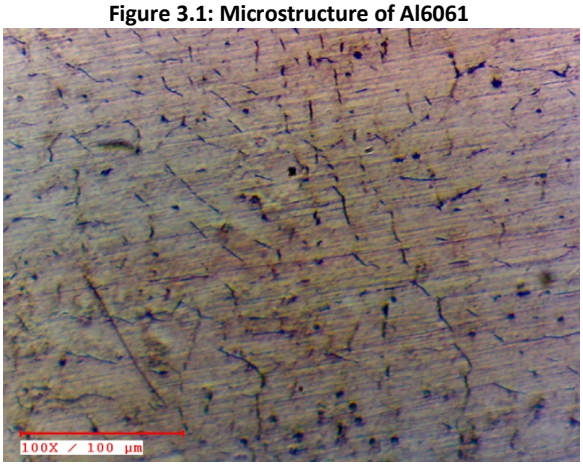

Figure 3.2: Microstructure of Al6061-2%hBN-2%Gr

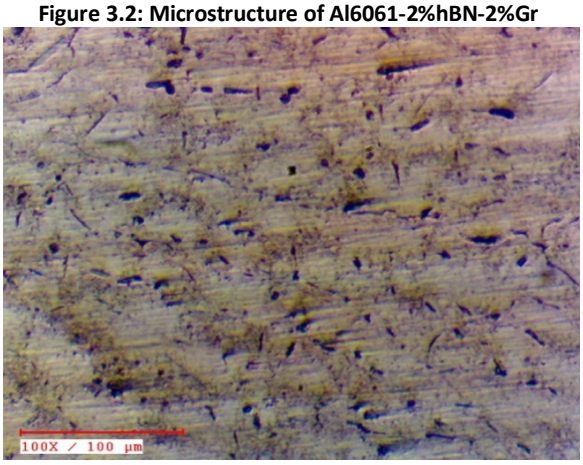

Figure 3.3: Microstructure of Al6061-2%hBN-4%Gr

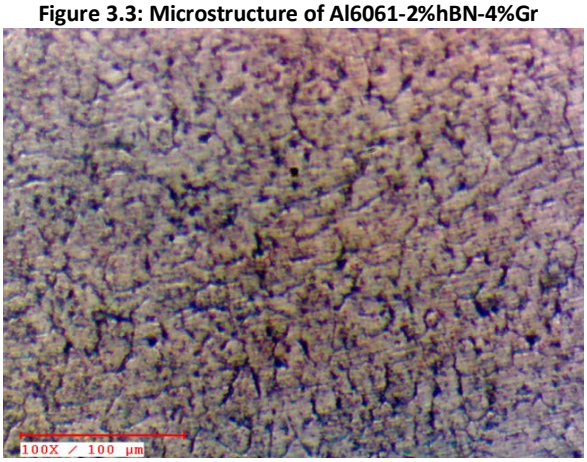

Figure 3.4: Microstructure of Al6061-2%hBN-6%Gr

The micro structural study reveals that there was uniform distribution of the hBN and Gr particles in Al6061 matrix. It was also found that the addition of graphite particles upto 6 % weight was accepted by the Al6061 matrix and porous sites were also minimum in the composites.

3.2 Density Results

The density test was conducted by water displacement method and the results are shown in table 2 and figure 1.The density of the composites was found to decrease with the increase in the % weight of graphite. The density of the Composition Awas more compared to that of the base metal. The density of Composition Bwas also found to be more than the base metal but was very nearer to the value of the base metal. There was a significant decrease in the density of Composition Ccompared to that of the base metal. This may be due to the presence of low density reinforcements in the Al6061 matrix.

Table 3.1: Density Test Results

Composition	Density (g/cc)
Al6061	2.69
Composition A	2.82
Composition B	2.71
CompositionC	2.57

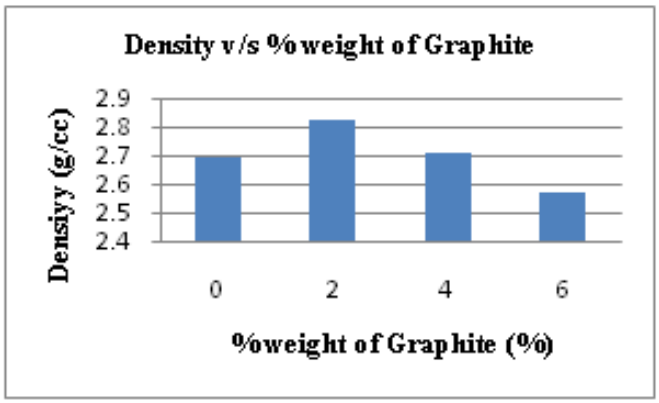

Figure 3.1: Graph of Density v/s % weight of Graphite particles

3.3 Hardness Results

The hardness test is conducted by Brinell hardness tester by applying a load of 1 kg force on the test specimens for about 10 seconds. The hardness of the composites was found to be decreased with increase in the % weight of the graphite but the hardness of the composites was more compared to that of the base metal. This may be because when a hard reinforcement like boron nitride is added it decreases the ductility thereby increasing the hardness. But the reduction in the hardness value of the various compositions may be due to the soft nature of the graphite.

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Table 3.2: Hardness Test Results

Composition	BHN
Al6061	49.59
Composition A	66.77
Composition B	61.99
Composition C	56.42

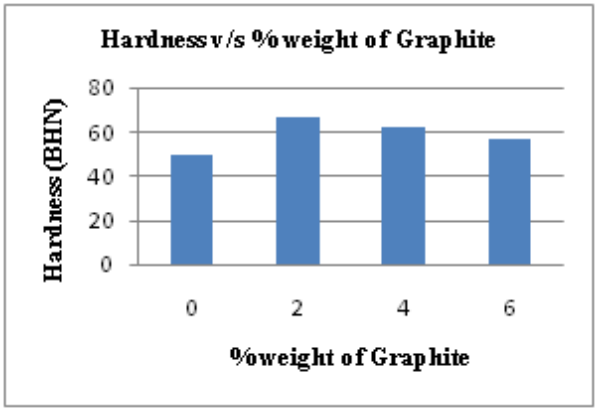

Figure 3.2: Graph of Hardness v/s % weight of Graphite particles

3.4 Tensile Results

The tensile tests are conducted on a computerized UTM which has a capacity of 100 KN. The ultimate tensile strength (UTS) was found to increase with increase in graphite content and the UTS of the composites was also more compared to that of the base metal because of the presence of reinforcements which take up the load. The percentage elongation of the composites also increased but composition A and B possess less percentage of elongation than that of the base metal because of the reduction in the ductility of the composite by the addition of boron nitride whereas the percentage elongation was found to be more for composition C than the base metal because of the increased % weight of the soft natured graphite.

Table 3.3: UTS and percentage elongation of various compositions and base metal

Composition	UTS (MPa)	Percentage of elongation (%)
Al6061	109.29	8.75
Composition A	134.72	3.98
Composition B	136.76	7.14
Composition C	150.79	10.75

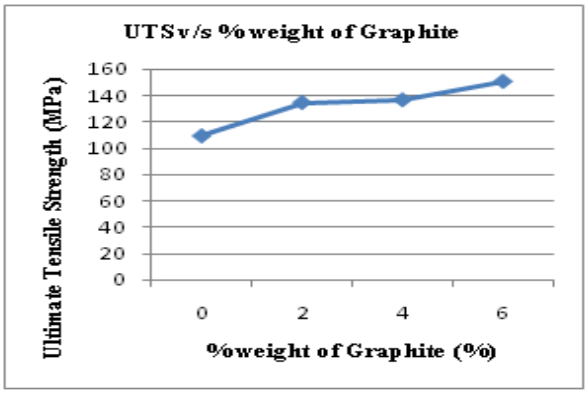

Figure 3.3: Graph of UTS v/s % weight of Graphite Particles

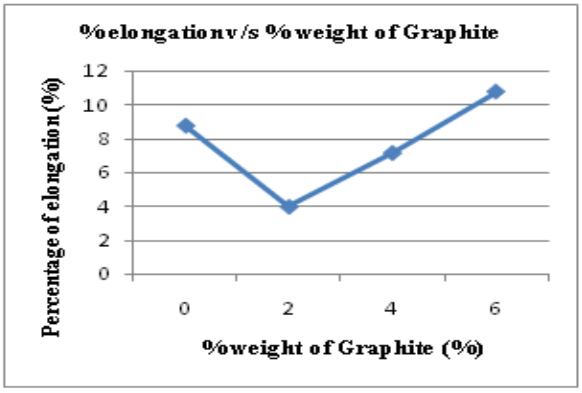

Figure 3.4: Graph of % elongation v/s % weight of Graphite Particles

4. CONCLUSION

- Aluminium based hybrid metal matrix composites have been successfully fabricated by stir casting method by addition of reinforcements combined with preheating of particles.
- The microstructural study revealed that there was uniform distribution of the hBN and Gr particles in Al6061 matrix.
- The density of the composites was found to decrease with the increase in the % weight of graphite
- The hardness of the composites was found to be decreased with increase in the % weight of the graphite but the hardness of the composites was more compared to that of the base metal
- The ultimate tensile strength (UTS) was found to increase with increase in graphite content and the UTS of the composites was also more compared to that of the base metal. The percentage elongation of the composites also increased but composition A and B possess less percentage of elongation than that of the base metal whereas composition C has more percentage of elongation than that of the base metal.

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