

Evaluation of Mechanical Properties of Aluminium 6061 Reinforced with Boron Nitride MMC's using OM

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ABSTRACT: This paper deals with the fabrication and mechanical investigation of Aluminium 6061, hexa Boron Nitride (hBN) 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. 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, Stir casting, Mechanical properties.

I. 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 can be changed.

Lokesh K M et.al [1] conducted 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 antifricition properties.

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Gangatharan T et.al [2] studied the properties of Al 2024 in the presence of graphite and hexagonal boron nitride. Aim of this paper is to compare the tribological properties of materials for plain bearings which are used in centrifugal pumps. Here four kinds of materials were taken for comparison. They are as follows. Commercially available Aluminium 2024 alloy, red brass (UNS C23000), Al 2024 reinforced with graphite (4wt. %) and Al 2024 reinforced with hexagonal boron nitride (4wt. %). The above mentioned two composites were produced by stir casting technique. The wear and frictional properties of the four different kinds of materials were established by performing the wear test using a pin-on-disc apparatus. The samples were tested at different loads and sliding velocities. Pin-on-disc apparatus was used to compare the co-efficient of friction. Pin on disc apparatus also used to compare wear resistance of the pins.

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The volumetric wear loss and co-efficient of friction of aluminium 2024 alloy, red brass and composites with sliding distance at loads 20 N and 30 N and sliding velocities of 0.75 m/s and 1.5 m/s are compared. Wear rate and coefficient of friction are reduced at increased loads and sliding velocities.

Cunguang Chen et.al [3] studied the influence of Al matrix composite reinforced by hexagonal boron nitride matrix composite reinforced by hexagonal boron nitride (hBN) with nearly full densification was successfully fabricated by the semisolid powder metallurgy technique. The h-BN/Al composites were synthesized with elemental pure Al powder size of $d_{50} = 35, 12$ and $2\mu\text{m}$. The powder morphology and the structural characteristics of the composites were analysed using X-ray diffraction, scanning and transmission electron microscopy. The density, Brinell hardness and compressive behaviour of the samples were characterized. Density measurement of the Al composites revealed that the composite densification can be effectively promoted by plenty of embedded liquid phase under pressure. Composites prepared using Al powder with varying granularity showed different grain characteristics, and in situ re-crystallization occurred inside the original grains with $35\mu\text{m}$ Al powder. A sharp interface consisting of Al/Al₂O₃/h-BN was present in the composites. Both the compressive strength and the fracture strain of the investigated composites increased with the decrease of the Al powder size, along with the Brinell hardness. The composite with $2\mu\text{m}$ Al powder exhibited the highest relative density (99.3%), Brinell hardness (HB128), compressive strength (763MPa) and fracture strain (0.299).

Maho Yamaguchi et.al [4]: Aluminium/boron nitride nanotube(BNNT) composites with upto 5wt% (i.e.,9.7vol%) nanotube fractions were prepared via spark plasma sintering (SPS) and high-pressure torsion (HPT) methods. Various microscopy techniques, X-ray diffraction, and energy dispersive X-ray analysis confirmed the integration of the two phases into decently dense and compact composites. No other phases, like Al borides or nitrides, formed in the Al-BNNT s macro composites of the two series. The BNNT s were found to be preferentially located along Al grain boundaries in SPS samples (grainsize was $10-20\mu\text{m}$) creating micro-discontinuities and pores which were found to be detrimental for the sample hardness, whereas in HPT samples, the tubes were rather evenly distributed with in a fine-grained Al matrix (grain size of several hundred nm). Therefore, the hardness of HPT samples was drastically increased with increasing BNNTs content in Al pellets. The value for Al-BNNT 3.0wt% sample was more than doubled (190MPa) compared to a pure Al-HPT compact (90MPa). And the room temperature ultimate tensile strength of Al-BNNTs HPT samples containing 3.0wt% BNNT ($\sim 300\text{MPa}$) became 1.5times larger than that of a BNNT-free HPT-Al compact ($\sim 200\text{MPa}$).

II. EXPERIMENTAL DETAILS

A. Materials

In this work for preparing metal matrix composite, aluminium 6061 (Al6061) is used as base material. Hexa Boron Nitride in the powder form is used as the reinforcements.

i. Aluminium 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 machinability etc. Al6061 is quite 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 aluminium oxide, silicon carbide, silicon dioxide, graphite, boron nitride, boron carbide etc.

ii. 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.

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B. 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 at a temperature of 800 °C. The hBN particles are pre -heated at a temperature of 400 °C for 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.

Magnesium of 0.5 % weight was added into the melt in order to reduce the non-wetting behaviour 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 = Al6061-0%hBN

Composition B = Al6061-3%hBN

Composition C = Al6061-6%hBN

Composition D = Al6061-9%hBN

C. 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. Theoretical Density is calculated by rule of mixture for base alloy and composites for Different wt. % of reinforcement. Experimental Density of the Prepared specimens was obtained by the Archimedeian method of weighing the specimens in water. Rockwell 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.

III. RESULTS AND DISCUSSION

A. Micro structural Study

The study of microstructure helps in the analysis of the distribution of distinct phases in the Al6061 metal matrix phase. Figures 1,2,3,4 shows the microstructure of composite with composition A,B,C,D which was observed by using optical microscope.

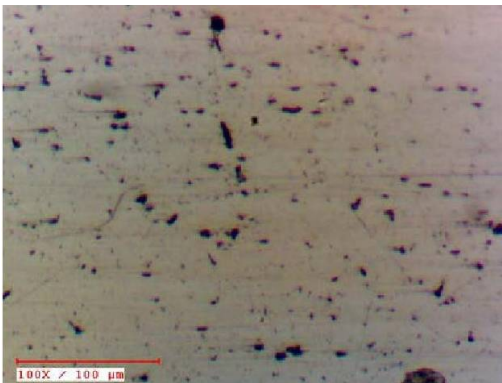


Figure 1: Microstructure of Al6061

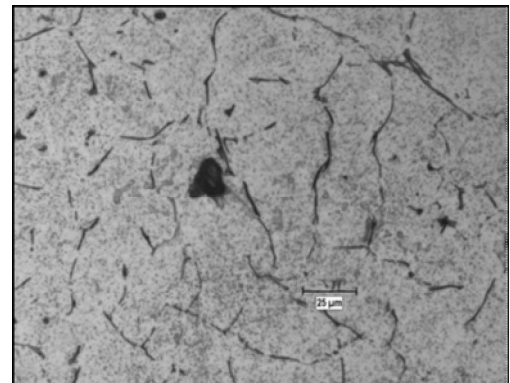


Figure 2: Microstructure of Al6061-3%hBN

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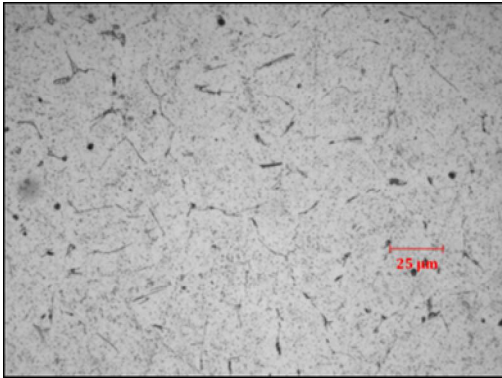


Figure 3: Microstructure of Al6061-6%hBN

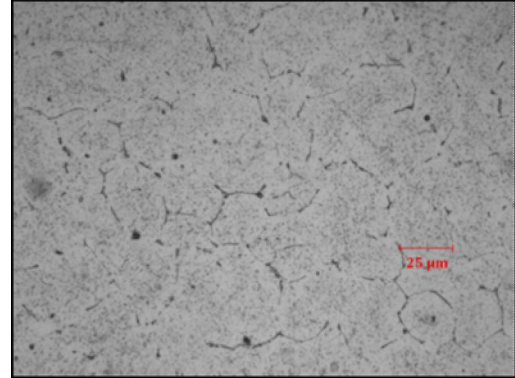


Figure 4: Microstructure of Al6061-9%hBN

The micro structural study reveals that there were fine precipitates of alloying elements dispersed along the grain boundary in the matrix of aluminium solid solution. Particles are dispersed in the matrix.

B. Density Results

Table 1 show the density test results which was conducted by water displacement method. The density of the composites was found to decrease with the increase in the % weight of Boron Nitride. The density of the Composition A was less compared to that of the base metal. The density of Composition B was also found to be less than the base metal. There was a significant decrease in the density of Composition C compared to that of the base metal. This may be due to the presence of low density reinforcements in the Al6061 matrix.

Table 1: Density Test Results

Experimental Density(g/cm3)	Theoretical Density(g/cm3)	Percentage of hBN (%)
2.71	2.7	0
2.682	2.677	3
2.6488	2.6488	6
2.6349	2.6349	9

C. Hardness Results

Hardness is the measure of how resistant solid matter is to various kinds of permanent shape change when a force is applied. Macroscopic hardness is generally characterized by strong intermolecular bonds. There are three types of tests used with accuracy by the metals industry; they are the Brinell hardness test, the Rockwell hardness test, and the Vickers hardness test. But in our present work we considered only Rockwell hardness test. The Rockwell scale is a hardness scale based on the indentation hardness of a material. The Rockwell test determines the hardness by measuring the depth of penetration of an indenter under a large load compared to the penetration made by a preload. Table 2 and Figure 5 shows the Rockwell hardness test results for varying percentage of boron nitride.

Table 2: Hardness Test Results

Hardness HBW	Percentage of Boron Nitride (%)
49.59	0
51.7	3
57.9	6
59.3	9

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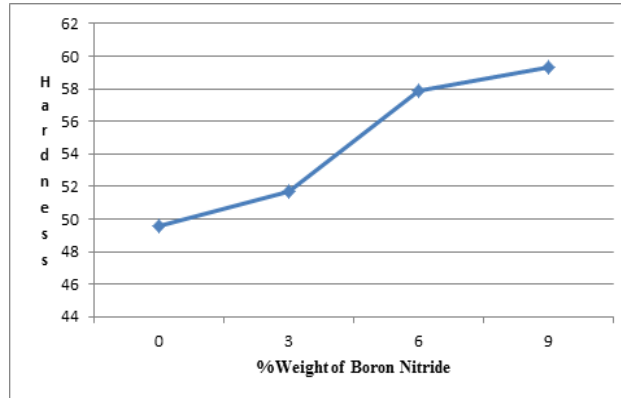


Figure 5: Graph of Hardness v/s % weight of Boron Nitride

D. Tensile Results

The tensile tests are conducted on a computerized UTM which has a capacity of 100 KN. The graph showing the effect of particulate addition on UTS of the composites is presented in Figure 6. It is observed from Table 3 that the UTS of the composites monotonically increase as the particulate content is increased up to 9%. The increase in strength can be attributed to the addition of Boron Nitride which impart strength to the matrix alloy their by enhanced resistance to tensile stresses. There is a reduction in the inter-special distance between particulates, which cause an increase in the dislocation pile-up as the particulate content increased. This leads to restriction to plastic flow due to the random distribution of the particulate in the matrix, thereby providing enhanced strength to composite.

Table 3: Tensile test results

Tensile Strength (N/mm ²)	Percentage of Boron Nitride (%)
102.29	0
134.72	3
142.76	6
156.82	9

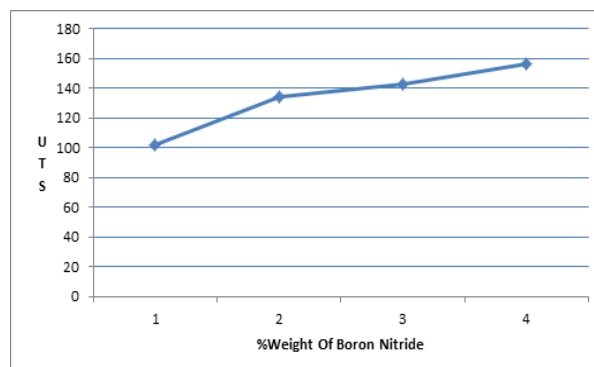


Figure 6: Tensile test results for Al 6061 v/s % of Boron Nitride

IV. CONCLUSION

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1. Aluminium based hybrid metal matrix composites have been successfully fabricated by stir casting method by addition of reinforcements combined with preheating of particles.
2. The microstructural study revealed that there was uniform distribution of the hBN in Al6061 matrix.
3. Tests conducted to determine the Hardness revealed very encouraging results as the reinforced composite was able to take Higher Loads of Indentations due to presence of Boron Nitride, the Hardness is increased.
4. Increase in The wt. % of reinforcement, There is Increase in the Hardness and it is found to be 59.3 HBW for 9% of Reinforcement.
5. Similarly With increase in the wt. % of Reinforcement, There is Increase in the Ultimate Tensile Strength (UTS), The Maximum UTS was found to be 156.72 Mpa at 9% of reinforcement.
6. Metal matrix composites of Al 6061 reinforced with Boron Nitride particulates is found to have improved tensile strength when compared to Al 6061 alloy alone.

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