Characterization Of Particulate-Reinforced Aluminium 6061 / Boron Carbide Composites

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ABSTRACT
Aluminum-based metal matrix composite (MMC) materials are used in the design of ground transportation vehicles and aircraft. Compared with conventional, unreinforced alloys, composite materials usually exhibit higher strength, both at ambient and elevated temperatures, as well as good fatigue strength and wear resistance. MMCs could be produced by variety of methods such as Stir cast, Liquid Infiltration, Osprey and Powder metallurgy. Among this, the Powder Metallurgy process is one of the most effective methods for manufacturing Metal matrix composites (MMCs) due to its high volume reinforcement and fairly uniform distribution. The present work deals with the production of Aluminium 6061 alloy powder (20μm) reinforced with B4C particle (20μm). The composites were fabricated by varying the volume % of boron carbide particle (5%, 10% & 15 %). The Compacting was performed in Universal Testing machine (UTM) by applying the compacting load of 10000kg and then Sintering was done in Muffle Furnace at 530°C for 1 hour. The mechanical properties such as density, hardness, wear, compressive strength and crushing analysis were done in developed composites.

KEYWORDS: Metal matrix composites, Powder Metallurgy.

INTRODUCTION
Powder metallurgy can be defined as the art of producing powders of metals, alloys, ceramics etc. mixing them in necessary quantities which are blended, pressed into a desired shape (compacted), and then heated (sintered) in a controlled atmosphere to bond the contacting surfaces of the particles and establish the desired properties. It is commonly designated as P/M. P/M process is a unique part fabrication method that is highly cost effective in producing simple or complex parts close to final dimensions.

[1] studied uniform distribution of 32 vol%B4C has been achieved in B4C/Al composite by means of flake powder metallurgy (Flake PM), in which flake Al powder is used as the starting material. The flake Al powder exhibits higher apparent volume than spherical powders of the same mass, and thus can provide more space to accommodate the B4C particles. Therefore, compared with conventional PM, Flake PM can lead to more uniform distribution of B4C particles in the composite powder as well as in the consolidated composite. As a result, the Flake PM 32 vol%B4C/Al composite exhibits an ultimate tensile strength of 305 MPa and a uniform elongation of 6.6%, 63% stronger and 13% more ductile than its counterpart fabricated by conventional PM.

[2] studied the compressive formability of porous Al/SiC composites fabricated through mechanical alloying (MA) is investigated. Aluminum matrix composites consisting of pure Al reinforced with different amounts of 5, 10, 20 wt.% SiC with mean particle size of 16 μm and other composites containing 10 wt.% SiC with particle sizes of 12, 16 μm were produced by a powder metallurgy route. Instantaneous density coefficient
and instantaneous work hardening exponent of the samples, during deformation stages, show decreasing trends when density increased. It was also revealed that instantaneous work hardening exponent increase with increasing milling time, increasing weight percentage of the reinforcement and decreasing its particle size. The samples having higher initial densities, containing lower amounts of larger SiC particles show better workability.

[3] studied Al–nano MgO composites using A356 aluminum alloy and MgO nanoparticles (1.5, 2.5, and 5 vol.%). have been fabricated via stir casting and powder metallurgy (PM) methods. Different processing temperatures of 800, 850, and 950 °C for stir casting and 575, 600, and 625 °C for powder metallurgy were considered. Powder metallurgy samples showed more porosity portions compared to the casting samples which results in higher density values of casting composites (close to the theoretical density) compared to the sintering samples. Introduction of MgO nanoparticles to the Al matrix caused increasing of the hardness values which was more considerable in casting samples. The highest hardness value for casting and sintering samples have been obtained at 850 and 625 °C respectively, in 5 vol.% of MgO. The highest compressive strength values for casting and sintered composites have been obtained at 850 and 625 °C, respectively. Scanning electron microscopy images showed higher porosity portions in sintered composites and more agglomeration and aggregation of MgO nanoparticles in casting samples which was due to the fundamental difference of two methods. Generally, the optimum processing temperatures to achieve better mechanical properties were 625 and 850 °C for powder metallurgy and stir-casting, respectively. [4] studied the age-hardening ability of B4C/6061Al composites, fabricated by powder metallurgy technique, were systematically investigated through varying B4C contents (0–30 wt.%), hot-pressing temperatures (560–620 °C) and holding times (30–120 min). The results showed that the quantity of Mg2Si precipitates formed in the composites after T6-treatment decreased with increasing B4C content and hot-pressing temperature, attributable to the consumption of Mg resulting from interfacial reactions. The main interfacial reaction products were MgAl2O4 and Al3BC. The formation of MgAl2O4 was determined to be the primary factor degrading the age-hardening ability of the composites. Reducing the hot-pressing temperature and holding time and increasing the Mg content were beneficial to improving the age-hardening ability of the composites. It was experimentally verified that 580 C and 30 min were the optimal hot-pressing temperature and holding time, and the amount of additional Mg should be less than 1.5 wt%, when considering both the age-hardening ability and comprehensive properties of the composites.

[5] studied aluminium (Al)-based graphite (Gr) and silicon carbide (SiC) particle-reinforced, self-lubricating hybrid composite materials were manufactured by powder metallurgy. The tribological and mechanical properties of these composite materials were investigated under dry sliding conditions. The results of the tests revealed that the SiC-reinforced hybrid composites exhibited a lower wear loss compared to the unreinforced alloy and Al-Gr composites. It was found that with an increase in the SiC content, the wear resistance increased monotonically with hardness. The hybridization of the two reinforcements also improved the wear resistance of the composites, especially under high sliding speeds. Additionally, the wear loss of the hybrid composites decreased with increasing applied load and sliding distance, and a low friction coefficient and low wear loss were achieved at high sliding speeds. The composite with 5 wt.% Gr and 20 wt.% SiC showed the greatest improvement in tribological performance. The wear mechanism was studied through worn surface and wear debris analysis as well as microscopic examination of the wear tracks. This study revealed that the addition of both a hard reinforcement (e.g., SiC) and soft reinforcement (e.g., graphite) significantly improves the wear resistance of aluminium composites. On the whole, these results indicate that the hybrid aluminium composites can be considered as an outstanding material where high strength and wear-resistant components are of major importance, predominantly in the aerospace and automotive engineering sectors.

[6] studied fabrication and mechanical investigation of aluminium alloy, alumina (Al2O3) and boron carbide metal matrix composites. Aluminium is the matrix metal having properties like light weight, high strength and ease of machinability. Alumina which has better wear resistance, high strength, hardness and boron carbide which has excellent hardness and fracture toughness are added as reinforcements. Here, the fabrication is done by stir casting which involves mixing the required quantities of additives into stirred molten aluminium. After solidification, the samples are prepared and tested to find the various mechanical properties like tensile, flexural, impact and hardness. The internal structure of the composite is observed using Scanning Electron Microscope (SEM).

[7] studied Aluminium metal matrix composites (AMMCs) are now gaining their used in aerospace and automotive industries. Among many AMMCs, Aluminium metal matrix reinforced with Boron Carbide (B4C) is a novel composite. This composite is widely used in automotive industries (brake pads and brake rotor) due to high wear resistance, high strength to low weight ratio, elevated temperature toughness and high stiffness. Boron carbide shows exotic properties such as neutron absorbing compared to other reinforcements such as Al2O3 and SiC. In order to improve tribological characteristics of Al-B4C, the graphite is added as a solid lubricant. Due to the presence of hard ceramic reinforcement in metal matrix, it is very difficult to machining by conventional methods. Even nontraditional processes such as laser jet machining and electro discharge machining result in significant subsurface damage and heat affected zone to the work. Electrochemical
machining (ECM) is an advanced machining process that is used for the machining of aerospace and automotive components, and dies and molds, etc. In order to increase the material removal rate and surface quality of the work, fine size abrasive particles are mixed with electrolyte. This abrasive particles working along with anodic dissolution can increase the material removal rate.

[8] studied fabrication of aluminum/boron carbide metal matrix composite and investigation on its tribological behavior. The composite incorporated with 5 wt% of boron carbide particles with an average size 33 μm was fabricated through stir casting process. The microstructure of this composite was examined and uniform distribution of reinforced particles in the matrix was observed. Wear experiments were conducted on pin-on-disk tester based on Taguchi's L_{27} orthogonal array using three process parameters such as applied load, sliding velocity and distance; each varied for three levels. Loads of 10 N, 20 N, 30 N; velocities of 1 m/s, 2 m/s, 3 m/s and distances of 1000 m, 1500 m, 2000 m were considered for analyzing the wear behavior of composite. Optimum parameters were found out using Signal-to-Noise ratio by choosing 'Smaller-the-better' characteristics for wear rate and coefficient of friction. Influence of individual parameter and their interactions on the responses was predicted using Analysis of Variance. Results depicted that both wear rate and coefficient of friction increases with load and decreases with velocity and distance. Worn out surfaces of the composite specimen were analyzed using Scanning Electron Microscope for predicting the wear mechanism. It was observed that, severe delamination occurred as applied load increased from 10 N to 30 N. This tribological analysis can be utilized to replace the conventional automotive materials with aluminium metal matrix composites having better wear characteristics.

[9] Development of welding procedures to join aluminum matrix composite (AMCs) holds the key to replace conventional aluminum alloys in many applications. In this research work, AA6061/B,C AMC was produced using stir casting route with the aid of K_{2}TiF_{6} flux. Plates of 6 mm thickness were prepared from the castings and successfully butt joined using friction stir welding (FSW). The FSW was carried out using a tool rotational speed of 1000 rpm, welding speed of 80 mm/min and axial force of 10 kN. A tool made of high carbon high chromium steel with square pin profile was used. The microstructure of the welded joint was characterized using optical and scanning electron microscopy. The welded joint showed the presence of four zones typically observed in FSW of aluminum alloys. The weld zone showed fine grains and homogeneous distribution of B,C particles. A joint efficiency of 93.4% was realized under the experimental conditions. But, FSW reduced the ductility of the composite.

[10] Aluminum/boron nitride nanotube (BNNT) composites with up to 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 densely dense and compact composites. No other phases, like Al borides or nitrides, formed in the Al–BNNTs macro composites of the two series. The BNNTs were found to be preferentially located along Al grain boundaries in SPS samples (grain size was10–20 μm) creating micro-discontinuities and pores which were found to be detrimental for the sample hardness, where as 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 within creasing 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 (300MPa) became 1.5 times larger than that of a BNNT- free HPT–Al compact(200MPa).

[11] studied the cyclic strain-controlled response of 6061 aluminum alloy reinforced with submicron-scale alumina particles, processed by powder metallurgy and consolidated by hot extrusion. Reinforcement volume fractions of 10% and 20% were investigated. Low-cycle fatigue tests were conducted under fully reversed total strain at a fixed strain rate using smooth specimens loaded along the extrusion axis. Microstructural examination revealed nonuniform spatial distribution of the reinforcing particles in both composites. At small applied strain amplitudes, as-extruded AA6061/Al_{2}O_{3}/10_{p} and AA6061/Al_{2}O_{3}/20_{p} composites displayed cyclic hardening under tension and softening under compression.

[12] studied the materials with high specific strengths as well as damage tolerance are of great importance for automotive and aerospace applications. Ceramic reinforced metal matrix composites (MMCs) show good potential for these uses but have been hampered by insufficient ductility and production issues, both of which this work looks to resolve. Nanoparticle reinforced 6061 aluminium alloy matrix composites have been produced by a powder metallurgy route and shown to exhibit high strength and Young's modulus alongside good ductility and low density.

[13] studied the dry sliding wear behavior of AA 6061 nanocomposites reinforced with various nanolevel reinforcements, such as titanium carbide (TiC), gamma phase alumina (γ-Al_{2}O_{3}) and hybrid (TiC + γ-Al_{2}O_{3}) nanoparticles with two weight percentages (wt.%) prepared by 30 h of mechanical alloying (MA). The tests were performed using a pin-on-disc wear tester by sliding these pin specimens at sliding speeds of 0.6, 0.9 and 1.2 m/s against an oil-hardened non-shrinking (OHNS) steel disk at room temperature.
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[14] studied the 1.0 wt.% graphene reinforced aluminum 6061 (Al6061) composite was synthesized to investigate the effects of graphene dispersion by ball milling technique. The Al6061 powder and graphene were ball milled at different milling times. The composites were then synthesized by hot compaction in the semi-solid regime of the Al6061. A three point bending test was performed to characterize the mechanical properties of the composite. The ball milled powder and the fracture surfaces of the composites were analyzed using the scanning electron microscopy. A maximum enhancement of 47% in flexural strength was observed when compared with the reference Al6061 processed at the same condition.

[15] studied the wettability of 2519Al on boron carbide (B₄C) was investigated in detail by an improved sessile-drop method at temperature ranging from 1000 to 1250 °C. The interface reactions of B₄C–2519Al systems were analyzed by means of scanning electron microscopy (SEM), electron probe X-Ray microanalysis (EPMA) and X-ray diffraction (XRD). Typical flexural strength and hardness of infiltrated B₄C–2519Al composites were studied by three-point-bending tests and Rockwell hardness tester. It is found that the wettability and interaction between molten 2519Al alloy and B₄C are sensitive to the temperature and contact time. The contact angles significantly decreased and the solid–liquid interaction was more intense as the temperature increased. On the other hand, the formation of various compounds such as Al₂BC, Al₃B₈C₂ and AlB₃ was identified. Some Al₂Cu and Al₃Zr phases appeared in the 2519Al drop during cooling, while AlB₃ precipitated far away from the 2519Al/B₄C interface. Ternary compounds of Al₂BC and Al₃B₈C₂, formed along the interface, play a key role in the improvement of wettability of B₄C/2519Al. For infiltrated 2519Al–B₄C composites, the typical bending strength and HRA are 300.71 MPa and 80.3, respectively. The main fracture way of infiltrated B₄C/2519Al is transgranular rupture, which has smooth fracture surface and intrinsic brittle fracture mode.

**Experimental Setup:**

2.1 Material Selection:

In this work Aluminium and Boron Carbide powder are used to fabricate the composite material with the size of aluminium as 20 µm with purity of 98.56% and Boron as size of 20 µm. Aluminum properties include good appearance, ease of fabrication, good corrosion resistance, low density, high strength-to-weight ratio and high fracture toughness. Aluminum powder is a light, silvery-white to gray, odourless powder. It is a reactive flammable material. Aluminium powder is a fine granular powder made from Aluminium.

![Flow Chart](image)

**Fig. 2.1: Flow Chart**

2.1.1 Physical Properties of AL6061:

1. Density - 2.7g/cc

2.1.2 Mechanical Properties of AL6061: Metric:

1. Modulus of Elasticity - 68.90 GPa
2. Poisson Ratio - 0.33
3. Shear Modulus - 26.0 GPa

2.1.3 Thermal Properties:

1. Specific Heat Capacity - 0.896 J/g-°C
2. Thermal Conductivity - 166 W/m-K
3. Melting Point - 582-652 °C

2.1.4 Mechanical Properties of Boron Carbide Powder:

1. Density - 2.52 g/cc
2. Hardness - 3000 knoop hardness number
3. Flexural strength - 366 MPa
4. Poisson ratio - 0.17
5. Compressive strength - 2760 MPa
6. Fracture toughness - 5

2.1.5 Thermal properties of Boron Carbide Powder:
1. Coefficient of thermal expansion - $6.5 \times 10^{-6} / ^\circ \text{C}$
2. Thermal conductivity - 45 W/m K
3. Melting Point - 2773 ºC
4. Specific heat - 840 J/Kg k

2.2 Weighing Calculation For Powder Compacting:

2.2.1 Volume of the Pellet:

\[
\text{Volume of the Pellet} = \pi r^2 h
\]

where, \(d = 20 \text{mm}\), \(r = 1 \text{cm}\)

\[
= 3.14 \times 1 \times 1 \times 2
= 6.28 \text{ cc}
\]

2.2.2 Weighing of Powders:

Al-5% volume of B\(_4\)C powders are mixed by High Energy Ball Mill. The calculation for mass of aluminium and Boron carbide powder needed for a sample of 20mm thickness and 20mm diameter are as follows

- Weight of Al 6061 (95%) = 16.95 x 0.95 = 16.95 gms
- Weight of B\(_4\)C (5%) = 15.82 x 0.5 = 0.79 gms
- Total Weight = 16.95 + 0.79 = 16.899 gms

Al-10% volume of B\(_4\)C powders are mixed by High Energy Ball Mill. The calculation for mass of aluminium and boron carbide powder needed for a sample of 20mm thickness and 20mm diameter are as follows

- Weight of Al 6061 (90%) = 16.95 x 0.9 = 15.26 gms
- Weight of B\(_4\)C (10%) = 15.82 x 0.1 = 1.58 gms
- Total Weight = 15.26 + 1.58 = 16.84 gms

Al-15% volume of B\(_4\)C powders are mixed by High Energy Ball Mill. The calculation for mass of aluminium and boron carbide powder needed for a sample of 20mm thickness and 20mm diameter are as follows

- Weight of Al 6061 (85%) = 16.95 x 0.85 = 14.41 gms
- Weight of B\(_4\)C (15%) = 15.82 x 0.15 = 2.37 gms
- Total Weight = 14.41 + 2.37 = 16.786 gms

2.3 Powder Blending:
Mixing of two or more powder metals are called as blending. Here flake powder of aluminium and boron carbide was mixed with each other by High Energy Ball Mill. A ball mill is a type of grinder used to grind materials into extremely fine powder for use in mineral dressing processes, paints, pyrotechnics & ceramics.

2.4 Compacting:
The purpose of the compacting is to consolidate the powder into the desired shape and as closely as possible to final dimensions, it is designed to impart the desired level and type of porosity and to provide adequate strength for hardening. Compacting was done in UTM (Universal Testing Machine) as shown in the figure.
2.5 Sintering Process:

The compacted pellets were taken and heated in a muffle furnace in an inert atmosphere (99.99% pure Nitrogen gas) at temperatures of 530°C to density the compacted powder samples. A heating rate of 5°C/minute was maintained and the holding time for the samples was 1 hour. Pellets of 20mm diameter and 20mm thickness were obtained after sintering. The densities of the sintered samples were calculated and noted.
RESULTS AND DISCUSSION

Density Measurement:
A material’s density is defined as its mass per unit volume. Vernier caliper is used for measuring the diameter and height of each developed composite. In this measurement, we analyse the various densities such as

a. Theoretical Density
b. Density - After Compacting
c. Density - After Sintering

The Al-5, 10, 15% B$_4$C composites were prepared. The effect of compacting load on green density and sintered density as shown in Table 4.1

Table 3.1: Density variation about Composition

<table>
<thead>
<tr>
<th>Composition</th>
<th>Trial No.</th>
<th>Density as per Theory (g/cc)</th>
<th>Density After Compacting (G/Cc)</th>
<th>Density After Sintering (G/Cc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al-5%B$_4$C</td>
<td>I</td>
<td>2.691</td>
<td>2.59</td>
<td>2.48</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>2.35</td>
<td>2.48</td>
<td>2.43</td>
</tr>
<tr>
<td></td>
<td>IV</td>
<td>2.58</td>
<td>2.35</td>
<td>2.41</td>
</tr>
<tr>
<td>Al-10%B$_4$C</td>
<td>I</td>
<td>2.682</td>
<td>2.45</td>
<td>2.398</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>2.32</td>
<td>2.33</td>
<td>2.36</td>
</tr>
<tr>
<td></td>
<td>IV</td>
<td>2.42</td>
<td>2.42</td>
<td>2.311</td>
</tr>
<tr>
<td>Al-15%B$_4$C</td>
<td>I</td>
<td>2.673</td>
<td>2.36</td>
<td>2.31</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>2.29</td>
<td>2.27</td>
<td>2.282</td>
</tr>
<tr>
<td></td>
<td>IV</td>
<td>2.398</td>
<td>2.29</td>
<td>2.27</td>
</tr>
</tbody>
</table>

3.2 Densification:
Densification is the act of reducing porosity in a sample thereby making it more density.

% Densification = (Density of the sample / Theoretical density) ×100

Table 3.1: Densification about Composition

<table>
<thead>
<tr>
<th>Composition</th>
<th>SAMPLE NO</th>
<th>DENSIFICATION (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al-5%B$_4$C</td>
<td>I</td>
<td>92 %</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>90 %</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>89 %</td>
</tr>
<tr>
<td></td>
<td>IV</td>
<td>87 %</td>
</tr>
<tr>
<td>Al-10%B$_4$C</td>
<td>I</td>
<td>89 %</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>87 %</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>87 %</td>
</tr>
<tr>
<td></td>
<td>IV</td>
<td>86 %</td>
</tr>
<tr>
<td>Al-15%B$_4$C</td>
<td>I</td>
<td>86 %</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>85 %</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>84 %</td>
</tr>
<tr>
<td></td>
<td>IV</td>
<td>83 %</td>
</tr>
</tbody>
</table>
3.3 Hardness Test:

Hardness test was conducted by Micro Vickers testing machine using 136° included angle inverted diamond pyramid indenter. 0.2 kgf load was given for the Al/B₄C composites. The hardness of the composites was increased when increasing the amount of Boron Carbide in the Matrix Phase.

Fig. 2.5: Micro Vickers Hardness Tester

Table 3.1: Hardness about Composition

<table>
<thead>
<tr>
<th>Composition</th>
<th>Sample No</th>
<th>Micro Vickers Hardness At 0.2 Kgf</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al-5%B₄C</td>
<td>I</td>
<td>41.2 HV</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>46.8 HV</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>41.9 HV</td>
</tr>
<tr>
<td></td>
<td>IV</td>
<td>32.8 HV</td>
</tr>
<tr>
<td>Al-10%B₄C</td>
<td>I</td>
<td>32.2 HV</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>45.4 HV</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>39.8 HV</td>
</tr>
<tr>
<td></td>
<td>IV</td>
<td>39.6 HV</td>
</tr>
<tr>
<td>Al-15%B₄C</td>
<td>I</td>
<td>48.9 HV</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>51.7 HV</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>57.2 HV</td>
</tr>
<tr>
<td></td>
<td>IV</td>
<td>53 HV</td>
</tr>
</tbody>
</table>

Compression Test:

Compression testing is a very common testing method that is used to establish the compressive force or crush resistance of a material and the ability of the material to recover after a specified compressive force is applied and even held over a defined period of time. Compression tests are used to determine the material behavior under a load. The maximum stress a material can sustain over a period under a load (constant or progressive) is determined.

The maximum compression load 14.88 KN were obtained when the reinforcement percentage was 5%.
Table 3.1: Ultimate load about Composition

<table>
<thead>
<tr>
<th>Composition</th>
<th>Ultimate Load (KN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al- 5%B&lt;C</td>
<td>14.88</td>
</tr>
<tr>
<td>Al- 10%B&lt;C</td>
<td>13.065</td>
</tr>
<tr>
<td>Al- 15%B&lt;C</td>
<td>8.645</td>
</tr>
</tbody>
</table>

Crushing Test:
A localized compressive stress at the area of contact between two components which are not having relative motion between them, is known as crushing stress. The greatest compressive load a material can withstand without fracturing. The maximum stress a material can sustain over a period under a load is determined.

Table 3.1: Crushing Peak load about Composition

<table>
<thead>
<tr>
<th>Composition</th>
<th>Peak Load (KN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al- 5%B&lt;C</td>
<td>3.645</td>
</tr>
<tr>
<td>Al- 10%B&lt;C</td>
<td>3.15</td>
</tr>
<tr>
<td>Al- 15%B&lt;C</td>
<td>2.135</td>
</tr>
</tbody>
</table>

Wear Test:
Friction materials were tested for dry conditions. In this experiment, the wear of developed composites were tested by using Wear and friction test rig (Pin on disc type). The setup consists of a frame, ring arrangement, pin rod (cast iron) and metal discs (Aluminium and mild steel) supported on a board. The disc is rotated by a DC motor of 24.6W, with 3 rpm; the weights (Max 500g) is applied on the disc by placing the weights on the pin, to generate a wear pattern on the surface of the disc. The balancing of the rod holding the pin is done by the copper string and a metal wire having high tensile strength. The depth of penetration is measured using a range meter setup consisting of micro controller 89c52, IC 0804 and a LCD display. For lubrication HP racer 2 stroke engine oil is used about 500 sec.

Table 3.1: Wear Test about Composition

<table>
<thead>
<tr>
<th>Sliding dia (mm)</th>
<th>Exp No.</th>
<th>Applied Load (N)</th>
<th>Sliding velocity (m/sec)</th>
<th>Sliding Distance (m)</th>
<th>rpm</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>1</td>
<td>10</td>
<td>2</td>
<td>1000</td>
<td>1274</td>
</tr>
<tr>
<td>45</td>
<td>2</td>
<td>10</td>
<td>2</td>
<td>1000</td>
<td>849</td>
</tr>
<tr>
<td>30</td>
<td>3</td>
<td>10</td>
<td>2</td>
<td>1000</td>
<td>1273</td>
</tr>
</tbody>
</table>

Conclusion:
Preparation of Al6061/ B₄C composites by powder metallurgy technique is attempted during this project work. Composites are prepared by varying percentage of Boron carbide (5%, 10% & 15%). Better properties were obtained when the reinforcement percentage was 5%. Density was decreased when increasing the amount of the boron carbide in the matrix phase.

It was found that maximum densification of (92%) was achieved for the compacting load of 10000kg.

The hardness of the composites was increased when increasing the amount of Boron Carbide in the Matrix Phase.

REFERENCES


