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# Experimental Analysis of Aluminium Hybrid Composite with Various Operating Conditions

**K. Prabhakaran[1], B. Silambarasan[2], K. Santhosh[3], B. Yugendran[4],**

**V. Vinothkumar[5], M. SharveshRam[6]**

Assistant Professor[1,2], Students[3,4,5,6]
Department of Mechanical Engineering
AnjalaiAmmal Mahalingam Engineering College, Thiruvarur, India

**Abstract:** *This present study deals with the fabrication of Al7075/$B_4C$/HBN metal matrix hybrid composite and investigation of its tribological and mechanical behaviour. The aluminium alloy was reinforced with Hexagonal boron nitride (HBN) with various weight fraction (0%,2%,3%,4%) by keeping Boron carbide ($B_4C$) constant at 3%. Stir casting process was used for the fabrication of the composite. Wear experiment was conducted on pin-on-disc tester using four process parameters such as applied load (10N, 20N, 30N and 40N), sliding velocity (1m/s, 2m/s, 3m/s, 4m/s), temperature (25$^o$C, 50$^o$C, 100$^o$C, 150$^o$C) and percentage of reinforcement (0,2,3,4 HBN). The results indicated that the mechanical properties of the composite material were reduced at high temperatures. Hardness of the composites increases while increase the wt % of HBN. Hardness is minimum at 3rd composition. However, at high temperatures and humidity levels, some debonding was observed, which could reduce the mechanical properties of the material. Overall, the experimental analysis highlights the importance of considering the operating conditions when designing and using aluminum hybrid composites for various applications.*

**Keywords:** Al7075 , $B_4C$ , HBN, Wear, Hardness

## I. INTRODUCTION

The term "composite" broadly refers to a material system made up of a continuous phase (the matrix) and a discrete constituent (the reinforcement), and which derives its distinctive properties from the characteristics of its constituents, from the geometry and architecture of the constituents, and from the properties of the boundaries (interfaces) between different constituents. Compared to other popular materials like steel, composite materials are stronger and lighter.Regarding the matrix and reinforcement materials used in the creation of composite materials, there are generally two groupsIt is categorised as Metal Matrix Composites (MMCs), Ceramic Matrix Composites (CMCs), Polymer Matrix Composites (PMCs), and Carbon Matrix Composites (also known as carbon composite) based on the matrix material.Metal matrix composites (MMCs) are cutting-edge materials that combine the resilience of tough metallic matrix materials like magnesium and aluminium with the hardness of ceramic reinforcement to create composites with remarkable material properties.

Composites that combine two or more reinforcements are considered hybrid composites.The behaviour of hybrid composites is a weighted average of the constituent components, where the inherent benefits and drawbacks are more favourably balanced.MMCs have been studied for some time, and it is becoming increasingly obvious how they could be superior to conventional monolithic alloys.For composites, reinforcement materials are chosen based on a specific feature needed in the base material. A range of materials, including as particles, short fibres, whiskers, and continuous fibres, can be used as reinforcements for making MMCs. Due of its unique advantages, the stir-casting method is the most popular commercial production technique. Chemical compatibility between the matrix and the reinforcement is a significant problem in the manufacture of metal matrix composites (MMCs), particularly when using liquid metal methods.

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MMC casting is a popular processing technique because it is reasonably priced, offers a large number of materials, and allows flexible processing conditions.MMCs with intricate profiles can be produced by stir casting without endangering the reinforcements. It's important to establish a uniform distribution of reinforcement when creating composites with the stir-casting technique. One of the most abundant elements on earth, aluminium (Al), started to compete economically in engineering applications at the end of the 20th century. In recent years, attempts have been made to produce aluminium alloy items that are inexpensive and lightweight. Aluminium matrix composites (AMCs) have attracted a lot of interest, particularly in the automotive, aerospace, and aviation sectors. Due to their light weight, high strength, high specific modulus, low coefficient of thermal expansion, and good wear resistance qualities, AMCs have recently been employed for automotive items such engine pistons, cylinder liners, and braking discs and drums.

## II. LITERATURE SURVEY

M. Manikandan et al. conducted "A Study on Wear Behaviour of Aluminium Matrix Composites with Ceramic Reinforcements". This project involved the fabrication of AA 7075 reinforced with SiC, Al2O3, and B4C with sizes ranging from 16 to 20 mm using the liquid casting process. The metal matrix composites' wear characteristics are

a pin-on-disc wear tester was used to perform dry sliding wear tests at constant speeds of 3 m/s and 2000 m sliding distance while varying the loads of 20 n, 40 n, and 60 n, and at constant loads of 60 n and 2000 m sliding distance while altering the speeds of 1 m/s, 2 m/s, and 3 m/s.AMCs samples' mechanical characteristics, such as hardness and tensile strength, are evaluated. The tiny pictures were used to study the wear process. The results show that the wear rate rises when the applied load is increased and the sliding velocity is decreased. The microscopic study also shows that the AA 7075/BC Composite exhibits higher wear resistance.

S. BaluMahandiran et al.'s study "Dry sliding wear behaviour of Al-Sic composites using Design of Experiments" [4] was published. In this study, stir-cast AA6061 reinforced with silicon carbide particles (10% & 15% weight percentage of SiCp). The metal matrix composites' wear characteristics are employing a pin-on-disc wear tester, dry sliding wear tests were conducted at various weights of 10 N, 20 N, and 30 N, sliding speeds of 2 m/s, 3 m/s, and 4 m/s, and sliding distances of 500 m, 1000 m, and 1500 m. The DOE approach developed by Taguchi is the basis for the experiments. Both 10% and 15% Sic reinforced AA 6061 MMCS are created using ANOVA and regression models.The findings show that for Al-6061/10% Sic metal matrix composites, sliding distance (63.42%) has the greatest impact on wear rate, followed by sliding speed (18.26%) and applied load (9.95%).For AA 6061/15% Sic metal matrix composites, applied load (64.135%) has the greatest impact on wear rate, followed by sliding speed (11.777%) and sliding distance (1.47%). By providing a shield between the pin and counter face, increasing Sic percentage from 10% to 15% enhances composites' wear resistance. According to the aforementioned findings, sliding distance and applied load have the most effects on wear rates in both composites. The wear rate of AA6061 under intermediate circumstances has been reasonably predicted using a regression equation created for the 10% and 15% of Sic in MMCs. A confirmation experiment was conducted, and the experimental values were compared.According to the investigation, the inaccuracy caused by dry sliding wear in both composites ranges from 11.42% to 12.01%.As a result, the taguchi approach of experiment design is successful in predicting the wear behaviour of components

Viney Kumar et al. published a study titled "Comparison of Mechanical Properties and Effect of Sliding Velocity on Wear Properties of AA 6061, Mg 4%, Fly Ash and AA 6061, Mg 4%, Graphite 4%, Fly ash Hybrid Metal matrix Composite." [6] This study used MMCs created using the casting method. In the first instance, AA 6061, 4%MG was selected as the base metal, and different amounts of fly ash—10%, 15%, and 20%—were used as reinforcement. In the second instance, AA 6061, 4%MG, 4%Graphite was selected as the base metal, and different amounts of fly ash—10%, 15%, and 20%—were used as reinforcement. This research compares the mechanical characteristics of two metal matrix composites and examines the impact of rpm on the specific wear rate.They draw the conclusion that while fly ash can boost tensile strength by up to 15%, subsequent additions will result in a loss in tensile strength. Tensile strength drops with the addition of a given amount of graphite, or 4%, although it remains higher than base metal. The machining is made smoother by adding graphite. While graphite somewhat reduces hardness while improving machining, fly ash increases hardness.Up to 15% less wear occurs with a given proportion of fly ash. Fly ash is added further, the hardness of the composites rises, and it may be deduced that the material becomes less ductile as a result. This leads to an increase in the specific wear rate with increased fly ash addition. Specific wear rate falls when 4%

graphite is added in a set amount together with the same volume percentage of fly ash. Specific wear rates rise as rpm increases.This is because too much fly ash makes the material fragile.Due to the lubricating characteristic of graphite, the specific wear rate reduces up to 1500 rpm. Due to heat produced by high speed graphite diffusing, the composite becomes more ductile as r.p.m. rises.

## III MATERIALS

The materials selected for the manufacturing of the composites and their characterisation methods are discussed in the following section.

Aluminium alloy Al7075 Aluminium alloy 7075 comes under the category of a lightweight material that has a density value of 2.815 g·cm-3. It can be heat treated and it has the characteristics of better strength, high resistance to corrosion, and easy weldability.Aluminium is remarkable for the metal's low density and for its ability to resist corrosion due to the phenomenon of passivation. Structural components made from aluminium and its alloys are vital to the aerospace industry and are important in other areas of transportation and structural materials. The most useful compounds of aluminium, at least on a weight basis, are the oxides and sulfates.Despite its prevalence in the environment, no known form of life uses aluminium salts metabolically. In keeping with its pervasiveness, aluminium is well tolerated by plants and animals. Owing to their prevalence, potential beneficial (or otherwise) biological roles of aluminium compounds are of continuing interest.

Boron carbide is the third most rigid materials next to diamonds and cubic boron nitride and has high hardness (> 30 GPa), wear-resistance, a low density (2.52 g cm-3), a high elastic modulus (445 GPa), high impact capacity, and a high melting point (2450 °C). Boron carbide was selected as the reinforcement material in the current work due to its exceptional thermal and chemical stability in addition to the uniqueness of its hardness, high strength, and low density. In the recent decade, B4C has been employed in tank armour and bulletproof vests, which are excellent neutron absorbents, and a barrier in nuclear power plants. This is a hard material with important characteristics, such as increased strength, improved hardness, and the ability to maintain low-density values.

Hexagonal boron nitride (HBN) has a layered structure, similar to graphite, which each layer composed to a hexagonal lattice of alternating boron and nitrogen atoms. These weak interlayer forces are responsible for the lubricating properties of HBN, which has led to the use of solid lubricant in industrial applications. Overall, the bonding in HBN is a combination of strong covalent bonds within each layer and weak Van der Waal forces between the layers.

## IV METHODOLOGY

### Composite preparation

The hybrid composites were produced using the stir casting technique. During the casting process, the reinforcement was added while being stirred with a stirrer. The stir casting process was chosen over alternative techniques because it ensures appropriate mixing and particle bonding. To guarantee optimum filler dispersion in the matrix during the stir casting process, the melt temperature must be greater than the aluminium temperature. In the muffle furnace, the matrix and reinforcement were first heated.To ensure appropriate melting, the Al7075 matrix was initially heated above the liquidustemperature.A 4 kg piece of Al 7075 alloy, together with 3 weight percent preheated flux and 2 weight percent reinforcement, was placed in a stir casting machine and heated to 800 °C. To prevent oxidation, an argon gas atmosphere is given. For 20 minutes, the mixture is allowed to stir at 700 rpm. The melt is let to enter a 300 mm long by 27 mm wide mould die. For 3% and 4%, the same procedure is done. To prevent gas from being trapped, the flow of the slurry must be consistent when it is poured into the mould. Additionally, the distance between the crucible and the mould is crucial to the casting's quality.

| sample | % of aluminium | % of $B_4C$ | % of HBN |
|---|---|---|---|
| 1 | 97 | 3 | 0 |
| 2 | 95 | 3 | 2 |
| 3 | 94 | 3 | 3 |
| 4 | 93 | 3 | 4 |

Table 2 composition of mmc

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**Hardness test**

Measurement of the indentation depth yields the definition of hardness as indentation resistance. In this approach, a fixed force is applied to a certain indenter; a smaller indentation denotes a harder substance. The specimen would be flat and smooth based on the hardness test. According to the ASTME8 standard, the hardness was examined at 4 separate places for 40 seconds with a 400 g load. The resultant hardness was calculated as the average of all 4 values for a single sample.

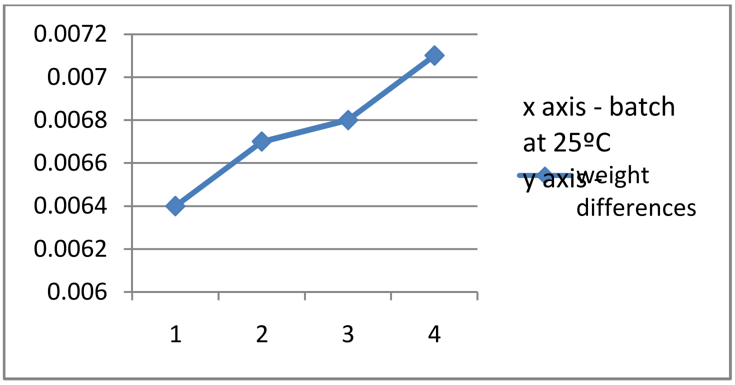
**Chamber heating wear test**

Al 7075/HBN/B4C hybrid composites' chamber heating wear test behaviour is examined using the pin on disc test. Pin specimens with dimensions of 10 mm in diameter and 30 mm in height that were made from the aforementioned composites were machined and metallographically polished. The test was run with varying load of10,20, 30, and 40 N while sliding at speeds of 1, 2, 3 & 4 m/s over a constant distance of 2000 m. A relative humidity of 65-70% and room temperature (40°C) were used for the test. An electronic weighing balance was used to determine the specimen's initial weight. Each test involved removing the specimen and cleaning it with an acetone solution after running the fixed sliding distance.The average of the recorded data was taken into consideration for all other studies after each test was performed three times with new pins and faces. Utilising friction factor data noted at the time of the wear test, the coefficient of friction (CoF) is determined.The weight loss technique was used to calculate the wear rate.

## V RESULT AND DISCUSSIONS

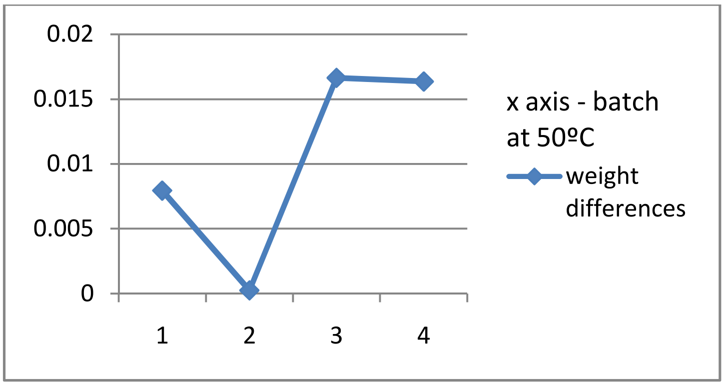
**Results of wear test:**

| samples | % of Reinforcement | Temp ($^0$C) | Applied Load | Speed | Initial Weight (gms) | Final Weight (gms) | Wear (Micro -meter) | Friction Force | Weight Difference |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 25 | 10 | 1 | 5.0541 | 5.0477 | 39 | 15.06 | 0.00640 |
| 2 | 0 | 50 | 20 | 2 | 5.0123 | 5.0044 | 77 | 14.26 | 0.00794 |
| 3 | 0 | 100 | 30 | 3 | 5.1087 | 5.0974 | 128 | 12.68 | 0.01130 |
| 4 | 0 | 150 | 40 | 4 | 5.362 | 5.3472 | 179 | 11.60 | 0.01482 |
| 5 | 2 | 25 | 20 | 3 | 5.1032 | 5.0965 | 20 | 18.00 | 0.00670 |
| 6 | 2 | 50 | 10 | 4 | 5.0147 | 5.0144 | 16 | 2.97 | 0.00025 |
| 7 | 2 | 100 | 40 | 1 | 5.0232 | 5.0024 | 196 | 12.96 | 0.02080 |
| 8 | 2 | 150 | 30 | 2 | 5.0021 | 4.9873 | 151 | 4.43 | 0.01480 |
| 9 | 3 | 25 | 30 | 4 | 5.0012 | 4.9944 | 35 | 17.62 | 0.00680 |
| 10 | 3 | 50 | 40 | 3 | 5.0236 | 5.0070 | 116 | 20.83 | 0.01663 |
| 11 | 3 | 100 | 10 | 2 | 5.1132 | 5.1081 | 19 | 3.50 | 0.00510 |
| 12 | 3 | 150 | 20 | 1 | 5.4652 | 5.4525 | 113 | 0.66 | 0.01270 |
| 13 | 4 | 25 | 40 | 2 | 5.118 | 5.1109 | 114 | 6.58 | 0.00710 |
| 14 | 4 | 50 | 30 | 1 | 5.1233 | 5.1070 | 100 | 15.13 | 0.01635 |
| 15 | 4 | 100 | 20 | 4 | 4.8546 | 4.8484 | 12 | 8.00 | 0.00620 |
| 16 | 4 | 150 | 10 | 3 | 5.0012 | 4.9968 | 10 | 2.05 | 0.00440 |



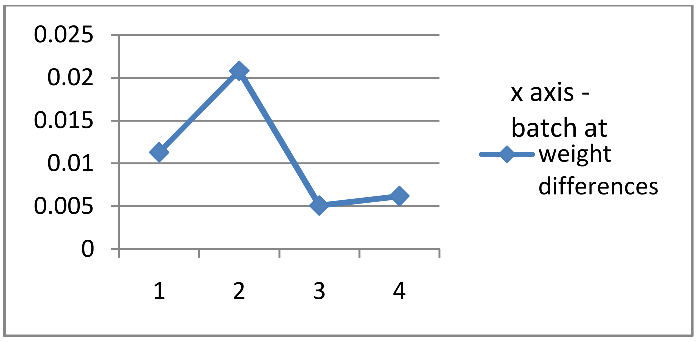
**Weight difference at 25°C**

Four different casting techniques have been used. Four wear specimens for each casting were made. Each casting had one sample removed from it, and that sample was worn at 25°C.And a range of 1 to 4 pounds in weight differential was discovered. Since sample 1 has a little weight difference whereas sample 4 has a significant weight difference



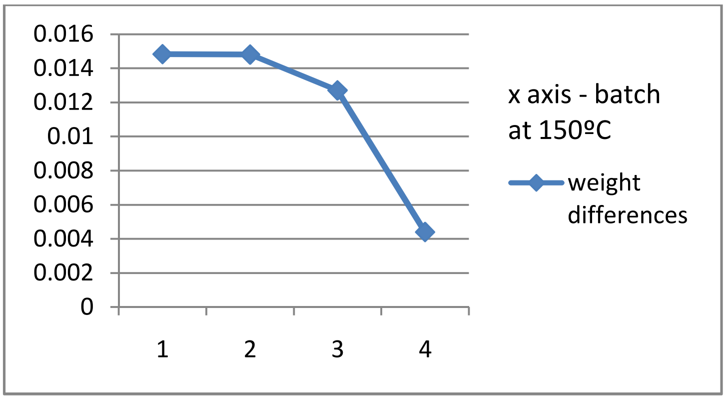
**Weight differences at 50°C**

Four different casting techniques have been used. Four wear specimens for each casting were made. Each casting had one sample removed from it, and that sample was worn at 50°C.And a range of 1 to 4 pounds in weight differential was discovered. Since sample 2 has a little weight difference whereas sample 3 has a significant weight difference



**Weight differences at 100°C**

We used four distinct casting techniques. Four wear specimens were made for each casting. One sample from each casting was taken, and when it was worn at 100 °C, the weight difference was discovered to range from 1 to 4. since sample 1 have a significant weight difference and sample 3 have a low weight difference



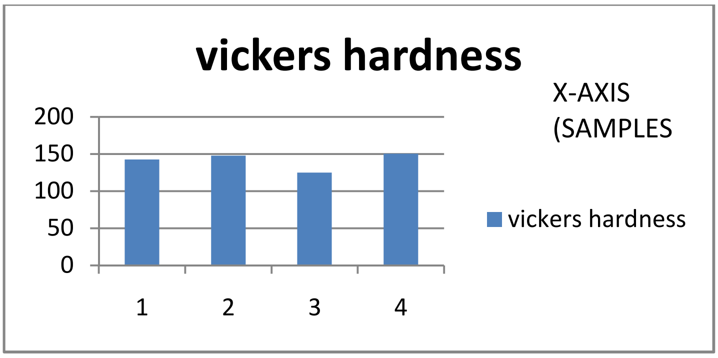
Weight differences at 150°C

Four distinct castings have been taken. For four wear specimens, each casting was ready. One sample was obtained from each casting, and after being worn at 150°C, the weight difference was discovered to range from 1 to 4. as opposed to sample sample 1 having a significant weight difference and sample 4 having a low weight difference

**Result of hardness test**

| Sample | Vicker Hardness (HV) | | | |
|---|---|---|---|---|
| | **Trial 1** | **Trial 2** | **Trial 3** | **Average** |
| 1 | 143 | 146 | 139 | 142.6 |
| 2 | 142 | 150 | 152 | 148 |
| 3 | 136 | 150 | 89 | 125 |
| 4 | 136 | 170 | 146 | 150.6 |

**Table Results of hardness test**



**Vickers hardness results**

Four distinct casting types were selected, and each casting was converted into a specimen for the hardness test. The micro Vickers hardness test was used, and each specimen of various castings was tested for three trials before the average was calculated based on the average value. The hardness level was varied for each specimen, with sample 3 having a low hardness value and specimen 4 having a high hardness value.

## VI CONCLUSION

- The results indicated that the mechanical properties of the composite material were reduced at high temperatures. This is likely due to the degradation of the interfacial bonding between the aluminum matrix and the reinforcing materials.
- Additionally, the loading rate was found to have a significant effect on the mechanical properties of the composite material, with higher loading rates leading to reduced strength and ductility.

- The weight loss at 25°C gradually increases while increases the wt% of HBN.At50°C weight loss is maximum at 3rd composition and minimum at 2nd composition. At 100°C weight loss is maximum at 2nd composition and minimum at 3rd composition. At 150°C weight loss gradually decrease & minimum at 4th composition.Hardness of the composites increases while increase the wt % of HBN. Hardness is minimum at 3rd composition

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