

Evaluation of Tribological Properties of Al 6061 Reinforced With B₄C Particulate composites

Santhosh T U¹, Dr. Hemanth Kumar T R², Dr. Siddesh Kumar N G³, Sridhar H S⁴

Department of Mechanical Engineering, Shridevi Institute of Engineering and Technology, Tumkur, Karnataka, India¹

Department of Industrial Engineering and Management, Sri Siddhartha Institute of Technology, Tumkur, Karnataka, India²

Department of Mechanical Engineering, Channabasaveshwara Institute of Technology, Tumkur, Karnataka, India³

Department of Mechanical Engineering, Sri Krishna Institute of Technology, Chikkabanavara, Bangalore, Karnataka, India⁴

ABSTRACT: The demand of today's and future aluminium alloys are best suitable materials in engineering application. Now a day's rapid changes in materials they are looking towards the strength to weight ratio. Aluminium Metal Matrix Composites (AMC's) take over conventional materials in the industrial world, due to its excellent mechanical properties. This work sought on the fabrication of Aluminium Matrix Composites (AMC's) reinforced with various weight percentage of B₄C particulate by stir casting process. The properties of reinforced aluminium alloy composites depend on the weight percentage and uniform distribution of reinforcement particles in the matrix. It was found that tensile strength and hardness properties increased with the increase in the weight percentage of reinforcement. The wear behaviour has been investigated under dry sliding condition using a pin-on-disc wear testing machine. The tribological results reveal that Wear rate of Al-B₄C composites decreases with increase in wt% of B₄C particles.

KEYWORDS: Stir casting, Tensile, Hardness, Wear, Pin-on-disc

I. INTRODUCTION

A collection of novel advanced materials as Aluminium metal matrix composites (AMC's) due to its high strength, light weight, high specific modulus, good wear resistance and low co-efficient of thermal expansion. In conventional material mixture of these properties are not available. This Aluminium metal matrix composites are widely used for automobile products like cylinder liner, engine piston, brake drum and brake disc etc [1]. With a economical casting method Aluminium alloy B₄C composites are produced and at the same time at the temperature below 1100°C wetting between Al and B₄C poor, in order to improve the Wettability between Al and B₄C improve their amalgamation behaviour into Al melts [2]. In MMCs Al6061 is preferred choice as a matrix material due to its enhanced formability characteristics. From newly developed composites particle reinforced metal matrix composites are widely used for industrial applications. An exceptional combination of good wear resistance, high elastic modulus, high specific strength and good thermal stability than the matrix alloy [3]. By increasing reinforcement, hardness of composites increases due to presence of higher harder reinforcement material in matrix material and the tensile strength of composites is higher than unreinforced matrix because of good bonding between the matrix and reinforcement [4]. The XRD analysis represents the phases of materials present in composites, the phases are identified by captivating the values of peak width, angles (2θ), peak intensities and d-values with respect to (h k l) values correspondingly. Use of aluminium metal-matrix composites in automotive applications is a significant feature in tribological behaviour and wear behaviour of Al-Si alloys are improved further by addition of ceramic particles. Increasing the hardness of composites by adding abrasive particles in order to improve tribological behaviour [6]. An intricate process connecting not only mechanical but also chemical and thermal interaction between two surfaces in contact for sliding wear of the composite. Due to tribological characteristics the wear resistance of these materials is extremely suitable in automobile applications [7]. In dry sliding wear characteristics of aluminum alloy based composites influence the wear behavior

composites by the effect of reinforcement, volume fraction, reinforcement size, sliding distance (D), applied load (L), sliding speed (S), hardness of the counter face, and properties of the reinforcement phase [8]. In AMMCs the wear rate is connected to sliding velocity, particle size, hardness, normal load and wear behavior of composites usually examined by the consequence of a single factor, such as sliding distance, sliding speed or contact pressure, on the wear presentation[9]. Al 6061 alloy reinforced with SiC and B₄C particulates up to 5 to 15 wt. % volume fraction has marked consequence on wear rate with increasing volume fraction of reinforcements the wear rate and coefficient of friction decrease [10]. The wear resistance increases with increasing reinforcement but decreases with increasing both for track velocity and normal load. The assessment of the worn surfaces by microscope demonstrates delamination, micro cutting, oxidation and thermal softening for MMC's [11]. With addition of reinforcements to matrix alloy the Wear resistance of composites increases and as the sliding speed and applied load increases because of formation of MML layer the wear rate decreases. At lower loads the wear mechanism shows Abrasion and it will changes to delamination at higher load [12]. An attempt is made in the present work to produce Al6061/B₄C composites and study the dry sliding wear behavior of Al 6061 and prepared composites.

II. EXPERIMENT DETAILS

2.1 Material

The matrix material used in the present investigation was Al 6061 and boron carbide was used as a reinforcement particle. The chemical composition of Al 6061 is as show in table 1.

Table 1: Chemical composition of Al, wt. %

Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
0.54	0.22	0.17	0.13	0.95	0.09	0.08	0.01	Balance

2.2. Fabrication method

Boron carbide with an average particle size 80µm was used as a reinforcing material and commercially available aluminium 6061 was used as a matrix material in this study. The stir casting method is adopted to fabricate composites of Al 6061-B₄C. The boron carbide is added to the matrix with 4, 6, 8 wt%. The Al 6061 is melted in graphite crucible using an electric resistance furnace. The degassing agent is added to the molten alloy to remove the gasses present. Before mixing of the boron carbide particles with the liquid Al 6061 the boron carbide particles were preheated at 250°C for one hour to to remove moisture. The matrix alloy is heated to 725°C then the preheated boron carbide particles added to the liquid Al 6061 in 3 steps rather than introducing all at once. At every stage after introduction of reinforcement particles stirring of the molten alloy for a period of 10 min was achieved by using stainless stirrer. Finally the melt was poured into a preheated metallic mould. The Al 6061-B₄Ccomposites were obtained in the form of cylinders of diameter 12.5mm and length 125mm.

2.3. Experimental procedure

Metallographic samples sectioned from the cast bars were prepared using 220, 400, 600, 800, 1000, 2000 grid silicon papers. In order to examine matrix and reinforcement interface, samples were etched with Keller's reagent. Microstructures were examined by SEM analysis. The hardness specimens are prepared same as microstructure specimens. The hardness was measured at different locations in the specimen. The micro hardness of polished specimens was measured using zwick Vicker's hardness tester at a load of 100g for 10s. The tensile specimens were prepared as per the ASTM E08 standard. The dimensions of the specimens are as show in fig 1. Tensile tests were conducted at room temperature on computerized universal testing machine of capacity in load range of 0-100KN.

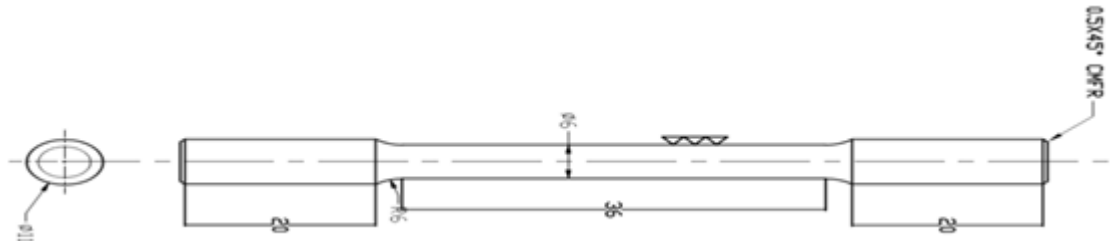


Fig 1: Figure shows the Dimension of tensile specimen

Dry sliding wear tests for the aluminium and composites have been conducted using pin-on-disc machine. Wear tests have been conducted using cylindrical samples of diameter 10mm and length 25mm that has flat surface contact region. The pin is fixed to the holder and is held stationary against the rotating disc made of EN-32 steel having hardness of 64HRC. Wear test is conducted in 3 sets. In the first set the wear test have been conducted under the loads of 10N, 30N, 50N, 70N and at a fixed sliding speed of 400rpm and sliding distance 565.48m were maintained constant for all the composites. In the second set the wear test is carried at different sliding speed of 200rpm, 400rpm 600rpm 800rpm and constant load of 30N and sliding distance of 565.48m. In the third set wear test is carried at sliding distances of 282.74m, 565.48m, 848.23m, 1130.97m and sliding speed of 400rpm at a load of 30N. After each run the pin is removed from the holder and pin weight loss has been measured. The disk has been cleaned with acetone after each run to remove debris

III. RESULTS & DISCUSSIONS

3.1. Evaluation of Microstructure

Aluminium reinforced B_4C particle composites are successfully casted by stir casting. The morphology, type of reinforcement and its dispersion have a major influence on the properties of the composites. It is necessary to distribute the particles throughout the matrix material during the production of composites. It was observed from the figure 2,3,4 that, B_4C particles are dispersed uniformly in the aluminium matrix at all weight percentages which may be due to preheat of the B_4C particles before adding into the melt and the stir casting process is carried out at high temperature to increase the wettability. Good wetting between the solid ceramic phase and the liquid metal matrix is essential for the generation of a satisfactory bond between these two during and after casting. Effective stirring action and use of appropriate process parameters are attributed to the uniform distribution of B_4C particles throughout the aluminium matrix. Uniform distribution of the particles is a pre-requisite to enhance the mechanical properties of the matrix alloy.

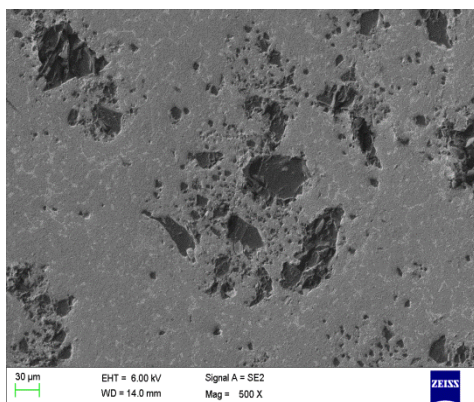


Fig 2: SEM image of 4% B_4C particles

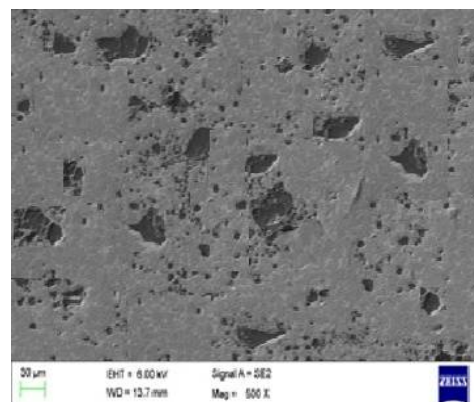


Fig 3: SEM image of 6% B_4C particles

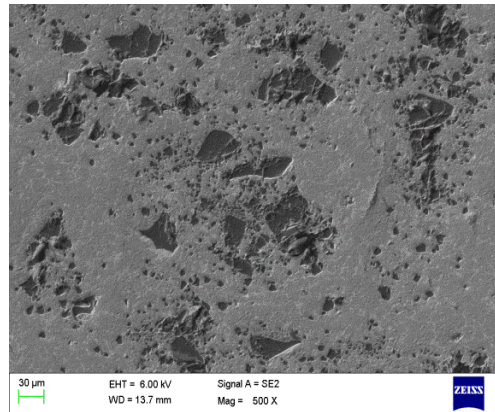


Fig 4: SEM image of 8% B₄C particle

3.2. Evaluation of Micro Hardness

Hardness is described as a measure of material's resistance to surface indentation or the stress required to producing surface deformation. The micro hardness is a direct, simple and easy method of measuring the interface bonding strength between the matrix and reinforcement. The micro hardness measurements were carried out on both the composites as well as base materials using Zwick vicker's hardness testing machine at a load of 100 gm for a time of 10 sec. The micro hardness of composite increased from 83.04 VHN to 112.05 VHN with increasing reinforcement weight percentage from 0, 4, 6 and 8 wt% which is shown in fig 5. The presence of such hard surface area of particles offers more resistance to plastic deformation that leads to increase in hardness of composites. The incorporation of B₄C particles at higher wt% in aluminium matrix improves the hardness of the composites and particle size improves the load carrying capability of the composites.

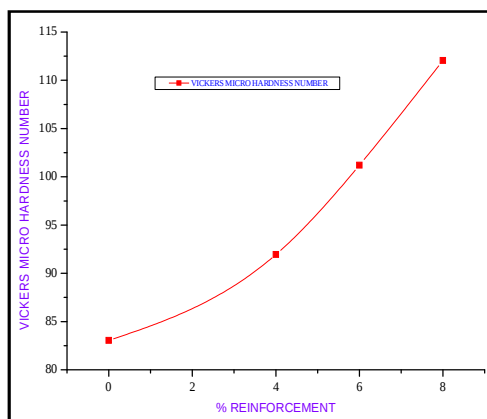


Fig 5: Showing the Hardness Results of Cast Al 6061 with Addition of 4, 6 and 8wt% of B₄C Particulates

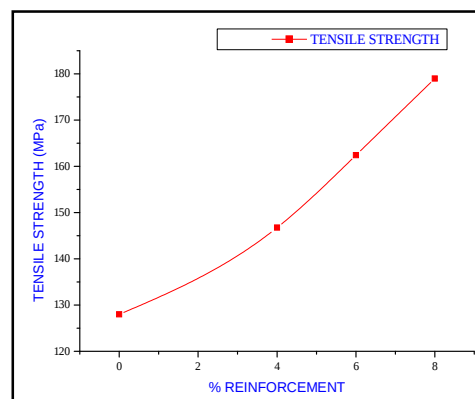


Fig 6: Showing the Tensile Test Results of Cast Al 6061, with Addition of 4, 6 and 8wt% of B₄C Particulates

3.3. Tensile Strength

In this study the experimental result shows that in general the tensile strength of the AMC's produced are higher than that obtained for the non reinforced Al6061 alloy. The tensile tests were carried out using computerized uni-axial tensile testing machine as per ASTM standards which is as show in fig 6. The tensile strength of composite increased from 125Mpa to 178.38Mpa with increasing reinforcement wt % from 0, 4, 6 and 8. The addition of B₄C particles in

the matrix induces much strength to the matrix alloy by offering more resistance to tensile stresses. The embedded hard particles in the matrix act as a barrier that resists the plastic flow of composites when it's subjected to strain. The property of the reinforcements controls the mechanical properties of the composites. Increases in strength of the composites are reasoned to the strong interface that transfers and distributes the load from the matrix to the reinforcement. Further the improved interface strength and better dispersion of the particles in the matrix is achieved by preheating the reinforcements. This can explain the improvement of the tensile properties in B₄C composites.

3.4 Wear test

To get a better understanding of the wear characteristics of the composites, it is essential to explore the various parameters that affect the wear performance. There are three principal parameters that affect the wear is load, sliding speed and sliding distance.

3.4.1 Effect of load

To study the effect of load on wear rate, the wear data of matrix and B₄C reinforced composite as presented in the fig 7. It is evident from the figure that the increase in load resulted in increase in wear rate for all specimens. Applied load affects the wear rate of alloy and composites significantly and is the most dominating factor controlling the wear behaviour. The cumulative volume loss increases with increasing applied load. Further, with increased applied load the contact surface temperature increases. By measuring the wear rate as a function of applied load, it has been reported that a critical load exists below this load, where the wear rate is mild and steady; above this load a severe wear rate occurs and the critical load decreases with temperature. If the load is further increased, then the unreinforced and reinforced composites eventually seize. The seizure event was accompanied by a sudden increase in wear rate, heavy noise and vibration. As the wear rate increases with increased applied load, the wear mechanism reported was adhesion and delamination at higher loads. At low loads, as particles act as load bearing constituents, the direct involvement of Al-alloy in the wear process is prevented.

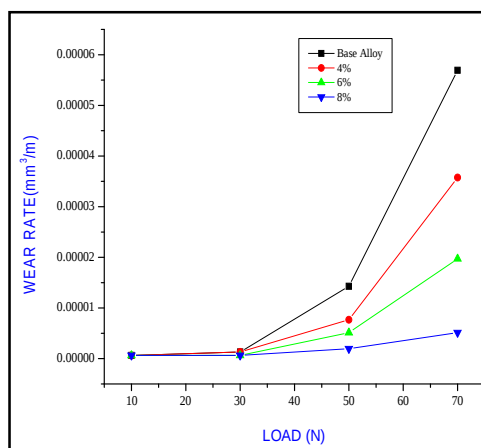


Fig 7: wear rate versus load

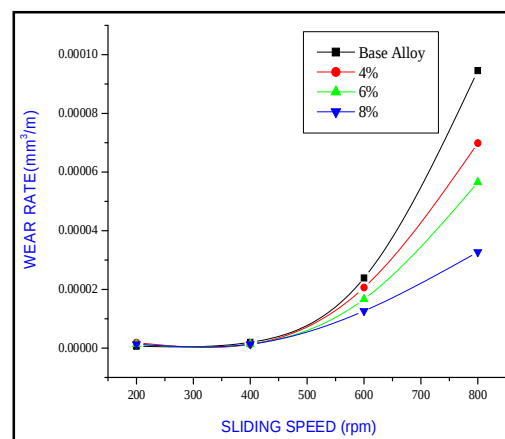


Fig 8: wear rate versus speed

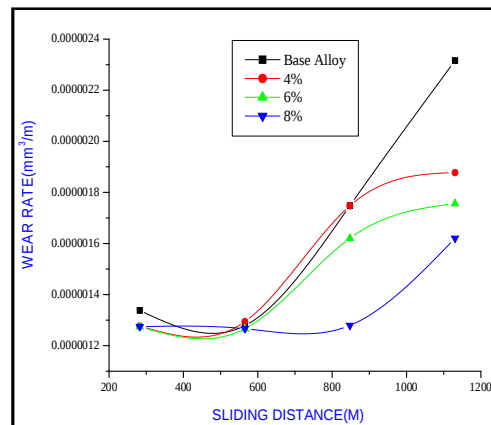


Fig 9: wear rate versus sliding distance

3.4.2 Effect of sliding speed

Another important factor that affects the wear performance is the sliding speed. The plots of wear rate versus sliding speed are as shown in figure 8. It is observed that the wear rate of aluminium matrix is found to increase significantly as speed increase, whereas in composite the wear rate is less when compare to aluminium matrix. . The sliding speed influences the wear mechanism strongly and at low sliding speed, the wear rate of the composites is lower. This may happen because at high speed, The micro thermal softening of matrix material may take place, which further, lowers the bonding effect of the reinforced particles with that of matrix material. At low speeds, the increase in strain rate results in increasing hardness or flow strength. This increase in flow strength reduced the true area of contact leading to low wear rates. However with high speeds, the increase in temperature due to frictional heating softened the material, increasing the true area of contact resulting in high wear rates.

3.4.3 Effect of sliding distance

It may seen from the figure 9 that for any given wear sliding distance the increased addition of B₄C particles results in a decrease in the wear rate of the specimen. It is observed that the wear rate is increases with increase in the sliding distance both in base matrix and the composites, but in composites the wear rate is less when compare to base matrix. This is due to the addition of hard B₄C particles.

3.5 Wear surfaces

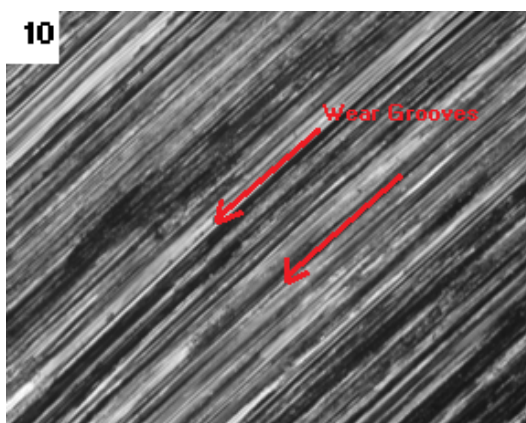


Fig 10: Grooves and scratch marks indicating abrasion wear.

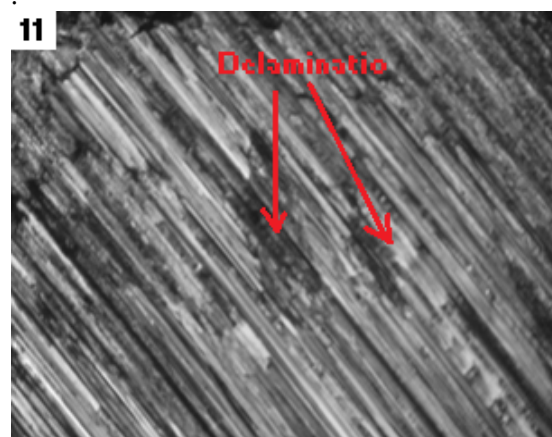


Fig11: Delamination of wear surface

Study of the wear surfaces of the pins reveals the wear type. Optical microscope is used to carry out the optical microscopy to observe the wear pin specimens. Optical micrographs are shown in Fig 10. Parallel grooves and scratches were observed in the direction of sliding, this is due to abrasion. It occurred primarily due to ploughing and wedge formation. Deep grooves and Delamination were also observed which is shown in fig 11. Adhesion wear was also observed in the materials at higher sliding speeds and loads. Under high loads, the protective layer of the reinforcing particles can no longer remain stable under the ploughing action. Material removal during the process is in the form of small pieces resulting in the formation of flake type debris.

3.6 XRD Analysis

The properties of the composites are influenced by the nature of the reinforcing material used. Hence there is a necessity to find out the presence reinforcing material in the composites. XRD studies have been used for this purpose. XRD spectrum confirms the presence of B_4C reinforcement within the matrix. Fig 12 shows the X ray diffraction pattern and results of Al 6061 alloy with 6 wt% B_4C . In X-ray diffraction pattern peaks have been observed in the ranging from 10° to 65° and the peaks at 2θ of 38.53° , 44.77° , 64.94° belongs to Aluminium and the peak at 2θ of 19.52° , 23.32° , 26.14° , 34.7° and 36.24° belongs to B_4C , the JCPDS card number of B_4C is 33-0225.

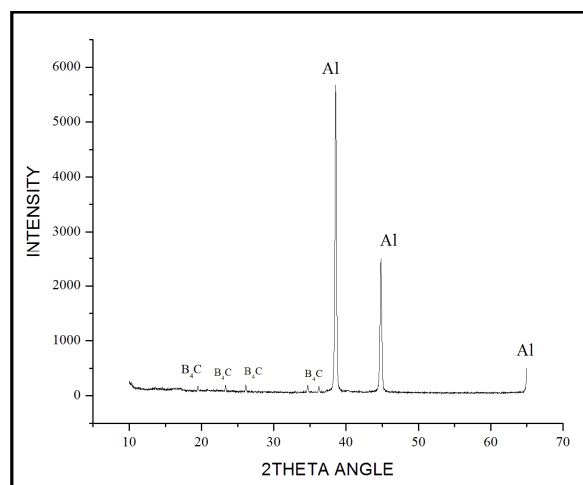


Fig 12: XRD pattern of Al6061- B_4C composites containing 6Wt% of B_4C

IV. CONCLUSIONS

The following conclusions can be drawn from the present investigation.

In this present work Synthesis of aluminium B_4C composites was completed successfully. Microstructure examination showed that the B_4C particulates distributed in the matrix and homogeneous particles of B_4C particles were seen. The micro hardness of the composite increased with respect to increase in the weight percentage of B_4C particles. The tensile strength of the composite increased with respect to increase in the weight percentage of B_4C particles. XRD analysis shows the presence of B_4C particles in the matrix. The wear rate is found to increase with load in all the materials studied. The increase in wear rate with load is more in the base alloy as compared to that of the composites. The increasing load is known to produce heating effect leading to thermal softening and seizure. Also it brings more area into sliding contact and thereby causes enhanced wear. The wear rate increases linearly with the increase in sliding speed and sliding distance However; the composites have shown a lower rate of wear as compared to that observed in aluminium matrix.

International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization

Volume 7, Special Issue 7, June 2018

One Day National Conference on "Recent Trends in Mechanical Engineering & Applied Sciences 2018"
(RTME & AS-2018)"

17th May 2018

Organized by

Department of Mechanical Engineering and Applied Science, Sri Krishna Institute of Technology, Bangalore, India

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