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Room Temperature Wear Behavior of 6061AL Alloy and Its Composite Prepared Through Three Stage Melt Stirring Process at 785ºc

Rajesh G L[1], Kushal K P[2], V Auradi[3]
R & D Centre, Department of Mechanical Engineering
Siddaganga Institute of Technology, Karnataka, India

Abstract--The paper reports on influence of boron carbide particulates addition on wear properties of 6061aluminum metal matrix fabricated via three stage stir casting. In order to facilitate the incorporation of B_4C_p into aluminum matrix, preheated potassium titanium fluoride flux with 0.25Ti/ B_4C_p ratio was added. Optical microphotographs show fairly uniform distribution of B_4C_p in aluminum matrix with no clustering. Mean micro hardness of 6061Al matrix was found 48.6% more upon addition of B_4Cp under 100grms load and 10seconds dwell time test condition carried out using micro Vickers hardness tester. Pin-On-Disk dry sliding wear tests at sliding speeds 6.67 r/s for normal loads varying from 9.81N to 68.67N were conducted at room temperature for pin specimens of as cast alloy and composite.6061Al alloy being softer, undergone severe plastic deformation when rubbed against 62HRC stainless steel disc at all normal loads. Combined effect of particles pullout, oxide layer formed and ceramic B_4C_p together has minimized direct contact of Al matrix with disc thereby reducing wear rate. The worn surface of composite was characterized by short grooves with small width at lower loads. The size and width of groove has increased with increase in normal load applied which were revealed in microphotographs. Mixed abrasive wear mechanism was observed after addition of 7 wt% of B_4C_p which indicates enhanced wear resistance of as cast 6061Al alloy
Keywords: Particulate MMC's; dry sliding; room temperature.

I. INTRODUCTION

The modern development in the field of science and technology demands the developments of advanced engineering materials for various engineering applications, especially in the field of transportation, aerospace and military engineering related areas. These area demands light weight high strength having good Tribological properties. Such demands can only be met by development and processing of composite materials. The main challenge in the development and processing of engineering materials is to control the microstructure , mechanical properties and cost of the product through optimizing the chemical composition ,processing method and heat treatment. This requires the sound theoretical and practical knowledge of the materials engineers. Composite materials often shortened to composites or composition materials are engineered or naturally occurring materials made from two or more constituent materials with significantly different physical or chemical properties which remain separate and distinct at the macroscopic or microscopic scale within the finished structure. A common example of a composite would be disc brake pads, which consists of hard ceramic particles embedded in soft metal matrix. Another example is found in shower stalls and bathtubs which are made of fibreglass. Imitation granite and cultured marble sinks and countertops are also widely used. The most advanced examples perform routinely on spacecraft in demanding environments. Composites are made up of individual materials referred to as constituent materials. There are two categories of constituent materials: matrix and reinforcement. At least one portion of each type is required. The matrix material surrounds and supports the reinforcement materials by maintaining their relative positions. The reinforcements impart their special mechanical and physical properties to enhance the matrix properties [1]. A synergism produces material properties unavailable from the individual constituent materials; while the wide variety of matrix and strengthening materials allows the designer of the product or structure to choose an optimum combination engineered composite materials must be formed to shape [1]. The matrix material can be introduced to the reinforcement before or after the reinforcement material is placed into the mould cavity or onto the mould surface. The matrix material experiences a melding event, after which the part shape is essentially set. Depending upon the nature of the matrix material, this melding event can occur in various ways such as chemical polymerization or solidification from the melted state [1]. Metal matrix composites are composed of an element or an alloy matrix in which a second phase is embedded and distributed to achieve some property improvement. They have outstanding benefits due to the combined metallic and non-metallic properties, there by yielding improved physical and chemical properties. Among the various types of MMC's, particulate reinforced composites are the most versatile and economic one. MMC attributes include alterations in mechanical behaviour and physical properties by reinforced filler phase. Metal matrix composites are increasingly found in the mobile industry, these materials use a metal such as aluminium as a matrix, and reinforce with fibres. Al6061 metal matrix composites have been several applications like in automotive and aerospace industries several technical challenges exist with casting technology. The common one is high manufacturing cost. Achieving a uniform distribution of reinforcement with the matrix is one such challenge, which directly effects on the properties and quality of composites. The best part of effort in Al matrix composite has been directed towards development of high performance composite with high strength and good Tribological properties for using in automotive and aerospace application The Al matrix composite reinforced with SiC and B_4C particulate are a new range of advanced materials. In general, a hard material is employed as reinforcement because of potential improvement in mechanical properties such as hardness and tensile strength which are the desirable properties in Tribological application [1]. This greatest improvement in mechanical properties is generally obtained by means of reinforcement with appropriate particulates. The sliding wear of the composite is a complex process involving not only mechanical but also thermal and chemical interaction between two surfaces in contact. Our present interest is on evaluating mechanical and wear behaviour of Al matrix composites reinforced with boron carbide particulates produced by liquid metallurgy route.

II. LITERATURE REVIEW

Substantial literature has been studied on metal matrix composite, Aluminum, boron carbide, and liquid metallurgy methods. The review is organized chronologically to offer sight to how past research efforts have laid the groundwork for subsequent studies, including the present research effort. **Danny C.Halverson** *et.al* [2] explains about the processing of Boron Carbide –Aluminum composite. He states that, in these materials chemical reactions occur between 800°C and 1400°C. The interfacial reactions are the driving force for the wetting of B_4C by molten aluminum and also these chemical reactions cannot be eliminated, and it is necessary to process B_4C-Al by rapidly heating to near 1200°C to ensure proper wetting. **Isil Kerti** *et.al* [3] says it is possible to produce Al-B_4C composite with homogenous microstructure using K_2TiF_6 flux by stir casting method and addition of B_4C particles with bigger particle size(>20μm) results in more homogeneous composite microstructure compared to the composite samples containing smaller particle size of B_4C(<10μm) due to agglomeration. **K.Kalaiselvan** *et.al* [4] investigated that the mechanical properties like hardness and tensile strength have improved with the increase in weight percentage of B_4C particulates in the aluminum matrix. **A.R. Kennedy** *et.al* [5] has found that B_4C particles can be introduced into molten Al if a flux containing Ti is used .The number of particles transferred to the melt depends upon the level of Ti present in the flux, a higher Ti level resulting in increased particle transfer. **T.R Chapman** *et al* [6] did work on wear resistant properties of aluminum-boron carbide cermets. They states that these materials exhibited wear rate more than an order of magnitude lower than current asbestos and semimetallic materials.

III. EXPERIMENTAL PROCEDURE

A. Fabrication Process

The proposed AMC was produced using 6061 Al alloy as a matrix material having the chemical composition as shown in Table 1. The chemical analysis was carried out using Atomic Absorption Spectroscopy (VARIAN model, Netherlands). The composites were produced by conventional method of stir-casting with a novel three stage mixing combined with preheating of the particles. Since, the wettability B_4C_p with Al matrix is poor; halide salt (Potassium titanium fluoride) is added as flux to the melt during stir casting process to improve wettability. Melting of aluminum alloy matrix is carried out in an electrical resistance furnace. The alloy is super-heated to 785°C and temperature was controlled to an accuracy of $\pm 1^0$C using digital temperature controller. Once the required temperature is reached, the melt is agitated with the help of a zirconia coated stirrer to form a fine vortex at 300rpm. Mixtures of preheated B_4C (200°C for 1hour) particles with an equivalent amount of Potassium titanium fluoride flux (with 0.25Ti/B_4C ratio) was added at a constant feed rate of 0.4-1.0g/s. After stirring the molten mixture, it was poured down into the preheated permanent CI mold. The AMCs having 0 & 7 weight percentages of B_4C_p were fabricated by the same procedure.

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Table-1: Shows chemical composition of 6061Al alloy Matrix used in the present study analyzed using Atomic Absorption Spectroscopy (VARIAN model, Netherlands)

Elements	Mg	Si	Fe	Cu	Mn	Cr	Zn	Ti	Al
% by Weight	0.95	0.54	0.22	0.17	0.13	0.09	0.08	0.01	Bal

B. Material Characterization

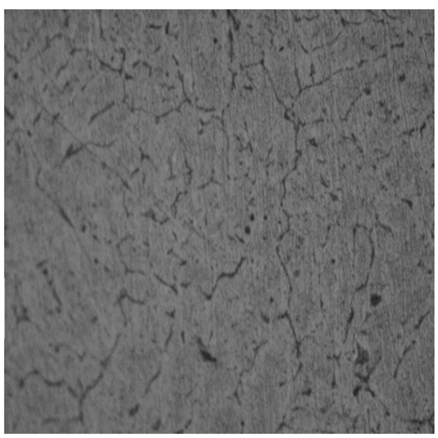
Micro structural characterization of the prepared composites was carried out using optical microscope in order to ensure dispersion and distribution of B_4C_p in 6061 Al matrix. For this purpose specimens were cut from center of the casting and were polished as per the standard metallographic procedure and were etched using Keller's reagent. The microstructures of etched specimens were recorded using an optical microscope (Olympus Microscope) attached with CCD camera. Micro-hardness measurements were carried out on the prepared composites. For this specimen of dimensions 12.5mm diameter and 10 mm length was taken from the castings and is polished using metallographic procedure till mirror finish surface is obtained. The micro hardness of polished samples was measured using micro-Vickers hardness tester (ZWICK Tester) with a load of 100g and dwell time of 10 sec. The hardness measurements were carried out at 30 different locations and average of 100 readings was reported. Dry sliding wear tests for different number of specimens were conducted by using a pin-on-disc machine. The pin was held against the counter face of a rotating disc (EN32 steel disc) with wear track diameter 90mm. The pin was loaded against the disc through a dead weight loading system. The dimensions of pin samples were 30 mm in length and 10 mm in diameter. The surfaces of the pin samples was slides using emery paper (80 grit size) prior to test in ordered to ensure effective contact of fresh and flat surface with the steel disc. The samples and wear track were cleaned with acetone and weighed (up to an accuracy of 0.001 gm using electrical balance) prior to and after each test. Dry sliding wear tests at sliding speed of 6.67 r/s under loads ranging from 9.81N to 68.67N for sliding distance of 565.4m were carried out for pin specimens of 6061Al-B_4C_p composites and base alloy at room temperature.

IV. RESULTS AND DISCUSSION

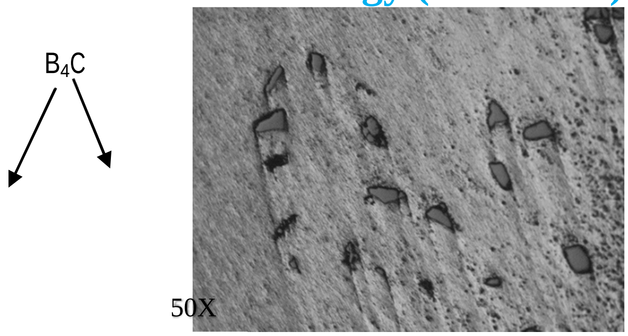
A. Microstructure

Fig1 (a-b) shows the optical microphotographs of as cast 6061Al alloy and 6061Al-7wt%B_4C_p composites. The addition of K_2TiF_6 flux has improved the wettability of B_4C particle in 6061Al matrix. The flux reacts on the melted surface of B_4C particle and produces Ti compounds around the surface of B_4C particles. This reaction is exothermic in nature and heat is evolved in the vicinity of B_4C particle–melt interface. This local increase in temperature enhances the incorporation of particles into the melt and bonding with the matrix. From figure 1 it is clear that B_4C_p particulates are fairly distributed in 6061aluminum matrix.

50X



(a)



(b)

Fig-1: Shows optical images of (a)as cast 6061Al alloy (b) 6061Al alloy reinforced with boron carbide particulates produced at 785ºC through three stage stir casting.

B. Hardness Measurement

Figure 2 clearly reveals that addition of B_4C_p to 6061Al matrix has resulted in improvement in hardness of the matrix.

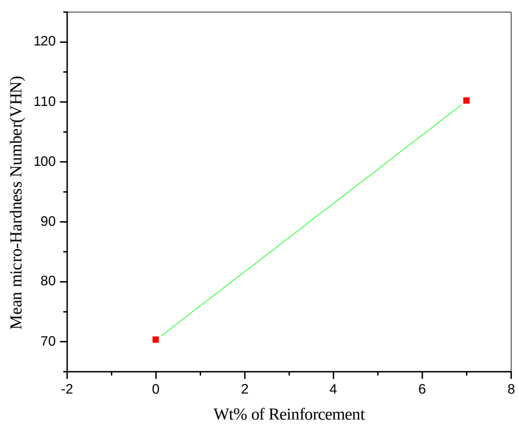


Fig-2: Showing micro-Vickers hardness test results of 0 & 7wt% B_4C_p composites.

The increase in hardness is mainly due to particulate strengthening effect. The presence of B_4C particles in the Al matrix hinders the movement of dislocations thereby pile of dislocations takes place. The pile up of dislocations is causing increase in hardness. Also, addition of reinforcement particles to the matrix increases the surface area of the reinforcement and the matrix grain sizes are reduced. The presence of such hard surface area of particles offers more resistance to plastic deformation which leads to increase in the hardness of composites.

C. Wear Studies

In order to study wear properties of the prepared composites, the tests were conducted using Pin-On-Disc wear and friction testing machine (Ducom, Bangalore, India) under ambient test conditions (room temperature with moderate humidity)

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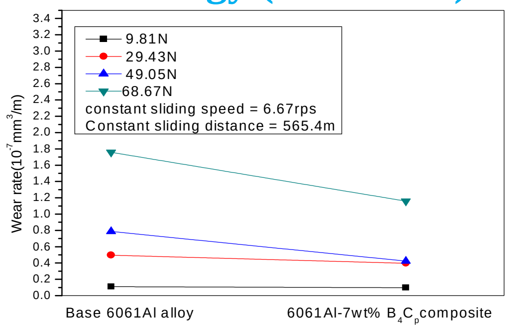
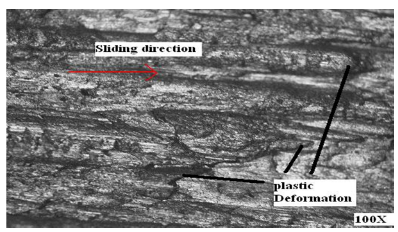


Fig-3: Graphs shows effect of varying load on as cast 6061Al alloy and 6061Al alloy reinforced B_4C_p particulate composite prepared at 785ºC through three stage stir casting**.**

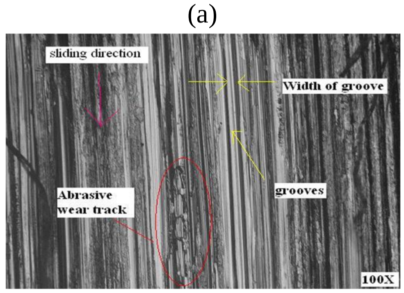
Wear loss was increased with increase in load for 6061 Al alloy at all normal loads whereas there was decrease in wear rate of 6061 Al -7wt%B_4C_p composites with increase in load compared to as cast Al alloy(figure 3). In case of as cast 6061 Al alloy, pressure exerted on specimen tip causes severe plastic deformation resulting in material removal at faster rate. But due to presence of hard ceramic reinforcement B_4C_p in Al matrix, reduces the direct metal to metal contact by generating tribolayers (consisting of pulled out particles, oxide layers and ceramic reinforcement) leading to lower wear rate of 6061Al matrix as revealed in figure 3.

D. Worn Surface Studies

Optical micrographs of unreinforced and reinforced Al alloy with 7wt% B_4C_p, composites at the sliding speed of 6.67rps and normal load of 49.09N are shown in the figure 4(a-b). The unreinforced alloy depicts high wear as compared to reinforced condition due to severe plastic deformation (figure 4(a)), whereas composite showed medium size grooves with smaller width (figure 4(b) indicating abrasive wear.



(a)



(b)

Fig- 4: Worn surface images of (a) Base 6061Al alloy (b) 6061Al-6wt% B_4C_p composite sliding at 6.67rps with 49.05N for 565.4m against stainless steel disc.

Thus, addition of hard boron carbide particulates improves wear resistance in ductile 6061Al matrix as evident from worn surface morphology.

E. Wear Debris Morphology

The debris collected from the samples was characterized morphologically. The non-reinforced alloy does not produce debris in plate form while 6061 Al -7wt%B_4C_p composites produce mixed type of debris. Moreover, the size of the debris collected from unreinforced Al alloys tends to be bigger because of surface delamination than the debris from the 6061Al-7wt%B_4C_p composites as

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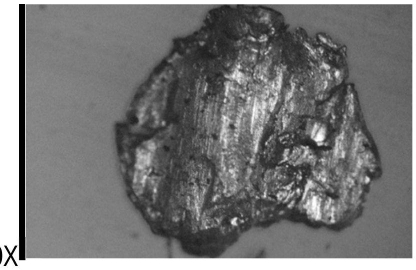
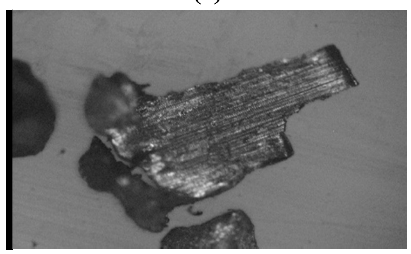
shown in figure 5(a-b).

Small sized debris with abrasion grooves (figure 5(b)) were generated during composite sliding which indicates better wear resistance of composite against steel disc.



50X

(a)



50X (b)

Fig- 5: Optical images showing wear debris of (a) 6061Al alloy (b) 6061Al-7wt% B_4C_p composite sliding at 6.67rps with 49.05N for 565.4m against stainless steel disc.

V. CONCLUSIONS

The 6061Al–B_4C_p composites were produced by stir cast route with 6 weight percentage of reinforcement and the microstructure, hardness and wear properties were evaluated. From this study, the following conclusions are derived.

Fabrication of 6061Al–7wt%B_4C_pcomposites at 785ºC through three stage stir casting was successful.

The Optical microphotographs revealed the fairly uniform distribution of B_4C particles in the 6061Al matrix. Addition of potassium titanium fluorite halide salt (ratio of 0.25) to 6061Al matrix has improved wettability of B_4C particles in the matrix alloy

Mean micro-hardness of 6061Al matrix was 48.6% increased upon addition of B_4C particles.

In case of as cast 6061 Al alloy, with increase in normal load applied wear rate has increased due to severe plastic deformation indicating adhesive wear behavior. Wear rate of composite containing 7 wt% of boron carbide was lower due to formation of tribolayers at pin disc interface thereby reducing less exposure of pin surface with hard steel disc.

Worn surfaces of 6061 Al - 7wt% B_4C_p showed medium size smaller width abrasion grooves, whereas surface delamination behavior were observed for as cast Al alloy.

Larger size wear debris were obtained for 6061Al alloy with increase in normal load applied. Abrasion grooves on the small sized wear debris of composite was observed which indicates abrasive wear mechanism.

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