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Effect of Boron Carbide on Tribological properties of Zinc Aluminium Metal matrix composites

Puneeth Kumar MV, T Krishna Rao, Manohar H S, Bharath V

Abstract: ***Metal-Matrix Composites (MMCs) are novel composite materials in which nano/micro-phase such as particles or rods like structured materials are reinforced with metals or alloys to improve the physical, mechanical, wear and other properties. The results of previous works have shown that the addition of B_4C reinforcement to aluminium alloys has improved the hardness, tensile strength and Young's modulus. Hence, the present work is focused on development and characterization of B_4C reinforced MMCs. evaluating the outcome of the reinforcement on the physical properties such as wear property studies were carried out. The wear results exhibited reduction in wear volume compared to the unreinforced alloy samples and the coefficient of friction is beneath at lofty loads.***

Keywords: ***Zinc Aluminium metal-matrix composites, Machinability, Wear properties, Boron Carbide.***

I. INTRODUCTION

Present day innovation has put an expanding request on materials. The necessity for better materials is especially more in the field of structures exposed to dynamic loads, where high quality as well as low density is the primary criteria. The performance of components in space, aircraft, high-speed machining tools, energy generation and aerospace can be increased by enhancing the productivity of the materials. Thus, plainly mechanical improvements in different fields rely upon the advances made in the field of materials. [2]

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The investigation on MMCs has turned into a significant region of research in the material world. For the most part man made materials are mixed, which may have two or more extraordinary phases those have constrained together. The preliminary phase is called the matrix material, which possess a material with lower density, for example, aluminium, titanium, steel and so on. The subordinate phase is the reinforcement, which are usually particulates, whiskers and fibers.

Hence the composite material has significantly better mechanical properties and higher execution than any single material from which it is framed.

Aluminum alloy composites as a substitute of monolithic aluminum alloy in structural applications, is becoming gradually attractive due to their greater strength, and stiffness, which is combined with their good performance in fatigue and wear [3-4]. The application of aluminum reinforced with B4C , SiC and Gr particles is in automotive industry for part like pistons, engine blocks, brake rotors, drums, calipers, connecting rods, drive shafts, where the mechanical and tribological [5-7].

II. COMPOSITE PREPERATION

In the present research work, ZA43/B_4C MMCs have been prepared by liquid metallurgical technique. The furnace used for the synthesis of the Al / B_4C particulate composite is basically an electrically heated three phase resistance furnace of 12 KW capacity as in fig.1 with grade-heating coils and reaches maximum temperature of 1200 ^{0}C (± 5 ^{0}C accuracy).

The heating rate of the furnace is 25 ^{0}C per min. B4C particulates were preheated to remove moisture content and minimize the thermal gradient between the matrix and reinforcement by using a muffle furnace at a temperature of 500 0C. The melting temperature of Al alloy is 670 - 725 0C. A known quantity of the Al alloy ingots are cleaned with NaOH (10%) solution for ten minutes at room temperature, it removes impurity, grease and dust from the surface of the ingots.

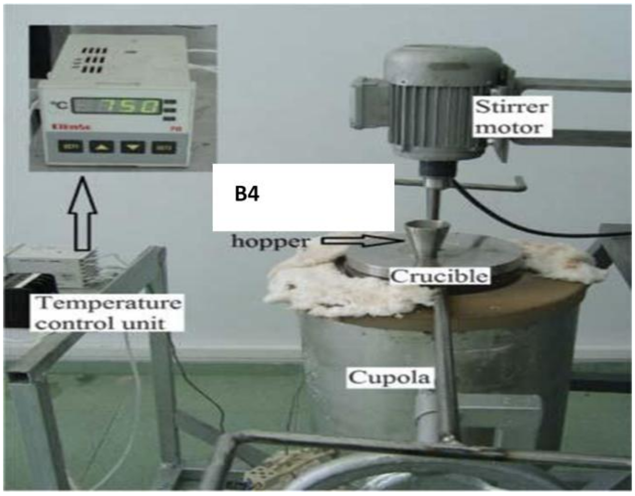

Fig.1 Furnace along with mechanical stirrer

The washed and dried ingots placed in the alumina crucible for melting and heated for about 700 0 C .The liquid melt was degassed by flowing nitrogen gas for 1 min at a rate of 1000 cc/ minutes. Preheated B4C was poured into the molten liquid uniformly during into the vortex and stirred using a mechanical stirrer for ten minutes. The mixture of both B4C and ZA43 melts was poured into the metallic die and then allowed to cool until the room temperature. Specimens were machined for given dimensions from the readied castings All specimens were cleaned for smooth surface completion with various grits of silicon carbide papers..

Fig.2 Casting Procedure for ZA43/B_4C composites

III. CHARACTERIZATION

In the present work, microstructural characterization of the ZA43 matrix alloy and ZA43/B4C MMCs were done. A detailed study in optical microscopy has been carried out using Scanning Electron Micrographs (SEM), in order to locate the particulate distribution in the composites. The specimens after sectioning were subjected to rough grinding, polishing and then with etching as per ASTM E3 standards. After usual machining and grinding, polishing was done by holding the specimen close by and scouring easily against the papers upheld on a level surface. As Al alloys are relatively soft, adequate consideration was taken to stay away from any profound scratch being shaped at the cross-section are comparatively soft, Reflection type optical microscope fitted with a camera was used to take the micrographs of the samples. The magnification used was x250 [8].

Fig. 3. Pin-on-disc Wear test rig.

The pin on disc wear machine was carry out the friction and wear tests shown in Fig.3. The tester is capable of testing friction and wear properties of lubricated or dry surfaces of various materials and coatings. The tester model was TR-20 which is DUCOM make (as per ASTM G 99 standard). The specimen pin was fixed on to the rotating disc with wear track diameter of 100 mm and was loaded through a weight loading system. The wear and friction test was performed on all the specimens for loads of 10, 20 and 30 N and with rotational speeds of 200, 300 and 400 rpm. The machine run time was set based on the speed selected. The pin weight was measured before and after each test to calculate the loss in the composite weight. The wear and friction force displayed on the monitor was noted down for further calculations. The surface morphology was studied under SEM

IV. RESULTS AND DISCUSSION

The prepared ZA43/B4C composites were analyzed using optical microscopy for better understanding microstructural parameters, and also extended the same work for wear studies. Analyzing the composites provides a basis for comparison between matrix alloy and reinforcement in order to better understanding the effects of B4C reinforcement on properties of the composites.

A. Microstructure Studies

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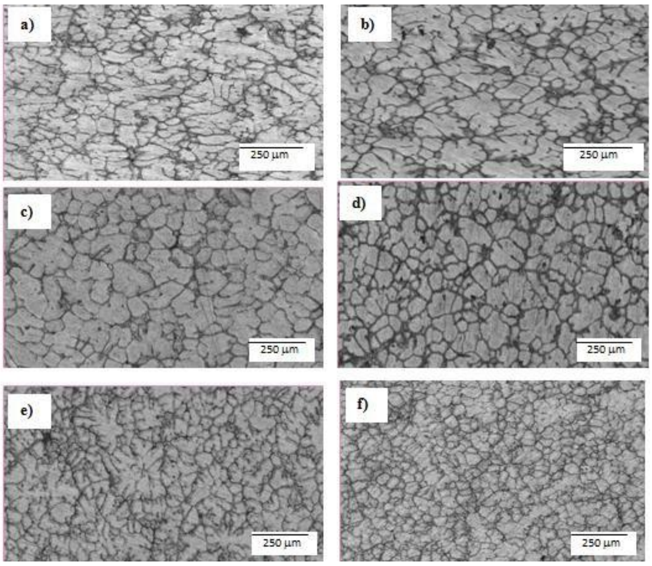

Fig.4.Micrographs of ZA43/B$_4$C composites at different reinforcements a) as cast, b) 2%, c) 4 %, d) 6%, e) 8 % and f) 10% of B$_4$C.

Figure. 4 show the microstructure of ZA43/B4C composites with different percentage of B4C for a particle size of 60 µm. The size of the B4C is in micrometer, it is very difficult to observe under optical microscope and even scanning electron microscope, and some voids are absorbed along with some black marks.

B. Wear Properties

The introduction of B$_4$C powder into ZA43 alloy definitely enhances its wear resistance of the mating surface. The influence of both wear load and wear speed were studied as a function of B$_4$C content.

- *Effect of Load and Sliding Speed on Wear Rate*

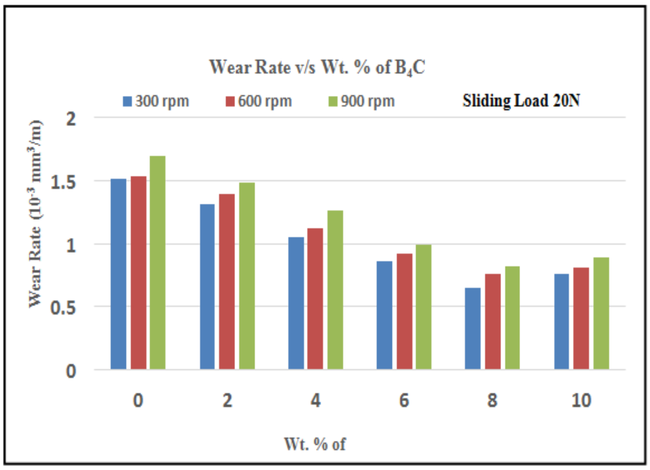

Fig. 5 Effect of wt. % of B$_4$C and sliding speed on wear behavior of the ZA43/B$_4$C composites at 20N

Keeping other conditions same, ZA43 varying percentage of B4C particulate dispersed in different directions were assessed for wear resistance compared to the base matrix without dispersion. As cast specimens were also included for testing. The wear rate in terms of weight loss / m for composites containing 0, 2, 4, 6,8 and 10 wt.% of Boron Carbide respectively is ascast condition .

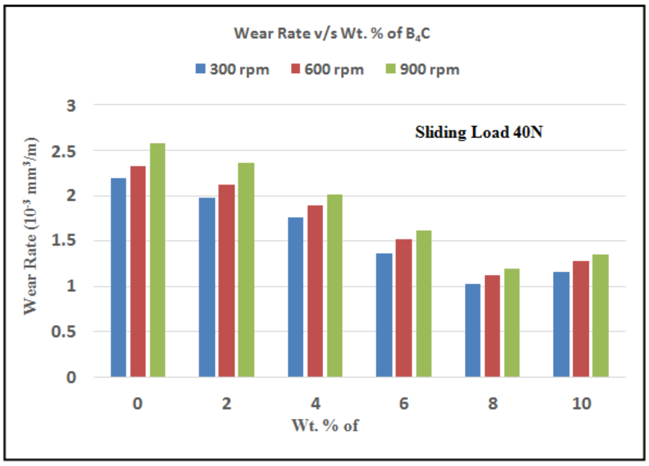

Fig.6 Effect of wt. % of B$_4$C and sliding speed on wear behavior of the ZA43/B$_4$C composites at 40N

The data recorded on wear rate of ZA43/ B4C reinforced metal matrix composites at different loads(20N and 40N), different speeds (300, 600 and 900 rpm) and at different Wt.% of Boron Carbide added to the ZA43 Alloy as reinforcement is presented. It could be seen from the data that as the wt.% of Tungsten Disulfide added to the Al Alloy as reinforcement material the wear rate of the composite material decreases irrespective of increasing load and sliding speed up to 8 wt.% of Boron Carbide (B4C). But there is an increase in the wear rate for 10 wt% of Tungsten Disulfide.

- *Effect of Tungsten Disulfide (WS2) on the Wear*

The causes of Boron Carbide (B$_4$C) on the wear characteristics of ZA43/ B$_4$C particulate for a wear test rotational speed of 300, 600 and 900 rpm and loads of 20, and 40N is shown in Figs 5 and 6, which are shown in graphs plotted based on wear rate results. The following is disclosed by the study of these Figures. The wear rate of the ZA43/ B$_4$C composites depend on the % of Boron Carbide (B$_4$C) is scattered. The wear rate was found by decrease with the increase in Boron Carbide (B$_4$C) content from 2 to 8 wt.%. but there is a result of increase in wear rate for the 10 wt.% of Boron Carbide (B$_4$C) when compared with the 8 wt.% reinforcement. The weight rate is minimum for the composite containing 8 wt. % Boron Carbide (B$_4$C) dispersoid in the as cast as observed. The wear rate remained almost constant at lower loads with increase in rpm. Comparatively, light wear rate was shown by ZA43 without dispersoid but steadily this loss decreased. Perhaps, due to hard particles of Boron Carbide (B$_4$C) dispersed in the base matrix there is relatively rapid attainment of stability in the wear resistance, as seen. As Boron Carbide (B$_4$C) reinforced Al composites show predominantly improves in the wear resistance of Al composites at all circumstances. Due to the adhesive property of aluminum and ferrous, the aluminum sticks on the wear disc during the sliding contact. The incorporation of ceramic into the metal or alloy resulting in reducing the adhesive properties of composites hence lower Al materials transfer to ferrous disc [9].

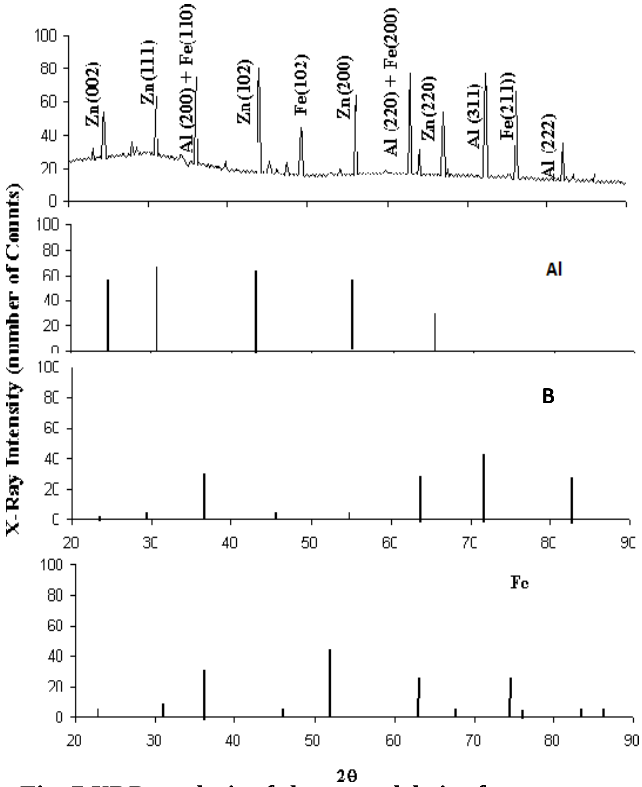

Fig. 7 XRD analysis of the wear debris of ZA43/B_4C Composites at 5 ms^{-1} and load of 50 N

If MML layer was removed from the specimen due to high temperature and higher shear force, exposing the fresh material from the specimen for further wear. The removal of MML is possible, if only there is discontinuous and lesser adhesive in nature. It was observed that MML hardness is better than the substrate; the MML exhibits the hardness approximately 6 times more when compared to that of the bulk composites [10]. Therefore, the MML will have a strong influence on wear rates. In severe wear huge material loss was observed at higher sliding and wears loading condition but these conditions are depending on B4C content in the composites. The sever materials of the wear pin transfer to the counter surface (wear disc) was seen. This indicate even stronger MML layer unable to protect the wear surface of the pin due to higher temperature and centrifugal force. At higher temperature and high speed, the material losses its adhesive property and high speed thrown outside the material due to its higher centrifugal force [11]. The dark line shows boundary between mild wear and severe wear regime, this has been drawn as per weight loss of the material during sliding wear at same condition. Below the transition boundary, the presence of the MML and B_4C in the wear track played a vital role in the dry sliding wear and it has been reported to be beneficial in reducing the wear rate and wear transition for Al matrix composites reinforced with B_4C particles sliding against steels.

V. CONCLUSION

In this paper, materials selection, preparation and micro structural characterization for the ZA43/B4C composites were studied. A homogeneous mixture of B4C powder was made by mixing 0–10 wt.% B4C with solution by ultrasonication followed by drying using a magnetic stirrer. It was observed that the distribution of B4C particles in the matrix was even without any visible accumulation. It was noticed that there was an increase in density of the MMCs with the increase in the weight percentage of the reinforcement. Dry sliding wear tests were ZA43/B4C composites using a pin on disc wear testing machine. Sliding velocity related transition wear has been studied. The sliding wear behaviour of the both reinforced composites and matrix alloy can be classified into two main wear regimes, namely a mild wear regime (steady state wear) and a sever wear regime (large and non steady state wear). Wear rates of both as cast and ZA43/B4C composite in steady state regime, were somewhat contrast in extent, composites have marginally lower wear rate than that of the unreinforced composites. Wear debris created from both sort of materials was little in measurement and dim in shading, the bulk of the debris being mostly metallic oxidizes is called MML. Wear rates of the reinforced materials were lower than for the unreinforced matrix at wear transition region. The raised wear rates were kept up just by the unreinforced alloy, while much diminished wear rates were seen with the reinforced composites. Serious wear is described by an immense plastic deformation because of thermal softening of the material. Extreme wear is related with delamination of composites layer contiguous contact surfaces bringing about plate-like debris particles. B4C particles not just lesser the wear rate likewise defer the transition to serious wear.

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