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Effect of Addition of Reinforcement on Tribological Properties of Al7050/B_4C Metal Matrix Composites

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Abstract: In the present study, an effort has been made to develop and study the tribological properties of Al7050-B_4C metal matrix composites. The composites were prepared by stir casting route (liquid metallurgical technique) in which amount of reinforcement is varied from 2-8 wt% in steps of 2 wt%. In case of each prepared composites of Al7050-B_4C, the reinforcement particles were pre-heated to a temperature of $500^OC$and mixed with Potassium titanium fluoride before adding into the vortex of the molten metal to improve wettability and distribution. The microstructural studies were carried out using scanning electron microscope which shows the uniform distribution of B_4C particulates in the matrix alloy. EDS analysis will be carried out to analyse the microstructure and the dispersion of the reinforced particles in the alloy matrix. The wear rate of the Al7050-B_4C composites depend on the % of B_4C dispersion. The wear rate was found to decrease with the increase in B4C content when from 2 % to 8 % the B4C, and also for the same percentage of B_4C, it is observed that wear rate increases as the load and sliding speed increases.

Keywords: l7050 alloy, B_4C Microstructure, wear rate, sliding speed.

I INTRODUCTION

Aluminium metal matrix composites (AMMCs) have considerable applications in aerospace, automotive and military industries due to their high strength to wear ratio, stiffness, light weight, good wear resistance and improvedthermal and electrical properties [1-2]. Ceramic particles such as Al_2O_3, SiC are the most widely used materials for reinforcement of aluminium. Boron carbide (B_4C) could be an alternative to SiC and Al_2O_3 due to its high hardness (the third hardest material after diamond and boron nitride). Boron carbide has attractive properties like high strength, low density (2.52 g/cm^3), extremely high hardness, good wear resistance and good chemical stability [3]. There has been an increasing interest in composites containing low density [4].

Suggested applications for Al-B4C composites include their use as structural neutron absorber, armour plate materials and as a substrate material for computer hard disks. [5]. Aluminium matrix composites (AMMCs) are emerging as advance engineering materials due to their strength, ductility and toughness. The aluminium matrix can be strengthened by reinforcing with hard ceramic particles like SiC, Al2O3, B4C etc. Wear resistance is an important function in the balance of properties provided by MMCs. The addition of hard reinforcements intrinsically improves the wear resistance of the host metal [6-7]. Further, additions such as graphite along with SiC, B_4C, and Al_2O_3 provide intrinsic lubricity. MMC materials have been engineered to provide exceptional wear resistance and represent an important family of applications.

Although much of the early work on Al-MMCs concentrated on continuous fiber types, most of the present work focused on discontinuously reinforced Al-MMCs because of their greater ease of manufacturing, lower production costs, and relatively isotropic properties [8]. Hard ceramic particulates such as zirconia, alumina and SiC have been introduced into aluminium based matrix in order to increase the strength, stiffness, wear resistance, fatigue resistance. Among these reinforcements B_4C is compatible with aluminium and forms good bond with the matrix.

II EXPERIMENTAL DETAILS

A. SELECTION OF MATERIALS

Matrix metal

Al 7050 will be used as Matrix alloy due to its excellent casting properties, reasonable strength and its suitability for mass production.

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Table 1. Chemical Composition of Al7050

Element		Composition
Silicon	Si	0.12
Iron	Fe	0.15
Copper	Cu	2.6
Manganese	Mn	0.10
Magnesium	Mg	2.6
Chromium	Cr	0.04
Zinc	Zn	6.5
Aluminium	Al (Balance)	87.89

Reinforcement

A limited research work has been reported on AMMC reinforced with B_4C due to higher raw material cost and poor wetting. B_4C is a robust material having excellent chemical and thermal stability, high hardness and low density (2.52 g/cm^3) and it is used for manufacturing bullet proof vests, Armor tank etc. Hence, B4C reinforced aluminium matrix composite has gained more attraction with low cost casting route, Boron Carbide (B_4C) of 40-micron particle sizes was used as reinforced materials.

B. COMPOSITE PREPARATION

The aluminium alloy Al7050 was melted in a graphite crucible using an electrical resistance-heated laboratory furnace. The temperature will be raised more than recrystallization and the melt will be stirred using a graphite impeller. After specified time, a specific quantity of pre heated B_4C particles upto 500^0Cwas mixed along with Potassium titanium fluoride to improve wettability and distribution, and the mix was added to the matrix alloy at a low rate for about 5 minutes while stirring will be continued. Once the required temperature is achieved, degassing is carried out using solid degasser 190 to expel all the absorbed gases. The slurry will be allowed to mix isothermally for another 15 minutes, then the impeller will be taken out and the composite slurry will be poured into metallic molds. The produced ingots will be cut into definite size and shape. The process is repeated for different wt% of B_4C.

C. SPECIMEN PREPARATION FOR MICROSTRUCTURE AND EDS

Sectioning

Specimens were removed from the metal mass by specimen cutter, care was taken to prevent cold working of the metal, which can alter the microstructural and complicate interpretation of constituents.

Grinding

The rough polishing was done by series of abrasive belts made up of SiC sand belts. The polishing specimen was done in two stages, rough polishing and finish polishing. For rough polishing, emery belts of 100, 200, 400, 600, and 1200 (0-emery paper) were rotated on 500–600 rpm.

Polishing machine wheels are used for both polishing stages consists of a medium-nap cloth (washable cotton), a suspension of MgO size of 5 µm particles mixed in distilled water (50 g per 500 ml ofH_2O) was used on the wheel for smooth polishing.

Finally, for finish polishing, a diamond paste (1 µm) was used on the wheel.The specimen also rotated about its own axis across the face of the polishing wheel. And cleaned with alcohol then dried and finally etched by using acetic glycol. Metallographic test samples of 5mm thickness were obtained by as cast and B_4C reinforced Al7050 alloy.

D. TESTING

The microstructure was observed using a scanning electron microscope. The wear specimens were tested under dry conditions in accordance with ASTM G99 standard using an pin-on-disc sliding wear testing machine. Specimen size 8mm dia x 15 mm length, the apparatus consists of an EN24 steel (BHN 229) disc of diameter 200 mm used as counter face. In the present investigation, normal loads of 20N, 30N, 40N, 50N and 60N respectively were applied on the specimen and the speed of the rotating wheel was varied from 200 to 500 rpm in steps of 100 rpm. A standard test procedure was employed for each specimen as follows:

III RESULTS AND DISCUSSION

A. MICROSTRUCTURE STUDIES

Figure 1 (a-e) shows the SEM microphotographs of Al7050 as cast aluminium alloy and Al7050 with 2, 4,6 and 8 wt. % of B4C particulate composites. In the figures it shows that there is the uniform distribution of B4C particles and very

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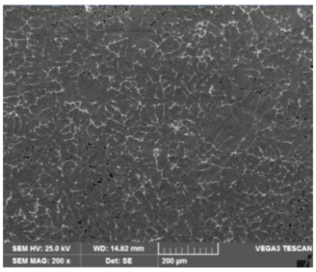
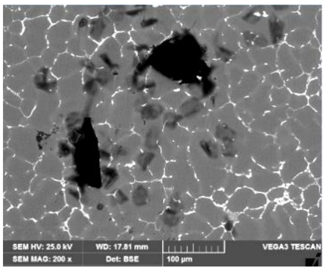
low agglomeration and segregation of particles, and porosity. Figure 1(b-c) clearly show and even distribution of B4C particles in the Al7050 aluminium alloy matrix. In other words, no clustering of B4C particle is evident.



(a)



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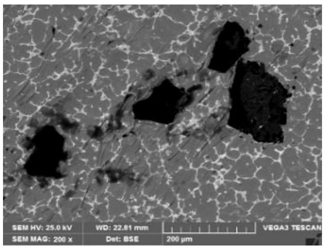

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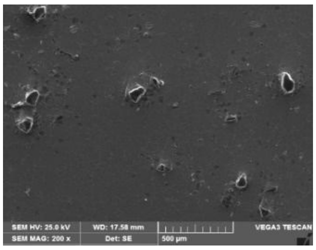

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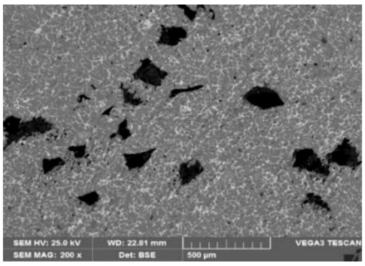
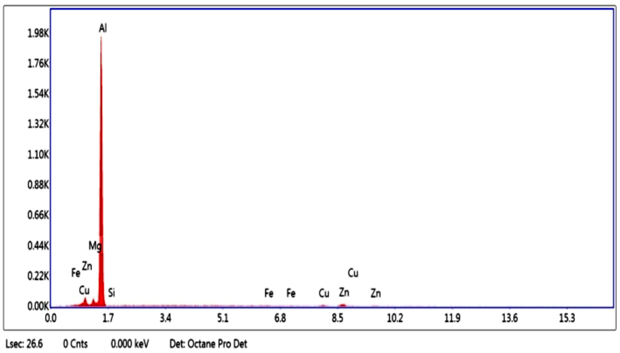
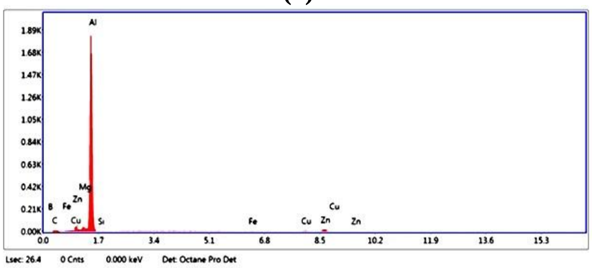


(e)

Figure 1: Shows the SEM microphotograph of (a) as cast Al7050 alloy (b) Al7050-2% B4C (c) Al7050-4% B4C (d) Al7050-6% B4C. (e) Al7050-8% B4C



(a)



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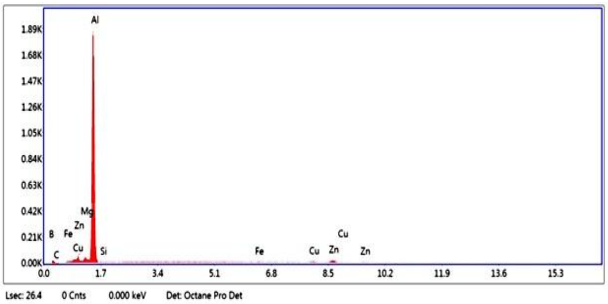

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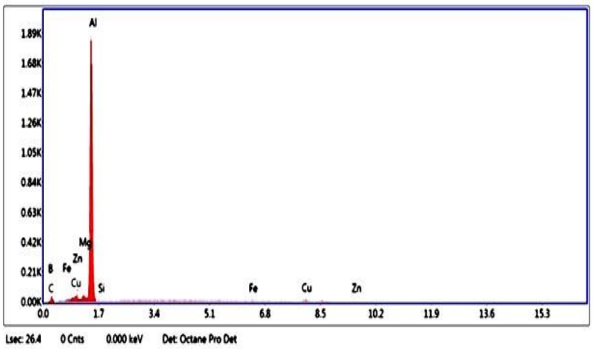

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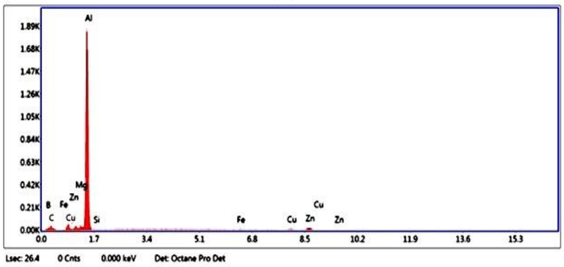

(e)

Figure 2: EDS analysis of Al7050 alloy and 2-8 wt.% B_4C Composite

Figure 2(a-e) shows the energy dispersive X-Ray spectrograph of Al7050 and Al7050-(2 to 8) wt. % of B_4C Composites. The EDS analysis confirmed the presence of B_4C particulates in Al matrix alloy. The presence of B_4C shows in the form of B(boron) and C(carbon), which is evident from the EDS spectrum.

B. WEAR BEHAVIOR OF AL7050 & B4C (40 MICRONS PARTICLE SIZE)

Keeping other conditions same, Al varying percentage of B_4C 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. Wear rate results in terms of weight loss / km (with respect to the original weight of the specimens) for composites containing 0%, 2%, 4% 6% and 8 % B_4C respectively is as cast condition are shown in below Graphs.

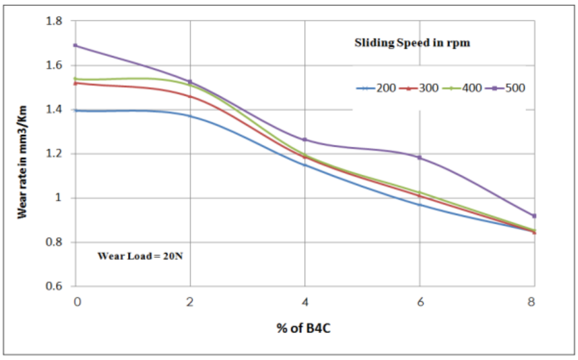

Figure 3a: Effect of wt% of B_4C and sliding speed on wear behaviour of Al/B_4C composites at 20N

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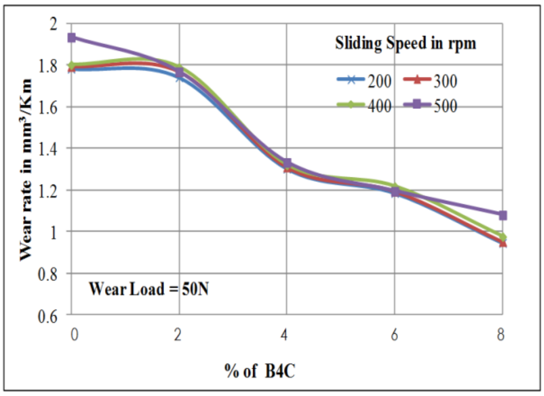

Figure 3b: Effect of wt% of B_4C and sliding speed on wear behaviour of Al/B_4C composites at 30N

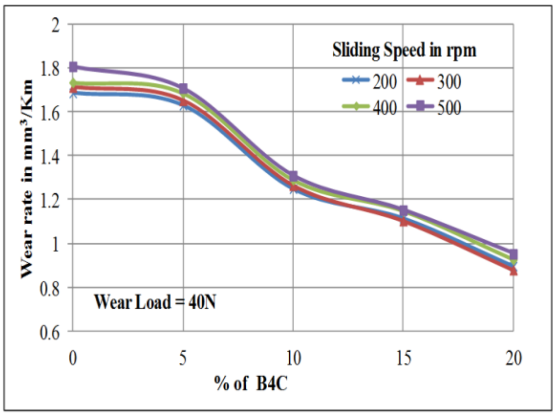

Figure 3c: Effect of wt% of B_4C and sliding speed on wear behaviour of Al/B_4C composites at 40N

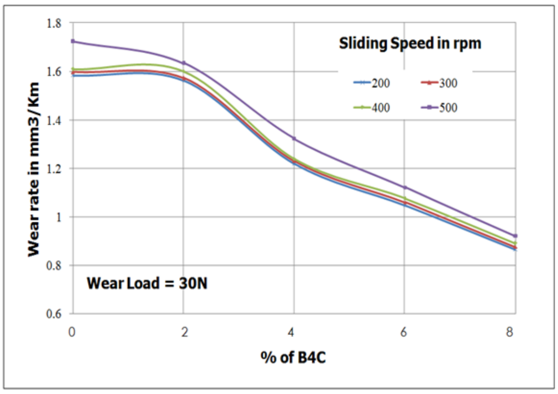

Figure 3d: Effect of wt% of B_4C and sliding speed on wear behaviour of Al/B_4C composites at 50N

The effect of B_4C content on the wear characteristics of Al B_4C particulate for a wear test rotational speed of 200, 300, 400 and 500 rpm and loads of 20, 30, 40 and 50 N is shown in Figure3a, 3b,3c and 3d which are the representative graphs plotted based on wear rate results.

The following is revealed by the study of these Figures. The wear rate of the Al/B_4C composites depend on the % of B_4C dispersion.The wear rate was found to decrease with the increase in B_4C content when from 2% to 8% the B_4C content is varied, from 2% to 80%. The weight rate by wear is minimum for the composite containing 8% B_4C dispersed in the as cast as observed. For the same percentage of B_4C, it is observed from the figures that wear rate increases as the load increases.

The wear rate remained almost constant at lower loads, with increase in rpm. Comparatively, light wear rate was shown by Al without dispersed but steadily this loss decreased. Perhaps, due to hard particles of B4C dispersed in the bas matrix there is relatively rapid attainment of stability in the wear resistance, as seen.

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IV CONCLUSIONS

The present work on processing and evaluation of Al7050-B4C metal matrix composite by melt stirring has led to following conclusions. Al7050- B_4C based composites have been successfully fabricated by melt stirring method using two stage addition method of reinforcement combined with preheating of particles. The SEM microphotographs of composites revealed fairly uniform distribution of reinforcement particulates in the Al7050-B_4C metal matrix. The addition of B4C particles to Al alloy matrix improves the wear resistance of the composite. The wear loss is dominated by load factor and sliding speed. The increase of loads and sliding speeds leads to a significant increase in the wear loss. The Al7050- 8% B4C composites haveshown lower wear loss as compared to that observed in as cast Al7050 alloy and 2 wt.% B4C reinforced composites matrix.B_4Creinforced MMCs exhibited reduced wear volume than the unreinforced alloy specimens and the coefficient of friction is lower at higher loads.

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