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Studies on wear behavior of AA2024-B_4C composites

Shivananda B K[1], Madeva Nagaral[2],D Madhu[3], V Auradi[4]

[1]PG Scholar, Mechanical Engineering, UVCE, Bangalore, Karnataka, India

[2]Design Engineer, Aircraft Research and Design Centre, HAL, Bangalore, Karnataka, India

[3]PG Student, Mech.Engg., Sri Nandhanam College of Engg. & Tech, Tirupattur,Tamilnadu, India

[4]R&D Centre Mechanical Engineering, SIT, Tumkur, Karnataka, India

E-Mail:- shivanand.b.k24@gmail.com

Abstract --- The present work, aims at investigating the wear properties of AA2024 alloy before and after introducing micro size Boron Carbide (B_4C) particulates. B_4C particulate reinforced AA2024 alloy metal matrix composites were prepared by stir casting method. Weight fraction of the reinforcement was varied 0 to 6 wt. % of B_4C in steps of 3 wt. %. For each composite, during processing the reinforcement particles were pre-heated to a temperature of 400^0C and then dispersed into the vortex of molten AA2024 alloy. The micostructural characterization was done using scanning electron microscope, which revealed uniform distribution of B_4C particles in Al matrix.Pin-on-disc wear testing machine was used to evaluate the wear of prepared specimens, in which a hardened EN32 steel disc was used as the counter face. The results revealed that the wear in terms of height loss was increased with increase in normal load and sliding speed for all the conditions. Further, wear studies also suggest that wear resistance of the AA2024-3 & 6 wt. % B_4C composites was lesser than that of the AA2024 matrix.

Keyword --- AA2024 Alloy, B4C, Stir Casting, Hardness, Tensile Strength

I. Introduction

Composite materials are growing constant over the years, because of its good mechanical and tribological properties. Among the three different types of composite materials, Metal Matrix Composites (MMCs) finds its application in various sectors like defense, automobile, and aerospace etc.; owing to their high strength, low density, good thermal property, low coast, and ease of availability [1].

For the fabrication of MMCs various alloys are used like, Al alloys, Mg alloys, Zinc alloys etc.; among the various alloys, Aluminium alloys is most commonly used as base matrix because of its low density, low corrosion, providing high strength to weight ratio, good fatigue resistance and widely reached the highest production stage in all industries sectors [2].

Some of the applications of Aluminum Metal Matrix Composites (AMMs) are engine pistons, cylinder liner, break drum etc. The MMCs are made complete by the addition of the reinforcement in the base matrix by various different process techniques. Some of the different methods which are adopted for producing MMCs are powder metallurgy, squeeze casting, spray deposition, and stir casting etc. Among this process stir casting is generally used because if its availability and less economy. A two-step process mixing of reinforcement is adopted in stir casting because which results in increases of hardness, impact strength and also excellent bonding between the ceramic and alloy. We can also observe that there will be no agglomeration and particles will be uniformly distributed and there will be lower wear rate than that of pure aluminium.

There are different hard and soft ceramic particles available like B_4C, SiC, Al_2O_3, Graphite, Mica, ZrO_2 etc.; these ceramic particles are reinforced into Al matrix which helps in strengthening and increasing the property of the base matrix [3]. The MMC_S are strongly influenced by some of the parameters of the reinforced particulates such as shape, size, orientation, uniform distribution and weight [4]. With the hard particles which are dispersed in a relatively ductile material Al matrix composite possess an ideal structure for wear resistant material 5]. In the above mentioned ceramic particles Al_2O_3, SiC and Graphite are the most reinforcing material which are used in various applications [6].

As of 2015 B_4C is the 3rd hardest ceramic particles and also as a nicked name as Black Diamond after naming for Cubic Boron Nitride and Diamond and it is used in application like Tank armor, bullet proof, and also has neutron absorber material. B_4C is so attractive because of its high strength, low density [2.52 gm/cc] which results in minimal density difference with Al matrix with high stiffness, and high hardness and also provides good wear resistance.

Therefore as revealed in the so far performed research most of the work has been done on Al_2O_3 and SiC ceramic particulates but only limited research work on B_4C particulates [7].

In present study an attempt has been made fabricate AA2024 alloy based B_4C reinforced composites. AA2024-3 and 6 wt. % B_4C composites were synthesized by stir

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casting process. Prepared specimens were tested for wear studies in terms of height loss for varying applied loads and sliding speeds.

II. Experimental Details

Matrix and Reinforcement Materials

Table1. Chemical composition of AA2024 alloy

Element	Symbol	Wt. Percentage
Zinc	Zn	0.20
Copper	Cu	4.5
Manganese	Mn	0.6
Magnesium	Mg	0.6
Ferrite	Fe	0.4
Chromium	Cr	0.1
Silicon	Si	0.4
Titanium	Ti	0.1
Aluminium	Al	Bal

In the current work, AA2024 is used as the base matrix and it is a Al-Cu binary alloy; which is commonly used in aerospace domain due to its excellent characteristics such as good weld strength, high strength to weight to ratio and as well as good fatigue resistance. AA2024 is one of the wrought Al alloys; the major alloying element is Al alloy along with Copper. The chemical composition of AA2024 used in the current work was investigated by using Atomic Absorption Spectroscopy and shown in table1.

The density of Al2024 is 2.78g/cm^3 and it is commonly extruded and it is available on billet form, flat form, and Al clad sheets.

The main advantage of introducing the reinforcement material to the base matrix is to increase the properties and also by enhancing mechanical and tribological properties of the composites. In the current work B_4C is used as the reinforcement material of the average size of 80 microns. B_4C is the third hardest material and it is highly economical, but the major advantage of this particle is that it as low density of 2.52g/cm3 which is lower than the base ally contributes in weight saving and less amount of research work has been carried out.

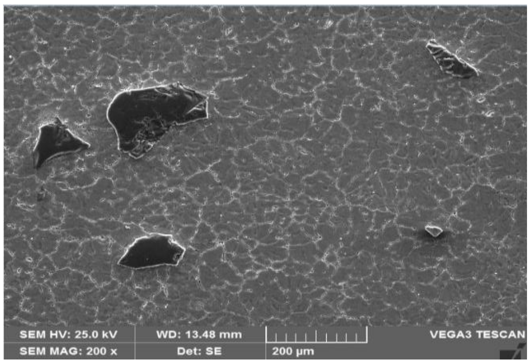
III. Preparation of AA2024-B_4C Composites

In the current work; the experiment was conducted to study the wear behavior of as cast alloy and AA2024-B_4C composites. The hard ceramic B_4C particle was reinforced into AA2024 alloy by different weight fractions of 0, 3, 6wt. % which was produced by liquid metallurgy stir casting by using two stage addition process. Initially the base matrix AA2024 was placed in a graphite crucible and then kept in an electric arc furnace at a temperature of 718^{0}C. Once the matrix is completely melted then the degasing tablet C_2Cl_6 i,e hexacloroethane is added to the melt to expel all the absorbed gasses. Meanwhile the reinforcement particles were preheated to 250^0-300^0 Celsius to remove the adsorbed gases. During the process a spindle speed of 300rpm was maintained and a clear vortex was formed by the stirring process with an electric motor.

Then the pre heated particles were introduced in steps of two at a constant feed of 1.2-1.4g/cc. Due to two stages addition of reinforcement into matrix there will be uniform distribution of particles and thereby avoiding unwanted defects. While adding the reinforcement into matrix a continuous stirring process was done, this was maintained at a speed of 300rpm. After the continuous stirring of 10 to 15 minutes entire molten metal was poured into cast iron die. Then the prepared composites were machined as per the ASTM standard and tested for micro structural and wear studies.

IV. Wear Testing

Dry sliding wear tests were carried out on AA2024 alloy and AA2024-B_4C composites using a pin-on-disc wear test apparatus. Cylindrical pin specimens of 8 mm diameter and 25 mm length were mounted vertically on a pin holder. The end of specimens were polished with abrasive paper of grit size 600 and followed by grade 1000. During the test the pin was pressed against the counterpart EN32 steel disc with hardness of 60 HRC. Prior to each run, the steel counter-face was ground with 320grit and then 600grit SiC abrasive for few minutes followed by cleaning with acetone. Test conditions included load-speed settings of 100, 200 and 300 rpm under a 3 kg normal load, and 1, 2 and 3 kg loads at 300rpm speed for constant sliding distance of 2000m. The initial weight of the specimen was measured in an electronic weighing machine with ± 0.01mg accuracy. Data collected and analyzed for wear in the form of height loss.



(b)

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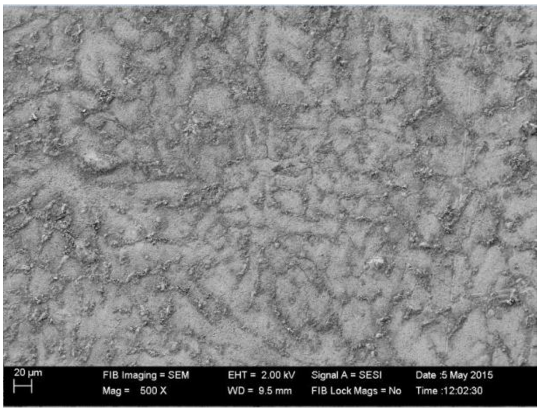
V. Results and Discussion

Micro structural Studies

The microstructure analysis of the fabricated composites is done by the scanning electron microscope (SEM).

Micrographs are recorded by scanning electron microscopy in BMS College of Engineering, Bangalore. AA2024 alloy and its composites are polished by fine emery papers and etched by Keller's solution.

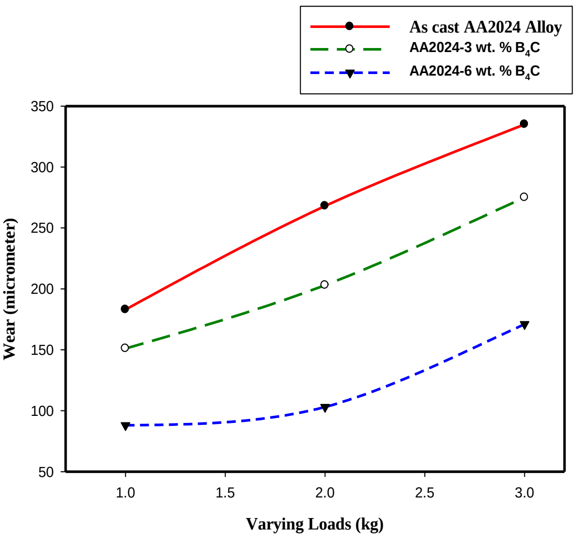


(a)

Figure 1. Showing SEM micrographs of (a) as cast AA2024Alloy (b) AA2024-3% B_4C (c) AA2024-6% B_4C

Fig. 1 a-c shows microphotographs of AA2024 alloy and AA2024- 3 and 6 wt. % B_4C composite. The micron size B_4C reinforcement uniform distribution is observed in SEM micrographs. The fig. 1b and 1c also indicates that there is good interfacial integrity between the reinforcement and aluminium matrix.

Wear Studies



(c)

Figure2. Showing the wear in terms of height loss for AA2024 alloy & its composites at 300rpm speed and varying loads

The variation of wear rate as a function of normal load, sliding speed and sliding distance for the AA2024alloy and its composite is shown in fig. 2 and 3. It is seen from the plots that, with the addition of B_4C particulates, the wear of the composite is decreased. The increase in the wear resistance can be attributed to the strengthening of the matrix due to the reinforcement addition, which results from an increase in the dislocation density and thermal mismatch between the reinforcement and the matrix AA2024 [8, 9].

Fig. 2 show the influence of reinforcement and load on the dry sliding wear behavior of the AA2024-B_4C composite under different loads varying from 1kg to 3kg in steps of 1kg with constant sliding speed of 300rpm for a sliding distance of 2000m. The results clearly indicate that the increase in load increases the wear rate. The rise in wear rate with increase in the wear load may be due to increased effects of oxidation, matrix softening and cracking. During wear at high loads, the temperature increases appreciably lowering the strength of the materials in contact resulting in increased contact area which increases the frictional force between two sliding surfaces [10-12]. The rise in frictional force gives high wear.

Fig. 3 shows the wear rate as a function of sliding distance at 3kg load and100, 200 and 300rpm sliding speed and at 2000m sliding distance. The wear rate increases with increase in sliding speed and wear rate of unreinforced alloy is found to be higher than that of the composite. As the sliding speed increases from 100 to 300rpm the wear of composite and alloy increases, this gives a direct relation between wear rate and sliding speed. Further, the increase in wear rate may be due to the breakage of particles at high sliding speed.

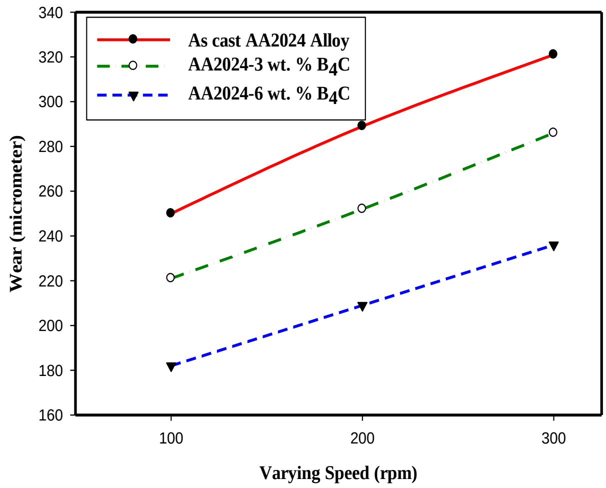


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Figure 3. Showing the wear in terms of height loss for AA2024 alloy & its composites at 3kg load and varying speeds

VI. Conclusions

The present work "studies on wear behavior of AA2024-Boron Carbide" metal matrix composite by two stage melt stirring has led to following conclusions:

1. Stir casting technique is successfully adopted in the preparation of AA2024-B_4C composites.
2. The micro structural study revealed the uniform distribution of the particles in the matrix system.
3. Wear in height loss was lower in case of AA2024-B_4C composites as compared to base AA2024 alloy.
4. As applied load and sliding speed increases there was increase in wear for both B_4C reinforced AA2024 alloy and un-reinforced alloy. Further, wear was less in AA2024 alloy reinforced with B_4C particulates.

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