Microstructure and Wear Behavior of Al2014-B_4C Composite

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Abstract- **The present work reveals the effect of B_4C reinforcement on Al-2014 alloy, which effects the mechanical characterization of the composites. The method of stir casting is used to prepare the samples and an effort is made to study the properties of AMMCs by reinforcing Al-2014 matrix with varying proportion of Boron carbide. Aluminum Al-2014 alloy matrix of varying proportions of 90 micron boron carbide particulates were fabricated with the addition of K_2TiF_6 as a wetting agent. The SEM images for the reinforcements were studied and dry wear behavior test was conducted on the specimens made by stir casting for various parameters and the results were plotted.**

Keywords— Key words: SEM, Wear, Stir casting, EDAX, Friction.

I .INTRODUCTION

Composite materials are engineered or naturally occurring materials which contain two or more distinct constituents with significantly different chemical, physical and mechanical properties. International Union of Pure and Applied Chemistry (IUPAC) has defined composites material as 'Multi-component material comprising of multiple, different phase domains in which there is at least one type of phase is continuous'. These types of materials have been extensively developed from the 20th century due to the limitations of performance of monolithic materials.

In this manner, the composite material contains no less than two independent and unmistakable synthetic stages. Of these two phases one is continuous called 'matrix', while the second one being discontinuous, is termed as 'dispersoids' or 'reinforcement' or 'filler'. The properties are improved by controlled conveyance of second stage in the matrix.

The essential constituents used in composites materials are matrix, reinforcement and interface. These matrix can be polymer, ceramic or metal. The reinforcement can be used in the form of particulate, whiskers or fibers. The reinforcement is selected based on its inherent properties like corrosion resistance, oxidation, hardness, stiffness etc., while matrix acts as binding element.

Aluminum matrix composite materials have enormous advantages such as high specific strength, high stiffness, high wear resistance, dimensional stability, high corrosion resistance and low weight of the finished part. Aluminum metal matrix composites are widely used for several applications such as automotive and various aerospace industries due to their outstanding properties such as high strength, high stiffness, high castability, abrasion resistance and excellent strength to weight ratio.

The process of blending of composites is done by stir casting process which is one of the advanced liquid cast metal technology in producing aluminum based metal matrix composites by employing stirring principle of liquid metal. Its advantages lie in its simplicity, flexibility, and applicability to large volume production. This process is the most economical among all the available routes for AMMCs production, and it allows very large-sized components to be fabricated. However, the following considerations for achieving AMMC via stir casting must be

Considered: no adverse chemical reaction between the reinforcement material and matrix alloy, no or very low porosity content in the cast AMMCs, wettability between the two main phases, and a uniform distribution of the reinforcement material.

The reinforcing stage gives the updated properties, for instance, quality and solidness. All around, the support is harder, more grounded, and stiffer than the matrix. The reinforcement is regularly a fiber or a particulate.

II. OBJECTIVES

In our present project work shows an attempt has been made to characterize, prepare and evaluate the mechanical properties of Al-2014 reinforced with Boron Carbide particulates by the stir casting methods.

The main objectives of the work are as follows.

1 Synthesis of Al2014-B_4C metal matrix composites by stir casting method and by varying the weight percentage of B_4C in steps of 0, 3, 6 and 9 wt. %.

2 Three step addition of reinforcement which increases incubation period their by improves wettability.
3 Characterization of the above prepared composites by Optical microscopy and Scanning Electron Microscopy to know the uniform distribution of particles in the matrix.
4 Analysis of the above prepared specimens by EDAX to know the presence of B_4C particulates in the Al2014 matrix alloy.
5 Preparation of test specimens for mechanical studies for both unreinforced and reinforced Al2014 alloy.
6 Obtaining the correlation between Micro structural features and extent of improvement in mechanical and wear properties.
7 Getting the values of wear and frictional force for these compositions with constant speed, constant radius and varying load.
8 Comparing the wear rate for different wt. % of B_4C composite with load conditions.

III. METHODOLOGY

The fabrication of Al2014-B_4C composites will be carried out by fluid metallurgy course via stir casting system. The fundamental parts of the throwing technique involve into zirconium covered steel impeller, electrical resistance heater and cast press perpetual shape. The power rating utilized here for electrical heater will be 60kw. The greatest temperature cutoff utilized here is 1200 degree Celsius. The mechanical stirrer used for blending the liquid combination in the midst of the readiness of composites will be covered by zirconium to withstand high temperature and to keep movement of ferrous particles from the stirrer material into Al2014 compound break down.
Calculated amount of the Al2014 alloy ingots are charged into the furnace for melting. The melting point of Aluminum alloy is 660 °C. The dissolve superheated to a temperature of 750 °C. The temperature will be recorded utilizing a chrome-alumel thermocouple. A stainless steel impeller covered with zirconium is utilized to blend the liquid metal to make a vortex. The stirrer will be pivoted at a speed of 300rpm and the profundity of inundation of the impeller was 60 percent of the tallness of the liquid metal from the surface of the liquefy. Advance, the B_4C particulates are preheated in a heater up to 500 °C will be brought into the vortex. Stirring is preceded until interface interactions between the fortification particulates and the matrix advances wetting. At that point, Al2014-0, 3, 6 and 9 wt. % B_4C blend are filled permanent cast iron form having dimensions 125mm length and 15mm diameter.
The micro structural study was carried out on the investigating composites utilizing optical microscopy and scanning electron magnifying instrument. Samples around 10 mm diameter cut from the castings and are cleaned appropriately. Keller's reagent is utilized to scratch the samples. Further, based on the microstructure think about, hardness, ultimate rigidity, yield strength, flexibility and pressure strength are evaluated according to ASTM standards.

A. *Material selection:*

Aluminium-2014 alloy
Aluminum combinations are picked as a framework in view of their low thickness, great isotropic mechanical properties, magnificent erosion resistance and sensible cost. Among aluminum composites, 2014 is an Al–Cu amalgam generally utilized for auxiliary applications because of its great quality, weld ability, consumption resistance, insusceptibility to stress erosion splitting and also warm treatability, framing encourages that expansion the quality at the cost of to some degree lessened pliability.

TABLE I: Chemical composition of Al 2014

Components	Al	Si	Fe	Cu	Zn	Mg
Amount (wt. %)	Balance	1.2	0.7	3.9	0.25	0.8

Physical Properties	Density	2.8 g/cm^3
	Melting Point	660°C
	Modulus of Elasticity	70-80 GPa
	Poisson's Ratio	0.33
	Brinell hardness(500 kg load,10mm ball indentor)	72
Thermal Properties	Co-Efficient of Thermal Expansion (20-100°C)	24.3x10^{-6} m/m.°C
	Thermal (warm) Conductivity	173 W/m.K

TABLE II: The Physical and Thermal Properties of Al-2014 alloy

B. *Reinforcements*

Boron carbide – B_4C
Boron Carbide is one of the hardest materials known, positioning third behind precious stone and cubic boron nitride. This material made in tonnage amounts and it is one of the hardest things. Initially found in mid19th century as a by-thing in the era of metal borides, boron carbide was quite recently contemplated in detail since 1930.
Boron carbide powder is mainly delivered by reacting carbon with B2O3 in an electric arc furnace, through carbothermal diminishment or by gas phase reactions. For commercial utilize B4C powders usually should be processed and refined to evacuate metallic contaminations.
In an indistinguishable way from other non-oxide materials boron carbide is hard to sinter to full thickness, with hot crushing or sinter HIP being required to accomplish more prominent than 95% of hypothetical thickness. Despite using these strategies, so as to accomplish sintering at sensible temperatures (e.g. 1900 - 2200°C), little amounts of dopants, for instance, fine carbon, or silicon carbide are typically required. As an option, B4C can be shaped as a covering on a reasonable substrate by vapor stage response methodologies for example by using di-borane or boron halides with the methane or another material carbon source.

TABLE III: Properties of Boron Carbide

Properties	Boron Carbide
Melting point	2072º C
Hardness (kg/mm^2)	3000
Density (g/cm^3)	2.52
Coefficient of thermal expansion(μm/m°C)	6
Fracture toughness(MPa-m$^{1/2}$)	3.5
Poisson's ratio	0.21
Colour	Dark

C. Fabrication

Melting of Al2014 alloy in a silicon carbide crucible which is held by resistance furnace of capacity 5kg, operating temperature 1000^{0}C and power rating 7.5kW. And stirrer used as stainless steel coated with Zr_2O_3 powder.
To prepare cylindrical billets of blended Al2014 + B_4C the following steps were followed

- Melting Al2014 alloy in a resistance furnace.
- Al2014 alloy mixed with B_4C in the proportionate weight ratio of 3%, 6% and 9% in a crucible.
- Stirring frequently for better mixing of both by stirrer.
- Pour the prepared molten mixture into the pre designed shape of mould/die and leave it for 20min to solidification and get semi-finished bars after solidification.
- Cut and machining the specimens into required size as per ASTM standards to examine various tests.
- Find the wear rate of casted materials by wear test machine(wear track dia.160mm, Specimen max diameter- 8mm X 30mm and RPM range 200 to 2000)

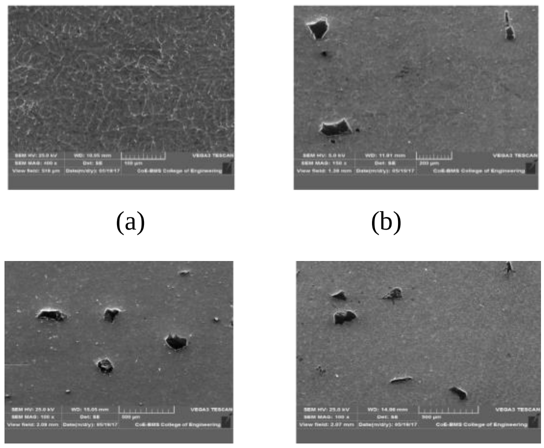
D. Computerized SEM Detection (Characterization Technique)

Particles distribution was evaluated with the help of optical microscope. The reinforcement pattern and the structure is examined using optical microscope shown in Figure 2. A section was cut from the casted specimen and grinded using 220 grit SiC paper followed by 400, 600, 800 and 1000 grades of emery paper. Before making the optical observation all the samples were making mechanically polished and etched by Keller's reagent (HCL+ HNO_3+HF+Water) to obtain the better contrast.

FIGURE 1: Computerized optical microscope to study microstructure.

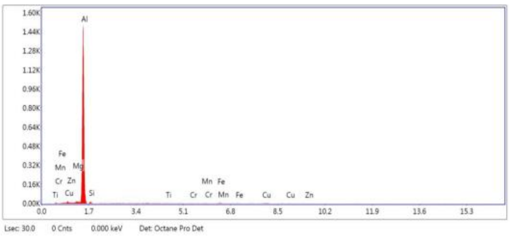
E. Microstructure Evaluation

Microstructure is envisioned with the assistance of optical magnifying lens. For the example readiness as a matter of first importance examples were cut into little round and hollow shape and afterward the diverse specimens were granulated on various coarseness estimate papers successively i.e. 220, 400, 600, 800 and 1000. In the wake of crushing the examples were mechanically by alumina glue and after that scratched by Keller's reagent to get better difference. The examples were imagined on various amplifications (50X, 100X) to demonstrate the nearness of reinforcement and its dispersion on the metal matrix. The microstructures of the considerable number of tests i.e. as cast, 3, 6, and 9 wt. % of B4C are appeared in Figures. In the present work, an endeavour has been made to plan Al-2014 aluminum combination matrix composites with miniaturized scale measure B_4C particles by blend throwing technique consolidated with preheating of the fortifying particles. The checking electron magnifying instruments s of as cast Al-2014 composite and Al-2014 combination fortified with 0, 3, 6 and 9 wt. % of B_4C are appeared in figure 5.1 an e separately. Optical micrographs used as Al-2014 mix composites revealed the uniform dispersal of B_4C particulates in the matrix, and no void and discontinuities were viewed. Fundamental giving defects such a part as porosity and shrinkages were not found in the micrographs. There was a not too bad interfacial holding between the B4C particles and Al-2014 compound matrix. Figure 2 a-d showing the scanning electronic photographs of as cast Al-2014 alloy (2a) and B_4C reinforced composites. Figure (2b) showing 3 wt. % B_4C reinforced composites and figure 2c, d and e showing scanning electron micro photographs of 3, 6 and 9 wt. % B_4C particulates reinforced composites respectively. From the scanning electron photographs, it is revealed that there is uniform distribution of secondary phase particulates in the Al-2014 alloy matrix. All the photographs showing the good interfacial bonding between the B_4C and Al alloy matrix, which further enhances the properties of Al-2014 alloy. The cases used in Al-2014-9 wt. % B_4C composites, there is more particulates in the Al-2014 matrix, which shows good castability and wet ability of Al-2014 alloy with ceramic reinforcements.



(a) (b)
(c) (d)

FIGURE 2: Scanning electron microstructure of (a) as cast Al2014 alloy (b) Al2014-3 wt. % B_4C composite (c) Al2014-6 wt. % B_4C composite and (d) Al2014-9 wt. % B_4C composite



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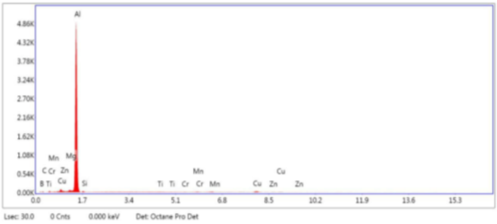

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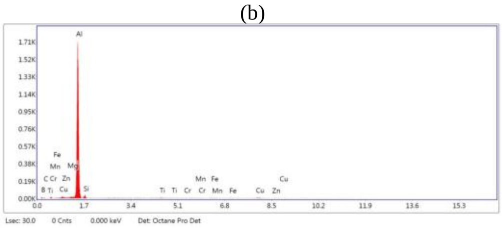

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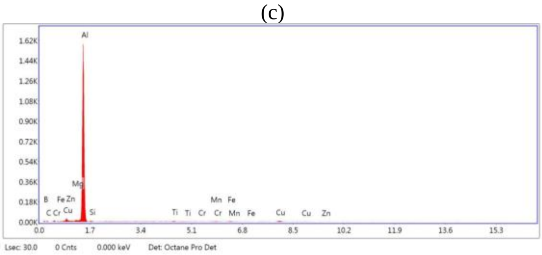


(d)

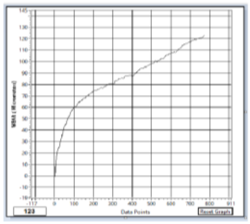
FIGURE 3: EDS reports of (a) as cast Al2014 alloy (b) Al2014-3 wt. % B_4C composite (c) Al2014-6 wt. % B_4C composite and (d) Al2014-9 wt. % B_4C composite

F. Evaluations of wear properties

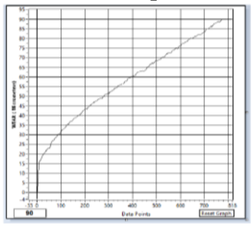
Testing example is casted by ASTM G99. A stick on plate wear testing arrangement is utilized to check wear properties of composite example. The example is rubbed against pivoting hard steel plate with no grease. Dry sliding strategy is taken after. Variable parameters, for example, speed, load and time which is varied between 1kg, 2kg and 3kg and wt% is varied between 0,3,6,9 wt percent of B_4C composite. Normal track breadth of 100mm is utilized to test the example. Subsequent to testing, the example is removed from the machine and weighed. Distinction in introductory and last weight gives the loss of material thus wear rate of the material. The example is measured utilizing electronic adjust. Tests are directed at typical room temperature. The key objective of investigation was to concentrate the impact of variation of ordinary load, sliding velocity and rate B_4C on wear rate.

FIGURE 4: Computerized pin on disc wear testing machine

The tests perform under dry for conditions according to ASTM G99-95 standard. The stick at first cleans with $(CH_3)_2CO$ and weighed definitely by an advanced electronic adjust. All through the test, the stick is held pushed touching a pivoting steel circle (hardness of 65HRC) by applying load to goes about as stabilizer and equalizations the stick. The track breadth was varied for each cluster of analyses in 100mm and the parameters, for example, the heap, sliding pace and sliding separation are varies in the reaches known as settled to 500rpm. The contrast between the first and last weights is measure of slide wear misfortune. For every condition, tests perform and the average value of weight reduction is report.



(a)



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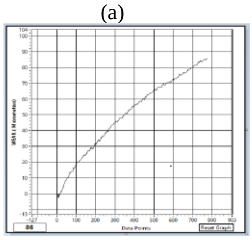

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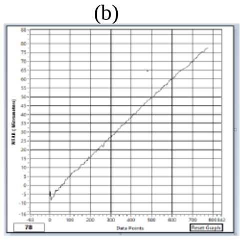

(d)

FIGURE 5: Wear plots with time for 3kg load, 300rpm and 50mm track radius (a) as cast Al-2014 alloy (b) Al-2014 -3 wt. % B_4C (c) Al-2014 -6 wt. % B_4C (d) Al-2014 -9 wt. % B_4C composite.

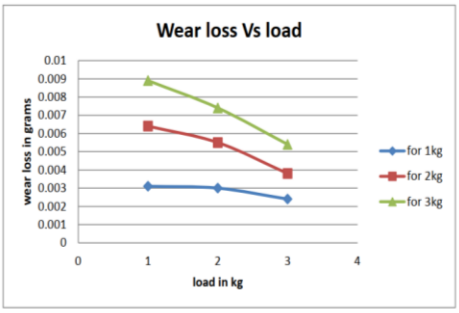

FIGURE 6: Wear loss Vs load plot for, 300rpm and 50mm track radius

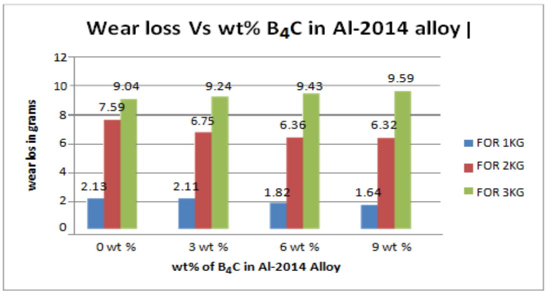

FIGURE 7: Wear loss Vs wt.% for different load conditions at 300rpm and 50mm track radius (a) as cast Al-2014 alloy (b) Al-2014 -3 wt. % B_4C (c) Al-2014 -6 wt. % B_4C (d) Al-2014 -9 wt. % B_4C composite

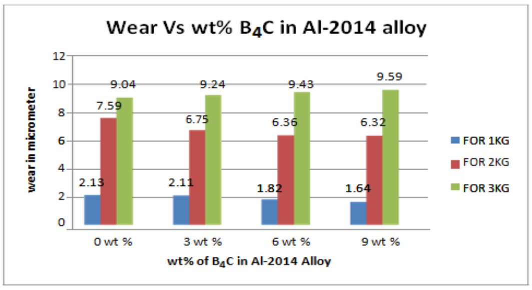

FIGURE 8: Wear Vs wt% plot for different load conditions at 300rpm and 50mm track radius (a) as cast Al-2014 alloy (b) Al-2014 -3 wt. % B_4C (c) Al-2014 -6 wt. % B_4C (d) Al-2014 -9 wt. % B_4C composite.

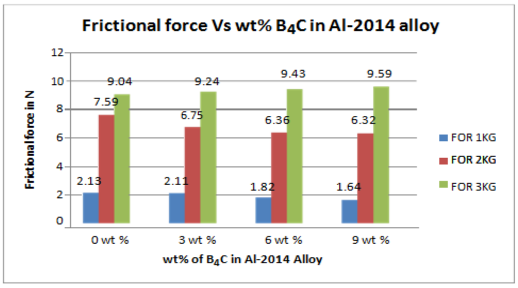

FIGURE 9: Frictional force Vs wt% plot for different load conditions at 300rpm and 50mm track radius (a) as cast Al-2014 alloy (b) Al-2014 -3 wt. % B4C (c) Al-2014 -6 wt. % B4C (d) Al-2014 -9 wt. % B4C composite.

CONCLUSIONS

The present study on "Microstructure and wear behavior of Al-2014-B_4C composites", has prompted taking after conclusions:

1. The method used like Stir casting technique is successfully adopted in the preparation of Al-2014-B_4C composites.
2. The EDS and Scanning Electron Micro photographs revealed the uniform distribution of B_4C particles in the Al-2014 alloy matrix system.
3. The wear loss has been decreased by the introduction of B_4C reinforcement in Al2014 alloy for constant speed and varying loading conditions.

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