INVESTIGATING ON THE INFLUENCE OF BORON CARBIDE REINFORCEMENT ON Al-2014-B_4C METAL MATRIX COMPOSITE FOR AEROSPACE APPLICATION

Kirankumar B[1,*], Mohammed Nihal V S, Mohammed Saud.[1], Muhammad Hisham.[2], Muhammed Misbah[1].

[1]Department of Mechanical Engineering, P. A. College of Engineering, Mangaluru, Karnataka, India.

*Corresponding Author: Kirankumar B Email: kirankumarbarkala@gmail.com

Abstract:

The experiment aimed to assess how incorporating B4C reinforcement affects various properties of Al-2014 alloy, including hardness, tensile strength, compressive strength, and wear resistance of these composites. These aluminum metal matrix composites, whether with single or multiple reinforcements, are gaining traction across aerospace, automotive, space, marine, and transportation sectors. The study focused on analyzing the properties of these composites by adding varying proportions of boron carbide to the Al-2014 matrix through stir casting. K_2TiF_6 was introduced as a wetting agent during fabrication. Examination of the fabricated AMCs through SEM and EDS revealed a uniform dispersion of B4C particles within the matrix. The analysis of hardness indicated a positive correlation with increased reinforcement levels. Similarly, tensile and compressive strengths exhibited enhancement with higher B4C reinforcement levels.

Key Words: B4C, Reinforcement, Stir Casting.

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I. Introduction

Traditional monolithic materials, such as metals and their alloys, ceramics, or polymeric materials, are unable to meet certain requirements, such as the high combination of quality, solidity, sturdiness, and thickness needed in the majority of the current creative applications. As a result, this has become a notable obstacle to their widespread usage in a variety of applications, such as high temperatures and various conditions, such as erosive and corrosive media. It is necessary to develop new materials in order to address these deficiencies and the constantly growing demand for cutting-edge innovation for superior materials. This is crucial because basic materials typically have low densities, sensibly improved quality, are solid, scraped spot and impact-safe, stable at high temperatures, and are not easily ingested. These materials are being used increasingly prominently in the aviation, power generation, and sports games industries. [1]

II. Composite Materials

A. Matrix

The matrix material serves as the reinforcement's connector, shield, and aids in efficiently transferring load from the reinforcement [1]. The selection of the matrix is based on the wettability, reactivity, application, and processing method used to create the composite. The matrix should typically be lightweight to reap the full benefits from the reinforcements concerning the characteristics. While ceramic creations have excellent bore and quality but are weak, metals generally offer stability and quality with reasonable adaptation.

B. Reinforcement

The stage of reinforcing delivers updated features, such as quality and solidity. The support is stiffer, more grounded, and tougher all around than the matrix. Typically, fibres or other particulates serve as reinforcement [2]. Estimates for particle composites are typically proportional in both directions. The reinforcing particle could be spherical, plate-shaped, or have another typical or peculiar geometric shape.

C. Interface

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The interface is a retaining surface or area where a defect occurs, irrespective of whether mechanical, physical, compound or others. It possesses qualities that are not represented in either of the pieces taken separately. For a composite to have desirable qualities, the linked load must be successfully transferred from the matrix to its filaments via the interface. This indicates that the interface between the matrix and the filaments must be wide and exhibit a strong grip. The fibre must be "wet" by matrix material to achieve this. "Wetted" filaments increase the surface area of the interaction all around. Sometimes, coupling specialists are utilised to improve wettability.

Classification of Composites

The composites are additionally divided into the following classes [3] based on the matrix material:

A. Polymer matrix Composites (PMCs)

Polymer Matrix Composites are known as FRP - Fiber Reinforced Polymers (or simply Plastics). These materials use a sap made of polymers as the matrix and a variety of strands for reinforcement, including glass, carbon, and aramid.

B. Metal matrix Composites (MMCs)

Metal Matrix Composites primarily find their uses in the fields of aeronautics and even the automobile industry. These materials may be made from a metal, such as aluminium, as the grid and infused with fibres, shards, or particles, such as silicon carbide.

C. Ceramic matrix Composites (CMCs)

Fired or ceramic Matrix Composites are utilized in the components that are employed in a high-temperature environment. These materials, like those constructed of boron nitride and silicon carbide, utilise an inventive network to strengthen them with small strands or flourishes.

D. Metal Matrix Composites (MMCs)

The name implies that the matrix is a substance because of MMCs. Compared to their base metal counterparts, these materials can be used at substantially higher operating temperatures.

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Additionally, the reinforcement may improve dimensional stability, scraped area resistance, particular robustness, and quality. These materials' advantages versus polymer matrix composites include things like higher operating temperatures, incombustibility, and greater resilience to deterioration by natural liquids.

E. Aluminum Metal Matrix Composites (AMMCs):

Aluminum is frequently employed as a matrix material because of its low weight, high strength, great resistance to wear, high melting point, relatively simple for making composites, and its availability in abundance. AMMCs have been processed using aluminium alloys that consist of aluminum-magnesium-silicon, aluminum-silicon, aluminum-zinc-magnesium, aluminum-copper, as well as aluminum-copper-magnesium.

III. Literature Survey

These study based on the ISI database by searching for the terms metal matrix composites, titanium-based composites, iron-based composites, magnesium-based composites, aluminum-based composites, lead-based composites, etc. This revealed that 2109 papers on aluminum-based composites (AMC) out of a total of 4,210 (roughly) publications on MMCs. Similarly, almost 150 of the approximately 275 patents on MMCs include a connection to AMMCs. In recent decades, metal matrix composite has drawn more attention as a building material. A composite material is produced by presenting ceramic components into a metal matrix. This material has an attractive combination of physical and mechanical qualities [4–14] that cannot be achieved with solid alloys. Compared to solid alloys, MMCs offer better qualities at elevated temperatures, reduced thermal extension, and improved wear resistance. They additionally possess higher strength-to-thickness and solidness-to-thickness proportions. Because of their wide range of custom-made physical, mechanical, and tribological qualities, metal matrix composites offer a lot of potential for use in aircraft and vehicle applications [15]. A few scientists have studied the characteristics of metal matrix composites using the matrix materials copper, magnesium, and aluminium.

Baradeswaran et al., [16]studied the hybrid Al7075-Al2O3-Graphite composites' mechanical and wear characteristics. The experiment demonstrates the possibility of graphite

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consolidation in the composite for minimizing wear. Liquid metallurgy was used to create the composites. The Al 7075-Al2O3-Graphite mixed composite was constructed using 2, 4, 6, and 8 wt.% Al2O3 and 5 wt.% graphite expansion. It has been found that the increased weight rate of the clay stage expands the hardness, flexibility, flexural quality, and weight quality of mixed composites. The wear characteristics of the graphite-containing half-breed composites demonstrated their unmatched wear resistance qualities.

Suresh et al., [17]announced the mechanical and wear behaviours of the blended cast Al-TiB2 composites. By using the blend casting technique, Al6061-TiB2 composites were created. Investigations were conducted into mechanical behaviours such as hardness, elasticity, and tribological behaviour. As the TiB2 content in the Al6061 alloy grew, the mechanical characteristics also increased. TiB2-reinforced composites had improved wear resistance.

Rajmohan et al., [18]specialised in the mechanical and wear characteristics of composites with aluminium and other metals. A356 alloy composites strengthened with mica and SiC particles were created using the mix casting technique. Investigations were done on the mechanical and wear characteristics of cross-breed composites. Al-10SiC-3 Compared to base alloy, mica half-breed composites had better mechanical and wear performance.

IV. Problem Definition

The mechanical characteristics for Al2014 reinforced using Boron Carbide particles have been prepared, characterised, and evaluated in our current work reveals. This has been done using stir-casting techniques.

The following are the work's main objectives.

A. This involved the synthesis of Al2014- B_4C metal matrix composites using the stir casting method, and the weight percentage of B_4C was varied in steps of 0g, 30g, 60g, and 90g for 1000g of Al2014.

B. Three-step addition of reinforcement increases the incubation period by improving hardness.

C. SEM and optical microscopy analysis of the mentioned composites to determine the uniformity of the particle dispersion in the matrix.

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D. A few of the mechanical qualities that are employed, such as ultimate tensile strength, hardness, percentage elongation, and compression strength, are evaluated.

V. Methodology

By using a stir casting technique, fluid metallurgy fabricated Al2014- B_4C composites.A cast press in consistent form is one of the fundamental components that make form the throwing technique, an impeller made of steel covered in zirconium, and an electrical resistance heater. Here, an electrical heater with a 60kw power rating will be used. Here, a temperature threshold of 1200 degrees Celsius is used as the highest possible. To survive high temperatures and prevent the passage of ferrous particles into the Al2014 compound breakdown, zirconium will be utilised to cover the mechanical stirrer being used to blend the liquid mixture during the preparation of composites.

The impeller was rotated at a speed of 300 rpm while being lowered to a depth of 60% of the height required to allow the metallic liquid to liquefy. B4C nanoparticles that have been preheated in a heater that reaches 500 °C will do this before entering the vortex. Stirring continues until wetness results from the interactions between the matrix with fortification particle interfaces. At that point, the Al2014-0, 3, 6, as well as 9 weight percent B4C mixture, is added into a permanent cast iron framework that is 125mm long and 15mm in diameter. The test composites' microstructural examination was finished using optical and scanning electron microscopy. Samples from the casting are thoroughly cleaned and cut into a diameter of approximately 10 mm. Samples are scratched with Keller's reagent. Additionally, in accordance with ASTM standards, pressure strength, yield strength, ultimate stiffness, and degree of hardness are evaluated based on microstructural factors.

VI. Experimental Setup

A. Aluminium-2014 alloy

Due to its low thickness, excellent isotropic mechanical qualities, outstanding erosion resistance, and affordable price, aluminium alloys are chosen as a framework. Due to its excellent quality, weldability, consumption resistance, susceptibility to stresses and erosion splitting, and warm

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treatability, 2014 is an aluminium composite that is typically used for auxiliary applications. Framing promotes quality expansion at the expense of significantly lessened pliability.

Table 1: 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

B. Reinforcements

One of the known hardest materials is boron carbide, ranking third in hardness after precious stones like cubic boron nitride. This material is considered to be one of the toughest things and is produced in tonnes. Borosilicate was first discovered in the middle of the 19th century, being a byproduct of the metal boride period, but it was not until 1930 that it was given serious thought. Carbon and B2O3 processes in electric arc furnaces, carbothermal diminishment, and gas phase reactions are the principal methods used to produce boron carbide powder. B_4C powders typically need to be processed and then refined to remove metallic contamination before being used commercially. [19].

VII. Results And Discussions

A. Microstructure Evaluation

Figures show the microstructures of a sizable number of tests, including as cast, 3, 6, and 9 weight percent of B_4C. Figures 1 and 2 a-d show, independently, the examination of electron magnifying devices for Al-2014 composite as cast and Al-2014 composite reinforced with 0, 3, 6, and 9 wt% of B_4C. The homogeneous dispersion of B_4C particles in the matrix could be seen in optical micrographs taken of Al-2014 mix composites; no voids or discontinuities were visible. Porosity and shrinkages, which are fundamental to providing faults, were not visible in the micrographs. The interfacial holding of the Al-2014 compound matrix and the B_4C particles was not very terrible. The secondary phase particles are distributed uniformly throughout the Al-2014 alloy matrix, as seen in the scanning electron images. All the images demonstrate the strong interfacial connection formed by B_4C and the aluminium alloy matrix, further enhancing the alloy's

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characteristics. In the Al-2014-9 wt.% B_4C composites examples, there are more particles in the Al-2014 matrix, demonstrating the alloy's excellent castability and wettability when reinforced with ceramic materials.

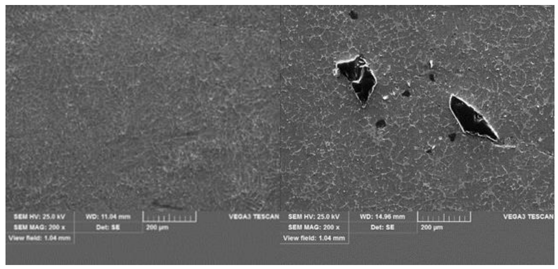

Fig 1: (a) As cast Al2014 alloy
(b) Al2014-3 wt. % B_4C composite

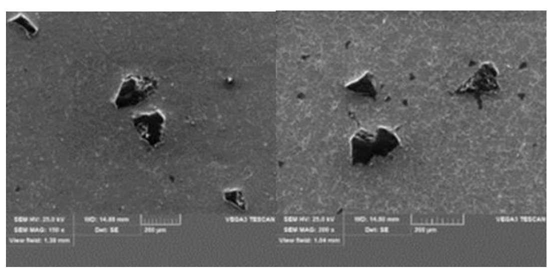

Fig 2: (c) Al2014-6 wt. % B_4C composite and
(d) Al2014-9 wt. % B_4C composite

B. Evaluation of hardness

The degree of hardness of cast Al-2014 along with Al-2014-B_4C composites with (0, 3, 6 and 9 wt. %) is determined by making use of ball indenter at an attached heap about 100kgf in abide time 5 seconds for every specimen at various areas. It is obvious that the composite's hardness is higher in comparison to that within its cast matrix, and the charts also demonstrate how the hardness is highest when the expanding weight percentage results in B_4C. Figure 3 depicts an increase in hardness when the B_4Creinforcement material is added. The B_4Cparticles' hardness, which is hard distributed and contributes to the composite's increased hardness by acting as obstacles to the motion of dislocations inside the matrix, is the cause of this increase in hardness. For 9 weight percent of B_4C composites, the hardness increased from 46.46 HRC to 64.56 HRC due to the B_4C

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particles' greater hardness than the matrix metal. The findings made and the results attained are in line with those of other researchers. Numerous researchers [20] have found an increase in the hardness of composite materials reinforced with hard particles.

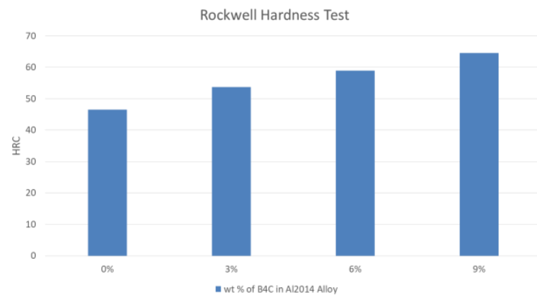

Figure 3: showing hardness of Al-2014-B_4C composites

C.Evaluation of tensile properties and Ultimate tensile strength

The ability of an alloy to resist dislodging movement on a smaller scale is crucial to the quality attributes of metallic materials.

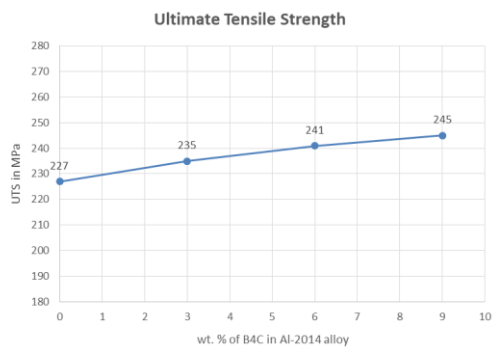

Figure 4:Showing the tensile strength of different composites prepared under study.

The results for the tests for tensile strength at ambient temperature are presented via the outputs with various weight % for B_4C particulates. The findings indicate that the ultimate tensile strength (UTS) rises as the overall percent weight fraction of reinforcing particles increases.

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D. Compression Strength

Uniaxial compression load is consistently applied to the majority of elements of structures, machinery, or gadgets. Compression behaviour is the way a material reacts to straightforward uniaxial compression. Compression testing is the term used to describe the procedure used for this.

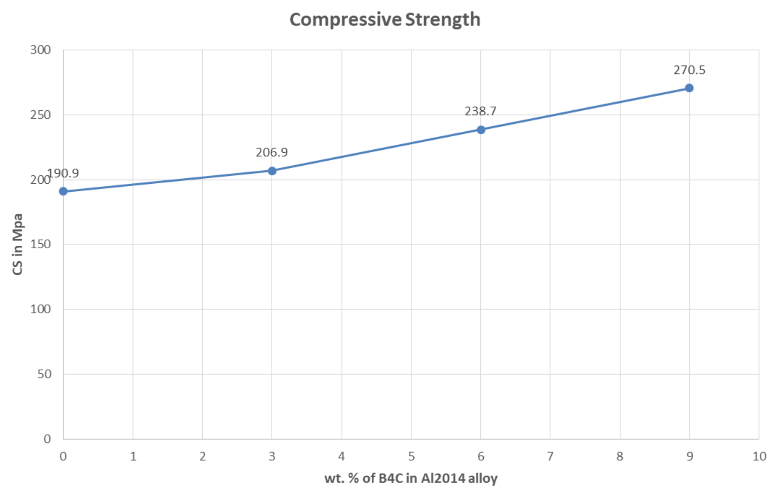

Figure 5: showing the compression strength of different composites prepared under study.

The figure 5 demonstrates the compression strength of Al-2014 alloy as well as various wt. % of B_4C composites. As can be seen from the graph, compression strength increases as B_4C reinforcement weight percentage rises from 0 to 9 wt.%. The high compression strength of ceramic particles [21–23] is the primary cause of this increase in compression strength. By introducing 9 weight percent of B_4C particles into the matrix, the compression strength of the Al-2014 alloy rose from 190.9 MPa to 270.5 MPa.

VIII. Conclusion

The present study shows that the approach used as a stir casting technique has been effectively utilized in the making of Al-2014-B_4C composites. The consistent distribution of B_4C particles throughout the Al-2014 alloy matrix system was visible in EDS as well as Scanning Electron Micro images. Increasing the weight percentage of B_4C particles enhanced the hardness of the Al-2014

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alloy. With an increase in B_4C concentration, the ultimate tensile strength also increases. The improved strength of composites is often attributed to the reinforcing material's and matrix's strong bonding greater than that of the unreinforced alloy Al-2014.

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