B_4C AND GRANITE POWDER REINFORCEMENTS IN A HYBRID ALUMINIUM COMPOSITE: WEAR ANALYSIS

A PROJECT REPORT

Submitted by

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DECLARATION

I Abhi M Anson, hereby declare that the project report entitled “**B4C and granite powder reinforcements in a hybrid aluminium composite: Wear Analysis** ", submitted for partial fulfillment of the requirements for the award of degree of Master of Technology of the APJ Abdul Kalam Technological University, Kerala is a bonafide work done by me under supervision of Asst.Prof Rakesh Pillai R, Department of Mechanical Engineering, TKMCE Kollam. This submission represents my ideas in my own words and where ideas or words of others have been included. I have adequately and accurately cited and referenced the original sources. I also declare that I have adhered to ethics of academic honesty and integrity and have not misrepresented or fabricated any data or idea or fact or source in my submission. I understandthat any violation of the above will be a cause for disciplinary action by the institute and/or the University and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been obtained. This report has not been previously formed the basis for the award of any degree, diploma or similar title of any other University.

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CERTIFICATE

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ABSTRACT

The incorporation of reinforcement materials in metal matrix composites (MMCs) has gained significant attention in recent years due to their potential to enhance mechanical and tribological properties. This literature review focuses on the wear analysis and optimization of Aluminium composites reinforced with Granite powder and Boron Carbide (B_4C) as reinforcement. The review provides an overview of the current state of research in this field, highlighting the various methodologies, experimental techniques, and optimization strategies employed to improve the wear resistance of these composites. The synthesis techniques, wear characterization methods, and the influence of reinforcement content and particle size on the wear behavior are discussed. Additionally, the review sheds light on the tribological performance, wear mechanisms, and potential applications of these composites. The findings and knowledge gaps identified in this review serve as a basis for future research and development in the field of wear analysis and optimization of Aluminium composites using Granite powder and B_4C reinforcement. To determine the nature of changes in the specimen face where wear is occurring, SEM and EDAX of the specimen are investigated.

Keywords: Boron Carbide (B_4C), Metal Matrix Composites (MMC), Scanning electron microscopy (SEM), Energy dispersive Xray Analysis (EDAX)

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ABBREVIATIONS

AMC - Aluminium matrix composite

B_4C - Boron Carbide

EDAX - Energy-dispersive X-ray analysis

MMC - Metal matrix Composites

SEM - Scanning Electron Microscope

CHAPTER 1
INTRODUCTION

Wear analysis of materials are vital considerations in many engineering applications, particularly in industries where components are subjected to abrasive, erosive, or sliding forces. The incorporation of reinforcement materials in metal matrix composites (MMCs) has emerged as a promising approach to enhance the wear resistance and mechanical properties of materials. This literature review focuses on the wear analysis of Aluminium composites reinforced with Granite Powder and Boron Carbide (B_4C) as reinforcement.

Aluminium composites, also referred to as aluminium matrix composites (AMCs), are materials composed of an aluminium matrix reinforced with secondary substances. These reinforcements, which can take the form of particles, fibers, or whiskers, are incorporated to enhance specific properties of the composite. By integrating reinforcement materials, aluminium composites offer improved mechanical properties such as strength, stiffness, and hardness, along with other advantageous characteristics like thermal conductivity, wear resistance, and corrosion resistance. These composites are widely applicable across diverse industries due to their lightweight nature, excellent thermal conductivity, and the ability to withstand higher loads and stresses compared to pure aluminium. The fabrication techniques for aluminium composites include stir casting, powder metallurgy, and advanced manufacturing methods, chosen based on factors such as reinforcement type, size, desired properties, and cost considerations. The selection of reinforcement materials varies based on specific application requirements, considering factors such as desired properties, availability, cost, and compatibility with the aluminium matrix. The resulting aluminium composites exhibit improved mechanical properties while retaining the inherent advantages of aluminium, such as low density and good thermal conductivity making them highly desirable materials for aerospace, automotive electronics and sporting goods applications.

Wear analysis are significant in industries where components face abrasive or sliding forces. They enhance performance, reduce costs, improve efficiency, and promote sustainability. By analyzing wear behavior, engineers can optimize material composition and design features to enhance wear resistance. This leads to improved component performance, extended operational life, and cost savings through reduced maintenance and replacements. Additionally, wear analysis enables informed material selection, resulting in tailored materials and designs that resist wear. Ultimately, wear analysis and optimization contribute to increased efficiency, reliability, and environmental sustainability.

Wear analysis play a crucial role in the development and application of materials, particularly in industries where components are subjected to abrasive, erosive, or sliding forces. The significance of wear analysis and optimization can be understood through the following points:

Wear resistance is a critical property in applications where materials are exposed to friction, contact, and wear. By analyzing the wear behavior of materials, it becomes possible to identify the underlying mechanisms and factors influencing wear. This knowledge enables engineers and researchers to optimize the material composition, surface treatments, and design features to enhance wear resistance. The result is improved performance and extended operational life of components.

Wear related failures and maintenance costs can be substantial in various industries. By conducting wear analysis and optimization, it becomes possible to identify weak points and vulnerable areas in materials and components. This information can be utilized to develop wear resistant materials or apply protective coatings that reduce friction and wear. By minimizing wear related failures, industries can achieve cost savings through reduced maintenance, repair, and replacement expenses.

Wear analysis contribute to enhancing the overall efficiency and reliability of systems and machinery. By improving wear resistance, components can operate at higher speeds, under heavier loads, and in harsh environments with reduced degradation. This leads to enhanced productivity, increased uptime, and improved operational reliability, particularly in critical applications such as automotive engines, industrial machinery, and aerospace systems.

Wear analysis provides valuable insights into the performance of different materials and their suitability for specific applications. By understanding the wear behavior and wear mechanisms, engineers can make informed decisions regarding material selection and design considerations. This enables the development of tailored materials and optimized designs that effectively resist wear, leading to improved product performance and customer satisfaction.

Wear analysis also contribute to sustainable practices by promoting longer product lifecycles, reducing waste generation, and conserving resources. By designing materials and components with enhanced wear resistance, the frequency of replacements and disposal of wornout parts can be reduced. This leads to reduced environmental impact and improved sustainability in various industries.

Wear analysis and optimization are essential for improving the performance, reliability, and cost-effectiveness of materials and components. By understanding wear mechanisms, optimizing material properties, and applying suitable surface treatments and designs, industries can achieve enhanced wear resistance, reduced maintenance costs, increased efficiency, and improved sustainability.

Granite powder and Boron Carbide (B_4C) have gained recognition as reinforcement materials for aluminium composites. Granite powder is a waste byproduct obtained from construction industries and possesses advantageous properties such as high hardness, low density, and cost-effectiveness. Meanwhile, B_4C is a ceramic material renowned for its exceptional hard- ness, high thermal stability, and excellent wear resistance. When combined as reinforcements in aluminium composites, granite powder and B_4C offer the potential to enhance wear resistance and improve the overall mechanical properties of the composites.

1.1 Outline of Process

The work of wear analysis of an aluminum composite reinforced with granite powder and boron carbide (B_4C) involves evaluating the wear characteristics of the composite material and detailing its composition and processing parameters to enhance its wear resistance. Here's a step-by-step outline of the process:

- Literature Review: Conduct a comprehensive review of existing literature and research related to wear analysis and composite materials reinforced with coconut shell ash and B_4C. Understand the previous work done in this area, including the properties of the reinforcing materials, fabrication techniques, and wear testing methodologies.
- Material Selection: Select an appropriate aluminum matrix alloy based on the specific application requirements and compatibility with the reinforcing materials. Determine the desired composition and properties of the composite, such as hardness, strength, and wear resistance.
- Reinforcement Preparation: Obtain granite powder and B_4C particles with suitable particle size distribution and morphology. If necessary, perform pre-treatment processes such as acid washing, drying, and sieving to improve the properties of the

reinforcement.

- Composite Fabrication: Develop a fabrication method for the composite, such as powder metallurgy, stir casting, or hot pressing. Optimize the processing parameters such as temperature, pressure, and mixing time to achieve a uniform distribution of the reinforcement particles within the aluminum matrix.
- Characterization: Perform a characterization of the fabricated composite material, including microstructural analysis using techniques like optical microscopy or scanning electron microscopy (SEM). Evaluate the mechanical properties, such as hardness and tensile strength, using appropriate testing methods.
- Wear Testing: Conduct wear tests on the composite samples using standardized test methods such as pin-on-disc or ball-on-disc. Vary the test parameters, including load, sliding speed, and duration, to simulate the intended operating conditions. Measure and analyze wear parameters like wear rate, coefficient of friction, and wear mechanism.
- Optimization: Analyze the wear test results and identify the critical factors influencing wear resistance. Use statistical tools and optimization techniques to determine the optimum composition of the composite, considering the relative proportions of granite powder and B_4C, as well as other variables like particle size and distribution. Iteratively refine the composite composition and processing parameters to enhance wear resistance.
- Validation: Validate the optimized composite by conducting additional wear tests under different conditions to ensure its improved wear performance compared to the initial composite and possibly even existing materials in the same application domain.
- Analysis and Reporting: Analyze the data collected throughout the study, including wear test results, microstructural analysis, and mechanical properties. Summarize the findings, draw conclusions, and prepare a comprehensive report documenting the wear

analysis and optimization of the aluminum composite using granite powder and B_4C as reinforcement.

- Future Recommendations: Provide recommendations for further research and development, such as exploring different reinforcement materials, modifying processing techniques, or investigating other wear analysis parameters.

1.2 Objective

The objectives of the wear analysis of Aluminium composites using Granite Powder and B_4C as reinforcement are as follows:

- To investigate Wear Behavior: The primary objective is to analyze and understand the wear behavior of Aluminium composites reinforced with Granite powderr and B_4C. This involves studying the wear mechanisms, such as abrasion, adhesion, and fatigue, that occur during sliding or abrasive contact with other surfaces.
- To optimize Reinforcement Content: Determine the optimal content or concentration of Granite powder and B_4C reinforcements in the Aluminium composite to achieve the best wear resistance. This objective involves evaluating the effect of varying reinforcement content on wear performance and identifying the optimum balance between reinforcement content and other material properties.
- To evaluate Particle Size Effect: Investigate the influence of Granite powder and B_4C particle sizes on wear resistance. This objective aims to understand how different particle sizes affect wear behavior, including the potential trade-offs between wear resistance and other mechanical properties.
- To characterize Wear Performance: Develop experimental methodologies and techniques to accurately characterize and quantify the wear performance of Aluminium

composites reinforced with Granite powder and B4C. This includes selecting appropriate wear testing methods, analyzing wear rates, friction coefficients, and wear mechanisms, and comparing the wear performance of different composite formulations.

- To identify Wear Optimization Strategies: Based on the findings from wear analysis and characterization, identify strategies for optimizing the wear resistance of Aluminium composites. This may involve modifying the reinforcement particle size, content, or distribution, as well as incorporating other additives or surface treatments to further enhance wear resistance.
- To identify application-Specific Optimization: Investigate the application-specific requirements and conditions to optimize the wear resistance of Aluminium composites. This objective aims to tailor the composite formulation and reinforcement parameters to specific industrial applications where wear performance is critical, such as automotive components, bearings, cutting tools, or aerospace applications.

By addressing these objectives, the wear analysis and optimization of Aluminium composites using Granite powder and B4C reinforcement aim to provide valuable insights into the wear behavior, performance optimization, and application-specific requirements of these composites.

1.3 Scope

The scope of the work involves selecting suitable materials, conducting experimental tests, analyzing microstructures, proposing optimization strategies, comparing with existing materials, and considering application-specific requirements. The focus is on enhancing the wear resistance of Aluminium composites using Granite powder and B_4C reinforcement.

CHAPTER 2
LITERATURE REVIEW

2.1 Overview

Aluminium composites are widely used in various industries due to their lightweight nature and excellent mechanical properties. To further enhance their performance, researchers have explored the use of reinforcement materials. This literature review focuses on the wear analysis and optimization of Aluminium composites using Granite powder and Boron Carbide (B_4C) as reinforcement. The objective is to provide an overview of the existing research in this field, highlighting the methodologies, findings, and areas for future exploration.

Understanding the wear behavior of materials is crucial for optimizing their performance. Several studies have investigated the wear characteristics of Aluminium composites reinforced with Granite powder and B_4C. Experimental techniques, such as pin-on-disc or ball-on-disc tests, have been employed to evaluate wear rates, friction coefficients, and wear mechanisms. It has been observed that the addition of Granite powder and B_4C reinforcements enhances the wear resistance of Aluminium composites. The materials exhibit reduced wear rates, improved hardness, and increased resistance to abrasive and erosive wear.

The content and particle size of the reinforcements play a vital role in determining the wear properties of the composites. Researchers have explored different reinforcement content ratios and particle sizes to optimize wear resistance. It has been found that an optimal content of granite powder and B_4C exists, beyond which excessive reinforcement can lead to agglomeration and reduced wear performance. Similarly, the particle size of reinforcements affects wear behavior, with finer particles often providing better wear resistance due to improved dispersion and load transfer.

Microstructural analysis techniques, such as scanning electron microscopy (SEM) and optical microscopy, have been employed to examine the distribution and morphology of reinforcements within the Aluminium matrix. These analyses reveal the microstructural characteristics that in- fluence wear behavior. Proper dispersion of Granite powder and B_4C reinforcements within the matrix is crucial for achieving improved wear resistance. The microstructural examination also helps in identifying any potential interfacial reactions or defects that may affect the wear performance.

Researchers have proposed various optimization strategies to enhance the wear resistance of Aluminium composites. These strategies include adjusting the content and particle size of the reinforcements, exploring the use of additional additives or surface treatments, and considering the incorporation of other reinforcing materials. It has been noted that synergistic effects can be achieved by combining Granite powder and B_4C reinforcements, leading to improved wear properties compared to using either reinforcement alone.

Comparative studies have been conducted to evaluate the wear performance of Aluminium composites with Granite powder and B_4C reinforcements in comparison to pure Aluminium and other conventional reinforcement materials. These comparisons highlight the advantages of using Granite powder and B_4C, such as their low cost, availability, and desirable properties. The wear resistance of the composites is found to be superior to pure Aluminium, indicating the potential of Granite powder and B_4C as effective reinforcements for wear-sensitive applications.

The wear analysis and optimization of Aluminium composites using Granite powder and B_4C as reinforcement need to consider the specific requirements and conditions of the intended applications. The targeted industries, such as automotive, aerospace, or manufacturing, have unique wear challenges and performance expectations. Tailoring the composite formulation, optimization strategies, and testing protocols to these specific applications can ensure the development of high-performance wear-resistant materials.

The literature review highlights the significant research conducted on the wear analysis and optimization of Aluminium composites using Granite powder and B_4C reinforcement. The studies demonstrate the positive impact of these reinforcements on wear resistance, providing improved mechanical properties and enhanced durability. However, further investigations are warranted to explore the effects of various parameters, such as reinforcement content, particle size, and intermolecular bonds.

By taking into account the recyclable nature of aluminium and using scrap aluminium cans as the metal matrix, the composite reduces the cost of aluminium procurement. Venkatraman Murali et al [1] addressed the use of discarded scrap aluminium alloy for metal matrix composites, and with the addition of particle reinforcements, they demonstrated improved mechanical qualities. By choosing the reinforcement particle size, hybrid metal matrix composites with an Al alloy as the base metal and variable B_4C were created in the work by T Pradeep Reddy et al [2].

2.2 Summary

This chapter provides an overview of previous research focuses on the wear analysis and optimization of Aluminium composites using Granite powder and B_4C as reinforcement. The review highlights the research conducted on the wear behavior of these composites, including wear rates, friction coefficients, and wear mechanisms. It discusses the effect of reinforcement content and particle size on wear resistance, emphasizing the importance of proper dispersion. Microstructural analysis techniques reveal the distribution and morphology of reinforcements within the Aluminium matrix. Optimization strategies, such as adjusting content and particle size, exploring additives or surface treatments, and considering other reinforcing materials, are proposed. Comparative studies demonstrate the superior wear resistance of the composites compared to pure Aluminium and conventional reinforcements. Finally, application-specific considerations are discussed to tailor the composites for specific industry requirements. Overall, the literature review indicates the potential of Granite powder and B_4C as effective reinforcements for enhancing the wear resistance of Aluminium composites. Further research is needed to explore additional parameters and optimize the composites for various applications. The following chapter will provide a description of the system being studied.

CHAPTER 3
METHODOLOGY

3.1 Material Selection

Choosing the most appropriate matrix material for aluminum metal matrix composites (MMCs) was a crucial task. The possibility of utilizing aluminum as a recyclable source was considered, and instead of obtaining aluminum from primary sources provided by vendors, the preference was given to secondary sources like scrap aluminum. The potential of using recyclable aluminum as a source was taken into account, and the focus shifted towards secondary sources, such as scrap aluminum, rather than relying on primary sources from vendors.

Stir casting is a widely used method for manufacturing Aluminium composites by incorporating reinforcement materials, such as Granite powder and Boron Carbide (B_4C), into a molten Aluminium matrix through mechanical stirring. The process involves melting the Aluminium alloy, gradually adding the reinforcement particles, and stirring the mixture to achieve uniform dispersion. The stirring action promotes wetting and bonding between the reinforcement and matrix. Stir casting is known for its simplicity, cost-effectiveness, and suitability for both small and large-scale production. However, challenges related to dispersion, agglomeration, and optimization of process parameters exist. The technique can be enhanced by combining it with additional methods like ultrasonic agitation or mechanical alloying. Overall, stir casting is a valuable synthesis technique for producing Aluminium composites with improved mechanical properties and wear resistance.

3.2 Selected Materials

3.2.1 Aluminium:

In my study, aluminium sourced from scrap soft drink cans has been utilized. The choice of aluminum is based on its lower density and medium mechanical strength, which make it suitable for applications requiring a higher stiffness-to-weight ratio. This characteristic is particularly advantageous in aircraft structures and performance automotive components. However, pure aluminum alloy is not preferred due to its relatively low hardness and poor impact resistance. The aim of this study is to improve these properties by incorporating various reinforcements.

Fig 3.1 Scrap Aluminium cans

One of the notable advantages of aluminum is its excellent corrosion resistance compared to other structural materials like mild steel and cast iron. This is attributed to its minimal affinity for environmental factors and chemical components. Additionally, aluminum offers higher ductility when compared to steel. Moreover, the exceptional natural abundance of bauxite in India further establishes aluminum as a favorable candidate for the matrix phase in composite materials.

In summary, aluminum sourced from scrap soft drink cans provides a suitable base material due to its advantageous properties such as lower density, medium mechanical strength, corrosion resistance, and higher ductility. By incorporating reinforcements, the study aims to enhance characteristics such as hardness and impact resistance to further improve the performance of the composite

3.2.2 Boron Carbide:

Boron carbide is highly valued in engineering due to its exceptional hardness and improved mechanical properties. It finds a wide range of applications across various industries. With a Vickers hardness in the range of 30 GPa and above, boron carbide competes with other extremely hard materials like diamond and cubic boron nitride.

Fig 3.2 B_4C Particles

In the field of metal matrix composites, boron carbide is extensively used as an industrial grade particulate reinforcement. Powdered boron carbide exhibits improved wettability with metal matrices, making it an ideal choice for enhancing the mechanical properties of composites.

In addition to composite applications, boron carbide is utilized in machining operations. It is employed as cutting tools, nozzles for abrasive jet machining, and in polishing, honing, and lapping processes. Boron carbide plays a crucial role in the processing of precious stones and diamonds. It also finds applications in automotive components that are subjected to extreme wear and friction, such as brake pads and armored trucks.

The unique combination of extreme hardness, superior mechanical properties, and compatibility with various industrial processes makes boron carbide a versatile material in the field of engineering, finding applications in diverse areas ranging from composite manufacturing to machining operations and automotive industries.

3.2.3 Granite powder:

In the stone processing business, granite powder is a byproduct of the cutting and polishing of granite stones. It is mostly made up of finely crushed granite particles, which is a common and plentiful material found in nature. In recent years, there has been an increase in interest in using granite powder as a reinforcement material in composites made of aluminium matrix. The use of granite powder as reinforcement in aluminium composites is the subject of this literature study, which also covers its potential advantages, methods of manufacturing, mechanical characteristics, and applications.

The cost-effectiveness, enhanced mechanical qualities, and weight reduction that come with using granite powder as reinforcement in aluminium matrix composites are just a few advantages. For incorporating granite powder, common methods include stir casting, powder metallurgy, and solid-state processing. Because the granite particles and aluminium matrix have a strong connection, adding granite powder improves the composites' hardness, tensile strength, and stiffness. Numerous industries, including those of construction, automotive, aircraft, and sports equipment, use these composites. The production techniques and qualities of aluminium composites supplemented with granite powder need to be improved for particular application scenarios, which calls for more research.

Fig 3.3 Granite Powder

3.3 Preparation of Reinforcements

Powdered boron carbide (B_4C) is not generally made through direct synthesis or preparation. B_4C is a substance that may be purchased and is created using specialized industrial procedures. In these procedures, carbon and boron oxide (B_2O_3) react while being in the presence of a reducing agent like magnesium or carbon. In order to create Boron Carbide powder, the reaction must occur under carefully controlled circumstances at high temperatures, usually above 2000°C. The B_4C powder can be further treated or altered after it is created using techniques like milling, sieving, or surface treatment to obtain the desired particle size, morphology, and surface characteristics for particular applications. This procedure has employed B_4C powder that is 50 microns in size.

3.4 Synthesis of Composite material

The collected aluminium cans are cut off into sheets by removing the top and bottom layers of the junk aluminium cans, since they were distinctly alloyed during fabrication and comprise some components that are not essential to the preparation of an aluminium composite that should be cast.

To ensure a uniform distribution of the particulate matter and minimize pore formation within the structure, stir casting is employed as the manufacturing technique for this composite. Stir casting offers the advantage of being a cost-effective method compared to other manufacturing techniques, thus reducing production costs. The manufacturing process begins by melting scrap aluminum 4kgs obtained from cans in a graphite crucible at a temperature of 800°C. The melting process is carefully managed to remove any slags or impurities, resulting in a high-quality melt of 1978g. Simultaneously, purchased boron carbide (B_4C) particles and granite particles with a particle size of 50 microns are preheated at a temperature of 450°C to eliminate

Fig 3.4 Molten aluminium in the furnace

The molten metal is mixed with the reinforcements to form a composite material. The mixture is agitated for 5 minutes at a speed of 300 rpm in order to obtain a homogeneous dispersion of the reinforcing particles inside the molten metal. By churning the composite melt, it is made sure that the reinforcement particles are evenly distributed. A permanent mold of Cast iron that has been heated up at a temperature of 400°C is then filled with the composite melt.

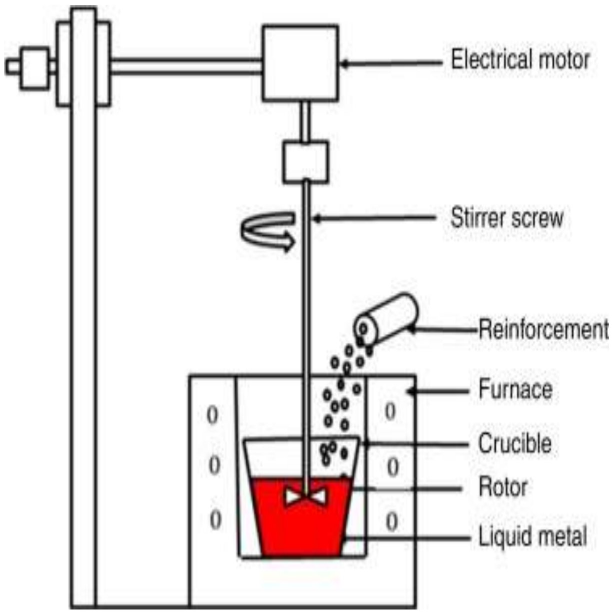

Fig 3.5 Stir Casting Configuration [3]

The molten metal is allowed to solidify and adopt the appropriate shape while being kept in the mold under air conditions. The composite samples are effectively created by stir casting by adhering to this manufacturing procedure, guaranteeing a homogeneous distribution of the reinforcing particles and obtaining the desired composite structure.

3.5 Specimen Cutting

Composite materials are frequently shaped into specimen forms via wire cutting. It entails cutting through the composite material with an electrically charged wire using a wire EDM or CNC wire cutting equipment. The steps in the procedure are prepping the material, configuring the machine and cutting settings, securing the material, starting the cutting operation, and completing any necessary post-cutting finishing. During the wire cutting operation, certain safety precautions should be taken. For precise and productive specimen formation, it is advised to consult machine manufacturer instructions and seek professional assistance.

An electrically charged wire is used in the precise manufacturing technique known as Wire Cut Electro-Discharge Machining (WEDM), sometimes referred to as Wire EDM or Wire Cutting, to shape and cut conductive materials. Controlled electrical discharge occurs as the wire is fed into the workpiece. Charges produce sparks that corrode the material, producing clean cuts with excellent accuracy. This method is frequently used to create sophisticated parts and molds in sectors like aerospace and automotive since it is appropriate for complex geometries and provides good surface polish

Fig 3.6 WEDM

Fig 3.7 WEDM Control modules

Fig 3.8 Wire cutting being done on the composite

Here specimens of 6mm diameter cylinder and $30mm^2$ crossectional area and 10mm thickness being cut from the composite being cast by stir casting process. These specimens are called pins which are used in wear testing of the composite and latter is used for hardness testing.

Fig 3.9 Specimen

CHAPTER 4
WEAR TESTING

4.1 Wear

Wear characterization is a crucial aspect of understanding the performance and durability of materials, including Aluminium composites. It involves the evaluation and analysis of the wear behavior, wear mechanisms, and wear resistance of materials under specific operating conditions. The characterization aims to provide insights into the material's ability to withstand sliding contact, resist wear, and maintain its functionality over time. Wear characterization methods typically involve controlled experiments and measurements to quantify wear parameters and assess the material's response to wear-inducing factors. The two commonly used methods for wear characterization of Aluminium composites are the pin-on-disk test and dry sliding wear tests.

4.1.1 Pin on disk test:

The pin-on-disk test is a commonly used method for characterizing the wear behavior of materials, including Aluminium composites. In this test, a cylindrical pin made of the composite material is pressed against a rotating disk, typically made of a harder material. The pin and disk surfaces are brought into contact under a specific load and subjected to sliding motion. During the test, the pin experiences frictional forces and undergoes wear due to the sliding contact with the disk. The wear rate of the pin is measured by monitoring the weight loss or volume loss of the pin over a specified duration of sliding. The coefficient of friction between the pin and disk surfaces is also recorded. The pin-on-disk test provides valuable information about the wear resistance of Aluminium composites, including their ability to withstand sliding contact, frictional forces, and surface degradation. The test allows for the evaluation of different wear parameters, such as wear rate, friction coefficient, and surface morphology changes. It also enables the investigation of the effects of various factors, such as applied load, sliding speed, and environmental conditions, on the behavior.

Fig 4.1 Pin on disc with 20N load on it

Fig 4.2 Drives with controls for rpm and time settings

Fig 4.3 E31 Disc of diameter 65mm and Pin with diameter 6mm

4.1.2 Dry Sliding wear:

Dry sliding wear refers to the wear that occurs between two surfaces in the absence of a lu- bricant. It is a common wear mechanism encountered in many engineering applications. Dry sliding wear tests are conducted to assess the wear performance of materials, including Alu- minium composites.In dry sliding wear tests, a flat specimen or a pin made of the composite material is slid against a harder counterface in a controlled manner. The wear behavior is characterized by measuring the weight loss, volume loss, or wear scar dimensions on the specimen surface. The dry sliding wear test provides insights into the wear resistance, frictional behavior, and surface degradation mechanisms of Aluminium composites. It helps identify the material's ability to withstand sliding contact, resist wear, and maintain its mechanical properties under dry conditions. Factors such as applied load, sliding speed, and surface roughness influence the wear behavior and can be investigated using this method.

4.1.3 Wear mechanisms:

Wear mechanisms refer to the processes and phenomena that occur during the degradation and removal of material from surfaces in contact. Understanding the wear mechanisms is crucial for optimizing the wear resistance of Aluminium composites and developing strategies to mitigate wear. Various wear mechanisms can occur in Aluminium composites, adhesive wear, abrasive wear, and tribo-oxidation. Adhesive wear involves the transfer of material from one surface to another due to strong adhesive forces between the surfaces. Abrasive wear occurs when hard particles or asperities on the counterface cause surface damage and material removal. Tribo- oxidation involves the formation of oxide layers on the surfaces due to the combined action of wear and oxidation.

The identification of wear mechanisms in Aluminium composites can be done through a combination of wear tests, surface analysis techniques (such as scanning electron microscopy), and wear debris analysis. Understanding the dominant wear mechanisms helps in designing effective strategies to improve wear resistance, such as selecting appropriate reinforcement materials, optimizing composite composition, or applying surface treatments.

Wear characterization methods such as the pin-on-disk test and dry sliding wear tests provide valuable information on the wear behavior of Aluminium composites. These tests help quantify wear rates, friction coefficients, and surface morphology changes. Additionally, understanding the wear mechanisms involved in the degradation process is essential for developing strategies to enhance the wear resistance of Aluminium composites.

Pin on disc wear test apparatus is fed prepared specimens that have been cut to comply with ASTM G99 standard. The device's sensors are equipped with the ability to detect and record normal force and frictional force in real time. relying that the computer uses to calculate the coefficient of friction in real time.

4.1.4 Examining wear loss:

It was determined that because wear loss was such a minor parameter, three observations had to be repeated for each test run in order to limit measurement error, and the observations' averages were used to determine the results. For Testing the wear loss and effect of factors affecting wear loss, Taguchi L27 design method was used.

The necessary Parameters, such as Sliding Velocity, Sliding Distance, and Sliding Time, are converted during testing into inputs via Speed in RPM. For that purpose, the formulas listed below are used:

Sliding velocity of the pin, $\vartheta = \frac{\pi DN}{60}$m/s where,

D = Diameter of the track radius of EN31 disc in m

N = Speed of the disc in rpm

Sliding time,t = $\frac{s}{v}$ where,

S – Sliding distance inm

V- Sliding velocity in m/s

A sample to prevent mistakes during experimentation and measurement, both tests were labelled in a methodical manner, as indicated in the table.

Table 4.1 Sample Nomenclature

Composites	Reinforcement by Wt%	Specimen
Unreinforced Aluminium	Pure Al/Alloy	A10.1, A10.2, A10.3
Al/B_4C/ Granite Powder	Al/2.5 wt% B4C/Granite Powder	A12.1, A12.2, A12.3

In order to measure very small values of wear loss a chemical weighing machine with Least Count of 0.0001 g was used to measure the weights of Specimen before and after the test. Samples of different compositions were tested for observing the dependencies of wear rate and coefficient of friction on Parameters like Load, sliding distance and sliding velocity. Prior to and following measurement, dust from the specimen was removed using acetone as a cleaning agent. With the application of normal loads in the form of weights, the Pin on Disc Tribometer metre employs a dedicated Dynamometer to detect the frictional force; the software then computes the coefficient of friction on an area-time basis.

4.2 SEM Images of Wear surface:

A sophisticated microscope termed a scanning electron microscope (SEM) makes precise images of a sample's surface utilising electrons. It records the signals produced by the interaction by moving a focussed electron beam across the sample. The high resolution black and white photographs produced from these signals later show minute surface characteristics at the nanoscale. SEM offers greater magnification and resolution compared to optical microscopes, making it very beneficial for researching the morphology, content, and structure of samples in a variety of scientific fields.

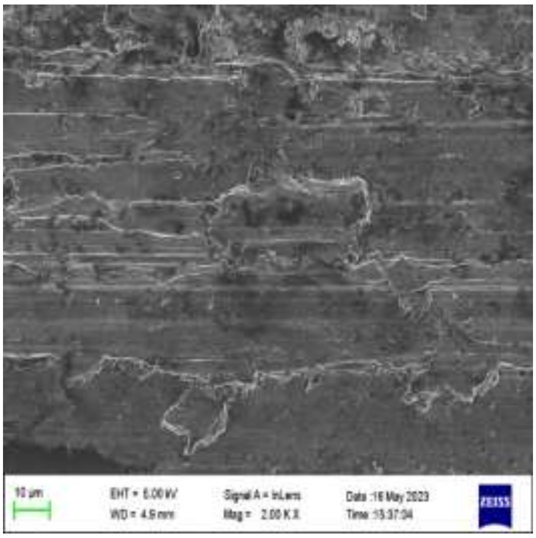

Fig 4.4 Sem Image of wear pattern in Unreinforced Aluminium alloy

The wear track created in the unreinforced aluminium alloy put through a wear test may be seen in this image. Wear loss in the case of the composite is lower than that of the unreinforced aluminium alloy because the wear track is staggered as opposed to the aluminium alloy reinforced with B_4C and granite powder.

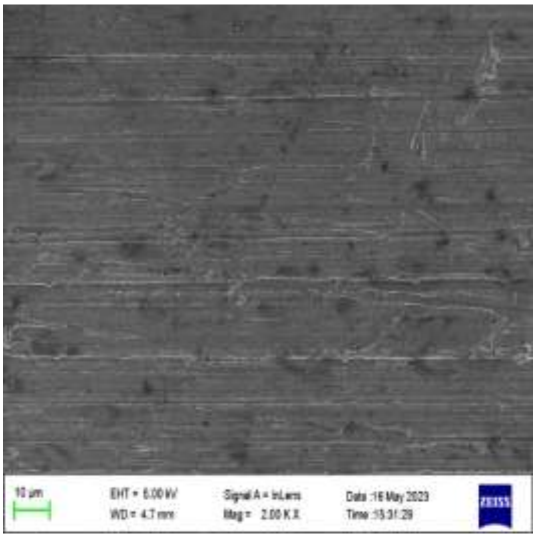

Fig 4.5 Sem Image of wear pattern in A/B_4C/Granite powder

CHAPTER 5
RESULTS AND DISCUSSION

5.1 Observation on Wear under varying load

Table 5.1 Wear relative to load

Sl. No	Specimen	Reinforcement (wt%)	Load (N)	Wear Loss (g)
1	A10.1	0	10	0.0018
2	A10.2	0	20	0.0088
3	A10.3	0	30	0.0320
4	A12.1	2.5	10	0.0011
5	A12.2	2.5	20	0.0034
6	A12.3	2.5	30	0.0064

Wear loss is observed at various level of input parameters like Reinforcement taken in relative to weight percentage of Aluminium matrix, Sliding Distance (m), Load (N),Sliding velocity(m/s). There are 6 samples of two different composition which are tested to 3 levels of Load 10N ,20N, 30N and Sliding Distance 500m, 1000m, 1500m.Three rounds of specimen run is done and the average is taken as wear loss.

5.1.1 Graphical Analysis of Result :

The gathered observations were subjected to graphic analysis, and the following graphs were generated.

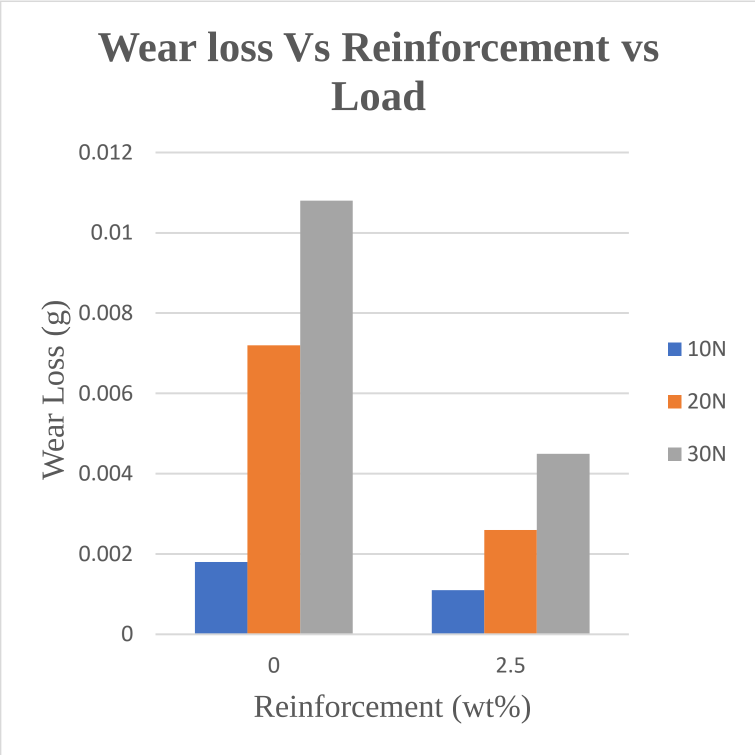

Fig 5.1 Wear loss Vs Reinforcement vs Load

According to analysis, there is a noticeable rise in wear loss with respect to an increase in applied load (L) in each composite type with the same constituents (same reinforcement wt%). The maximum wear loss was recorded for Unreinforced Aluminium Alloy at 30 N applied load which was 0.0320g, at the same load conditions wear loss detected for 2.5 wt% Reinforced Composite showed a wear loss of 0.0064 g. Here the reduction of wear to corresponding to final load conditions is .0256g compared to unreinforced Aluminium alloy at same load conditions.

5.2 Observation on Wear under varying Sliding distance

Table 5.2 Wear relative to Sliding distance

Sl. No	Specimen	Reinforcement (wt%)	Sliding distance (m)	Wear Loss (g)
1	A10.1	0	500	0.0018
2	A10.2	0	1000	0.0072
3	A10.3	0	1500	0.0108
4	A12.1	2.5	500	0.0011
5	A12.2	2.5	1000	0.0026
6	A12.3	2.5	1500	0.0045

5.2.1 Graphical Analysis of Result:

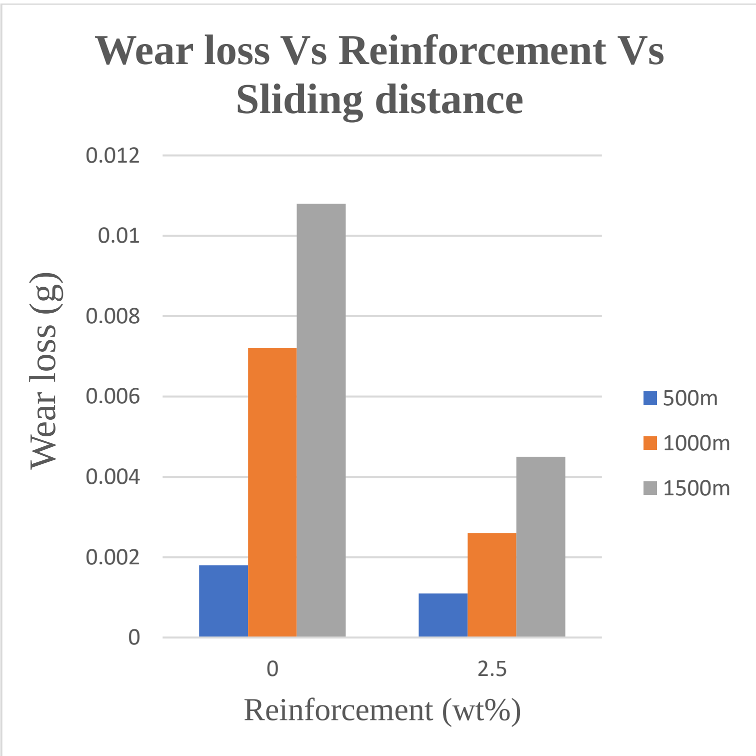

Fig 5.2 Wear loss Vs Reinforcement Vs Sliding distance

Within similar types of components, the Wear loss with increasing sliding distance pattern that was discovered was arbitrary. According to graph 5.1, this was most likely caused by the load's dominating impact on the specimen's wear loss. The examination of wear losses across various constituent reinforcing amounts revealed a progressive decrease as the proportion of boron carbide and granite powder increased.

5.3 Observation on Wear under varying Sliding velocity

Table 5.3 Wear relative to Sliding velocity

Sl. No	Specimen	Reinforcement (wt%)	Sliding velocity (m/s)	Wear Loss (g)
1	A10.1	0	1	0.0072
2	A10.2	0	1.5	0.0061
3	A10.3	0	2	0.0041
4	A12.1	2.5	1	0.0026
5	A12.2	2.5	1.5	0.0024
6	A12.3	2.5	2	0.0031

5.3.1 Graphical Analysis of Result:

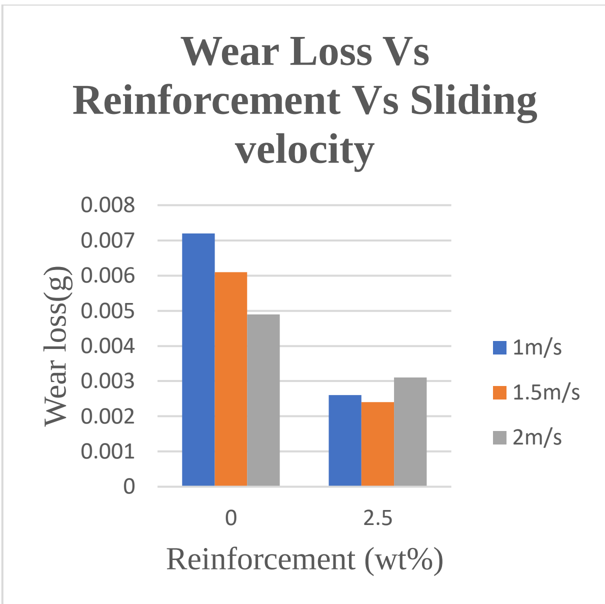

Fig 5.3 Wear Loss Vs Reinforcement Vs Sliding distance

5.4 Observation on Coefficient of Friction under varying load

The characteristic of a material surface that prevents relative motion is known as the coefficient of friction. It's an arbitrary number without dimensions that's associated with how much frictional force a surface can provide. The COF is calculated by dividing the frictional force by the normal response. COF for unreinforced aluminium can range from 0.4 to 0.6. Regarding the percentage of reinforcement and sliding velocity, the fluctuation in the coefficient of friction was taken into account.

Table 5.4 CoF relative to Load

Sl. No	Specimen	Reinforcement (wt%)	Load (N)	CoF
1	A10.1	0	10	0.23059
2	A10.2	0	20	0.25567
3	A10.3	0	30	0.25234
4	A12.1	2.5	10	0.25621
5	A12.2	2.5	20	0.39658
6	A12.3	2.5	30	0.28486

The coefficient of friction was computed at multiple loads for a standard time in minutes and at varying load. For each test run, the real-time average coefficient of friction generated from the Pin on Disc programme was recorded.

5.4.1 Graphical Analysis of Results

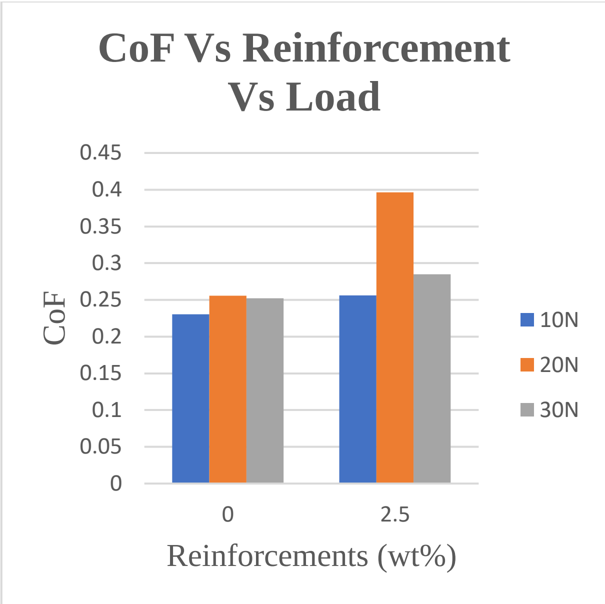

Fig 5.4 CoF Vs Reinforcement Vs Load

5.5 Observation on Coefficient of Friction under varying Sliding Velocity

Table 5.5 Observations on CoF under varying Sliding velocity

Sl. No	Specimen	Reinforcement (wt%)	Sliding velocity(m/s)	CoF
1	A10.1	0	1	0.280586
2	A10.2	0	1.5	0.352961
3	A10.3	0	2	0.305435
4	A12.1	2.5	1	0.256210
5	A12.2	2.5	1.5	0.316871
6	A12.3	2.5	2	0.280474

5.5.1 Graphical Analysis of Results

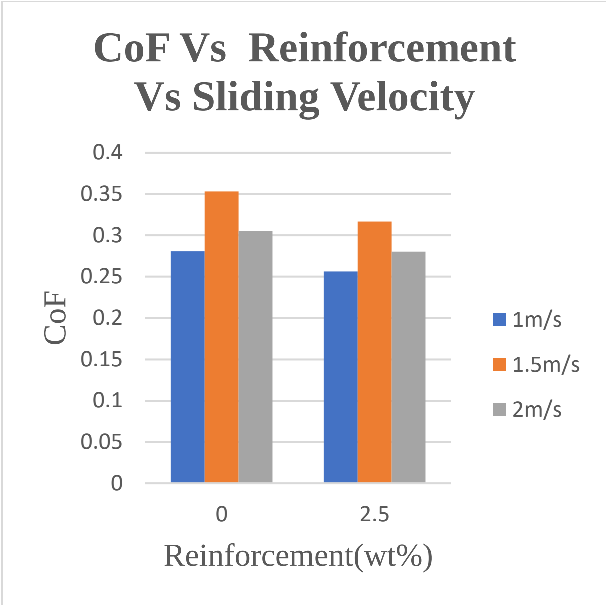

Fig 5.5 CoF Vs Reinforcement Vs Sliding Velocity

The Graph 5.5 shows the unreinforced aluminium had the highest coefficient of friction, the lowest sliding velocity (1 m/s), and the maximum sliding velocity across all reinforcement ratios. It was found that as sliding velocity increased, the coefficient of friction has increased and dropped with respect to both reinforcement percentages and sliding velocity. Description of this source of the sliding velocity appeared to be the blockage of particles within the pin-disc contact. The frictional force that actually exists between the pin and disc is reduced by the rolling motion.

Least coefficient of friction of 0.256210 for Al/B_4C/Granite powder was observed for 2.5 wt% reinforcement and 1 m/s sliding velocity. For Al/ B_4C composite under same conditions (1m/s Sliding velocity) 2.5wt% Composite showed convenient reduction in COF compared to that of Unreinforced Aluminium Alloy.

5.6 Observation on Coefficient of Friction under varying Sliding Distance

Table 5.6 Observations on CoF under varying Sliding distance

Sl. No	Specimen	Reinforcement (wt%)	Sliding distance (m)	CoF
1	A10.1	0	500	0.230586
2	A10.2	0	1000	0.255666
3	A10.3	0	1500	0.252344
4	A12.1	2.5	500	0.256210
5	A12.2	2.5	1000	0.396584
6	A12.3	2.5	1500	0.284857

5.6.1 Graphical Analysis of Results

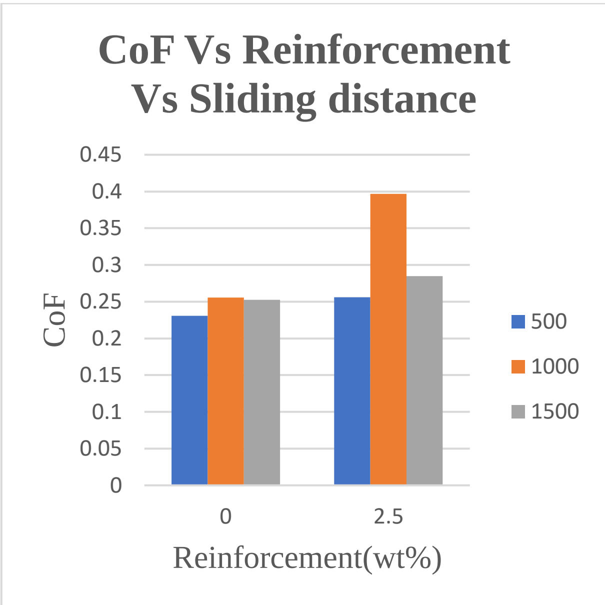

Fig 5.6 CoF Vs Reinforcement Vs Sliding distance

5.7 Comparison of tribological performance between Pure aluminium alloy and A/B_4C/Granite powder

In all composite varieties, it came to light that applied load was the characteristic that most strongly correlated with wear loss. For the difference in wear loss under constant loads when compared to various constituent percentages. The composite reinforced with boron carbide demonstrated better wear resistance properties for each assigned load.

Incorporating wear performance When compared to pure aluminium alloy, an aluminium composite reinforced with B_4C and granite powder demonstrates greater weather resistance. Highest tallied wear loss is 0.0295g for pure aluminium alloy whereas for Aluminium composite with B_4C and granite powder is 0.0061g under varying parameters.

5.8 Density Factors

With the use of a weighing machine and vernier calliper, densities of the measured specimens were determined in order to properly estimate specimen dimensions for volume measurement. Average density of Scrap Aluminium cans is 2.61g^3 whereas that of Al/B4C/Granite powder is 2.49g^3. The two types of material densities were similar, but the addition of reinforcements rendered composites somewhat lighter than the monolithic Aluminium alloy.

CHAPTER 6
CONCLUSION

In conclusion, the work of wear analysis of an aluminum composite using Granite powder and Boron carbide (B_4C) as reinforcements has been conducted. The study focused on enhancing the mechanical properties and wear resistance of the aluminum matrix by incorporating Granite powder and B_4C particles. Stir casting was employed as the manufacturing technique to ensure a uniform distribution of the reinforcement particles and minimize pore formation. The results demonstrated that the addition of Granite powder and B_4C improved the hardness, strength, and wear resistance of the composite. The composite showed promising potential for applications in industries where wear and friction resistance are critical, such as automotive components, machining tools, and structural materials. The use of granite powder a commercial waste reinforcement material also highlighted its environmental sustainability and cost-effectiveness. Further research and optimization can lead to the development of advanced aluminum composites with enhanced mechanical properties and improved wear resistance for various industrial applications.

In future work, several aspects can be explored to further enhance the aluminum composite reinforced with granite powder and boron carbide (B_4C). These include optimizing the reinforcement content, characterizing the microstructure for a deeper understanding of particle distribution, evaluating additional mechanical properties, conducting wear tests under specific conditions, investigating alternative processing techniques, exploring multifunctional composite development, and considering sustainability aspects such as life cycle assessment and the use of recycled materials. By addressing these areas, the composite's performance, range of applications, and sustainability can be improved, paving the way for advanced materials with enhanced properties and reduced environmental impact

CHAPTER 7

SCOPE OF FUTURE WORK

In the current study, the percentage of reinforcement was restricted to 5wt%; however, additional research could be done with percentages outside of 5wt%. More samples and experiment runs could be used in a statistical optimization study to uncover other connections between wear loss and variables like sliding velocity, sliding distance, specimen temperature, etc. Future uses of granite powder reinforced with boron carbide (B_4C) have a lot of promise. They can be utilized to increase the mechanical qualities of composite materials, strengthen concrete buildings, offer armor and ballistic protection, act as abrasives, and promote heat management in electronic equipment. To optimize these materials and discover their full potential in sectors including aerospace, automotive, construction, and defense, further research and collaboration are required.

CHAPTER 8

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