COMPARISON OF TRIBOLOGICAL BEHAVIOUR OF ALUMINIUM BORON CARBIDE AND COCONUT SHELL ASH COMPOSITES

A PROJECT REPORT

submitted by

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to

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in partial fulfillment of the requirements for the award of the Degree

of

Master of Technology

In

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Department of Mechanical Engineering

TKM College of Engineering

Kollam

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DECLARATION

I, Midhun A R, hereby declare that the project report "COMPARISON OF TRIBOLOGICAL BEHAVIOUR OF ALUMINIUM BORON CARBIDE AND COCONUT SHELL ASH COMPOSITES" 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 the supervision of Prof. Rakesh Pillai R, Assistant Professor, Department of Mechanical Engineering, TKM College of Engineering, 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 understand that any violation of the above will be a cause for disciplinary action by the institute and /or the University and also can 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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12/09/2022

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CERTIFICATE

This is to certify that the report entitled '**COMPARISON OF TRIBOLOGICAL BEHAVIOUR OF ALUMINIUM BORON CARBIDE AND COCONUT SHELL ASH COMPOSITES**' submitted by **MIDHUN A R (TKM20MECI07)** to the APJ Abdul Kalam Technological University in partial fulfillment of the requirements for the award of the Degree of Master Of Technology in Computer Integrated Manufacturing, Mechanical Engineering is a bonafide record of the project work carried out by him under my guidance and supervision. This report in any form has not been submitted to any other university or institute for any purpose.

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ABSTRACT

Composite materials became the cornerstones in Material Science and Technology spanning the last two decades. Improved performance with the introduction of affordable manufacturing techniques made composite materials a good alternative to conventional monolithic materials in many performance markets around the world, among these, Aluminium based composites have been extensively employed in Aeronautic/Aerospace/Sports and Recreational equipment Marine Transport applications due to their impeccable performance factors like Strength, Stiffness to weight ratio etc.. Our study focuses on the comparison of wear characteristics Aluminium/B4C composite and Aluminium Coconut shell Ash composite, also imploring the capability of such composites in solving the inherent shortcomings of monolithic Aluminium alloy. Scope of using biologically sourced and locally available reinforcements like coconut shell ash is also being discussed.

Keywords: - Composites, Performance Markets, Mechanical properties, Wear characteristics, Bio-reinforcements

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LIST OF ABBREVIATIONS

MMC - Metal Matrix Composites

CSA – Coconut Shell Ash

EDM – Electro Discharge Machining

COF – Coefficient of Friction

ASTM – American Society for Testing and Materials

CHAPTER 1: INTRODUCTION

1.1 MATERIAL SCIENCE AND TECHNOLOGY

Material Science and Technology is one of the rapidly expanding avenues of science, it is an interdisciplinary field in science and technology which covers the design and discovery of new materials and improvement of existing ones. M.S.T is literally the melting pot of various engineering disciplines including Mechanics, Composite Materials Technology, Metallurgy, Manufacturing science, applied chemistry etc. Its contributions to the world includes Composite Materials, Ceramics, Metals and Alloys, Nano-materials and Nano fibers, Smart Materials etc..

1.2 COMPOSITE MATERIALS

Composite material often referred as ‘composite’ is a combination of two or more monolithic materials which altogether forms a material which has the characteristics of component materials. Generally the phase which constitutes highest proportion in a composite material is referred as ‘matrix’ and those phases which are in smaller proportions are referred as ‘reinforcements’. They can be classified into different types based on different criteria, one such method is based on the type of matrix phase vis,

a) Metal Matrix Composites
b) Ceramic Matrix Composites
c) Polymer Matrix Composites

By physics the property of composites are governed by the corresponding properties of constituent phases. Rule of Mixtures are used to approximate the properties of composite materials, which can be stated as, Property of a composite = (property of matrix)*(proportion of matrix)

+ (property of reinforcement)*(proportion of reinforcement)

1.3 ALUMINIUM ALLOY BASED COMPOSITES

Discontinuously–reinforced Aluminium alloy–based MMCs containing particulate, short fiber reinforcements have been used in the time period spanning the last few decades. Due to the improved mechanical properties shown by such Hybrid composites now, Performance markets around the world extensively use them notably Automotive, Aeronautical, Aerospace, Rail transport, Marine Transport, Packaging and containerization, Electric Power transmission, Sports and recreational goods etc.

1.4 PROJECT OBJECTIVES

1. Investigate the scope of Aluminium Composites and the potential use of locally sourced reinforcements.
2. To Fabricate Aluminium composites using Scrap Aluminium and Boron Carbide and Coconut Shell Ash.
3. To Perform Individual Wear Tests on samples with varying Wear Parameters to observe the performance of Composites and Analyze how the factors are influencing wear characteristics of composites.
4. Compare the wear performance of Aluminium composites using inorganic reinforcement (B4C) and locally sourced reinforcement (CSA).

CHAPTER 2: LITERATURE REVIEW

2.1 Selection of suitable Matrix and Reinforcement Material

Selection of the most suitable material as Matrix for Aluminium Metal Matrix Composites was one of the paramount task. Possibility of Aluminium as a recyclable source was considered and instead of primary source of Aluminium from vendors secondary source like scrap Aluminium was preferred. Pradeep Kumar Krishnan et al. [5] discussed the scope of scrap Aluminium alloy from waste materials for Metal Matrix Composites and with addition for particulate reinforcements they showed better Mechanical properties.

T Pradeep Reddy et.al [4] manufactured suitable Aluminium Metal Matrix composites by stir casting process with variable proportions of Boron carbide and Fly ash (0-4%) and (0-6%) with specific particle size . Testing the specimens revealed incorporation of reinforcement particles sufficient improvement of Tribological characteristics like wear loss and hardness.

Suggestions from Arjunan et al. [8] in using agricultural wastes in combination with industrial grade reinforcements like boron carbide in suitable proportions showed sufficient improvement in Mechanical properties with cow dung as one of the reinforcement.

K. Ravi Kumar et. Al[1] incorporated Coconut Shell Ash in the 50 micron powdered form as well as Zirconium dioxide in pure Aluminium 6082 alloy through stir casting process. The reinforcement composition was varied from 0-max 10%. Scope of Coconut Shell Ash as a potential reinforcement for MMCs were discussed its chemical composition was determined with contents like SiO_2, Al_2O_3, MgO, Fe_2O_3, etc. Preparation methods were discussed with optimum temperatures and times. Solid lubricating behavior of coconut shell ash was discussed. Improvement in Mechanical properties in composites compared to pure Aluminium was observed.

Considering the effect of scrap Aluminium cans in polluting neighborhoods and with sufficient literature references on the use of Scrap Cans and Kitchenware, Scrap Cans were used as Matrix material for the composites. Availability of coconut in the premises proved helpful in selection of Coconut Shell Ash as one of the reinforcement. Boron carbide was selected as the other reinforcement due to price and availability.

2.2 Fabrication Techniques used for Metal Matrix Composites

2.2.1 Stir Casting

Stir casting follows the procedure of melting the metal in a crucible and then heated above its melting point. Upon melting the matrix material a stirrer is used for agitating which aims to distribute the heat within the material in an even manner. Introduction of reinforcement phases are followed under stirring. The composite material is taken out after completely solidifying. Literature studies show improved performance characteristics and lesser defects for the products made under stir casting [9].

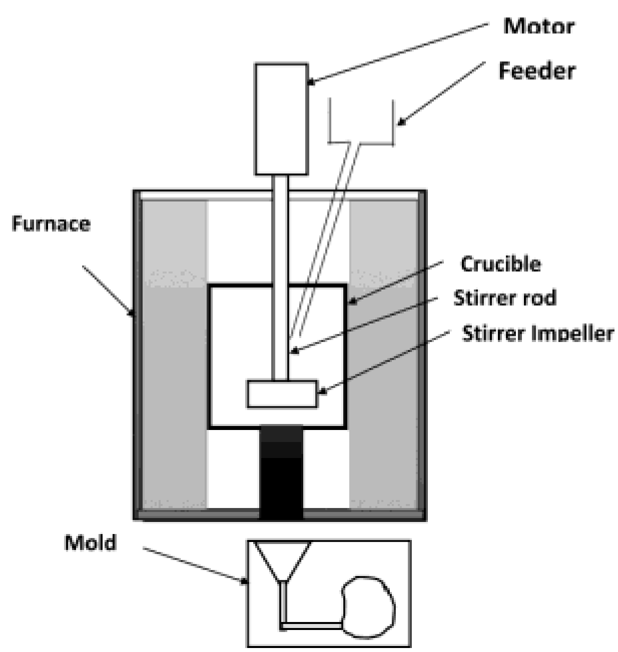


Fig 2.1 Schematic representation – Stir casting [16]

2.2.2 Squeeze Casting Infiltration

It is a forced infiltration method which combines the technical advantages of die casting, gravity die casting and some of those of forging process. It involves pressurized infiltration of molten metal with the help of a Punch Die .Squeeze casts boasts of higher refinement in microstructural characteristics and the cost is affordable for an industrial customer. But bit more expensive to researchers due to tooling, dies and other equipment. It involves placing a preform with reinforcement phases and the forced infiltration of liquid metal with the Punch die. [10] The parameters that affect composites made through squeeze process include Mould temperature, pouring temperature, die temperature, time delay in pressurizing the melt and filling velocity.

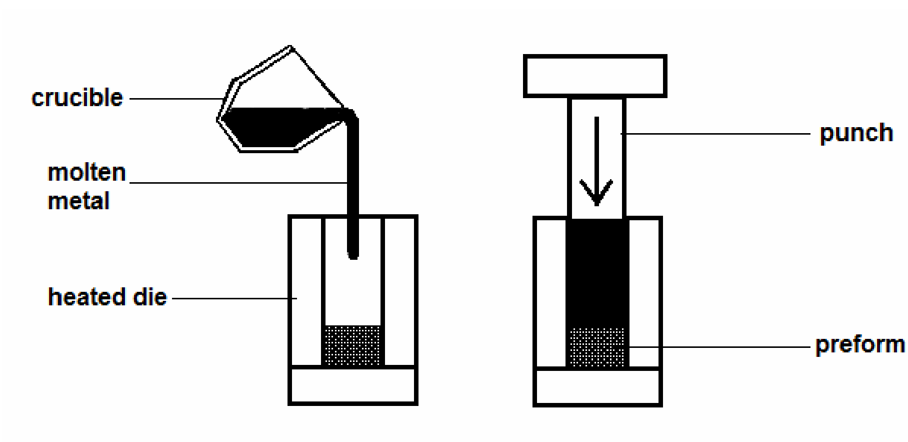


Fig 2.2 Schematic representation – Squeeze casting infiltration [16]

2.2.3 Gas Pressure Infiltration

Most suitable for heavy and large composites Gas pressure infiltration this process involves filling a tank with reinforcement with preforms and molten metal is poured up to a level. Under the application of substantial gas pressure the metal gets to infiltrate in between reinforcements and Composite gets formed.

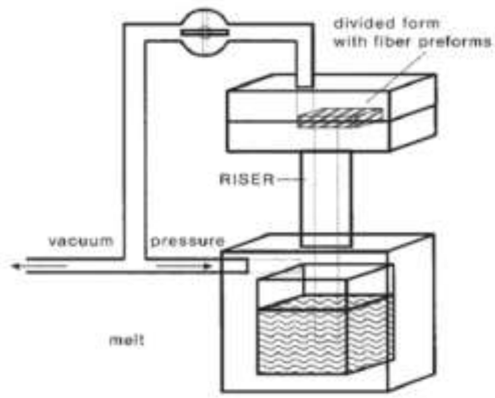


Fig2.3 Schematic representation of Gas pressure infiltration [16]

Cost of Gas pressure infiltration is high compared to other referenced techniques.

2.2.4 Powder Metallurgy

It falls under solid state Fabrication technique, here the Metal alloy powders are mixed with reinforcements and are compressed by large forces to compact using specific dies at room temperature. Its followed by the sintering phase where its subjected to higher temperatures to melt them with more time for sintering the final product density is liable to increase. Generally composites of Magnesium, Aluminium and copper are produced using Powder Metallurgical processes.

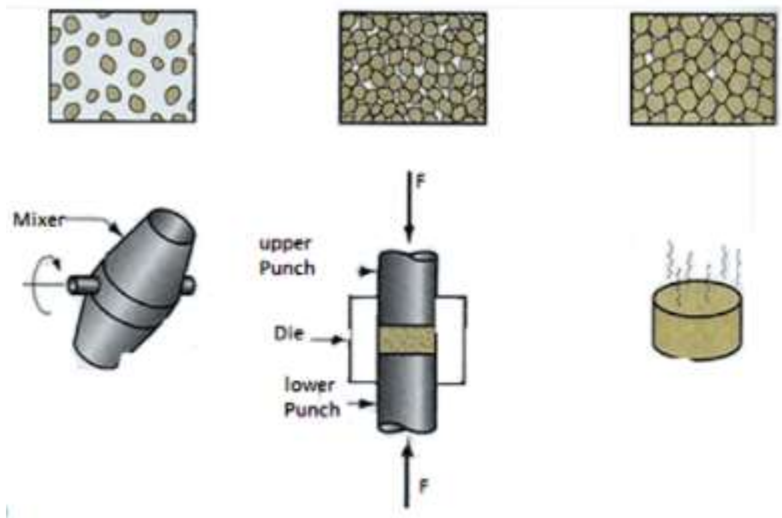


Fig 2.4 Schematic representation of Powder metallurgy process [16]

2.2.5 Diffusion Bonding

It's also a solid state fabrication method. Here the metal matrix in the form of foils and reinforcement phases in long fibers are piled up and elevated temperatures are applied. Simple composite parts can be manufactured using this technique but limitations exist for regular used composites with somewhat complex size and shape.

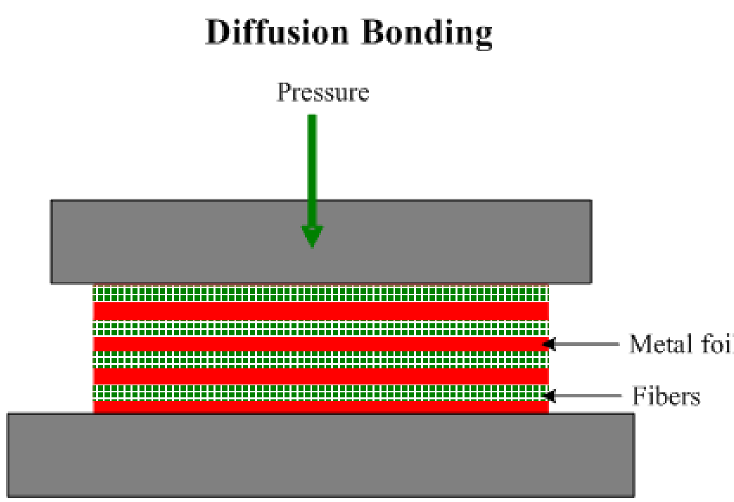


Fig 2.5 Schematic representation of Diffusion bonding [17]

CHAPTER 3: COCONUT SHELL ASH REINFORCED ALUMINIUM COMPOSITE

3.1 Properties of Constituent Phases

3.1.1 Aluminium

Aluminium sourced from scrap soft drink cans has been used in my study. Due to lower density coupled with medium mechanical strength makes it suitable for higher stiffness to weight ratio specific applications most notably aircraft structures and Performance automotive components, nevertheless pure alloy as such is least preferred because of not so high hardness and poor impact resistance, with the introduction of a few reinforcements we can improve such characteristics and that itself is the main focus in this study.

Aluminium offers excellent corrosion resistance compared to other structural materials like Mild steel, Cast iron etc. due to its least affinity of environmental factors and chemical components. It offers higher ductility than steel coupled with exceptional natural abundance of Bauxite in India makes it a suitable contestant for matrix phase in composite materials [11].

3.1.2 Reinforcement Phase – Coconut Shell Ash

Coconut shell ash (CSA) is composed of large number of inorganic oxides like SiO2, Al2O3, Fe2O3, MgO, due to excellent mechanical properties they can also be used as a prominent agro waste reinforcement material [1]. CSA's ability to be sourced from our agro wastes and the perceived impact on environmental conservation and cleanliness along with least cost of procurement makes it one exceptional contestant for our analysis.

3.2 Preparation of Composite

3.2.1 Preparation of Coconut Shell Ash

The raw material for CSA is Coconut Shells sourced from Oil Mills and Coir factories which are native to the State of Kerala. The outer and inner surface of the coconut shell collected locally was scrubbed and washed thoroughly to remove the impurities. The coconut shell was then dried in sunlight for 3 days to remove the moisture content. The dried coconut shell was crushed into small pieces, placed in a crucible and burnt in a furnace at a controlled temperature of 400 ºC for about 2 h [1]. The burnt particles were then subjected to heat treatment at a temperature of 800ºC for about 12 h to remove the carbonaceous material present in it. Sieved CSA particles in the size range of (0-75 µm) were used for the study [1].

3.2.2 Preparation of Coconut Shell Ash (CSA) Reinforced Aluminium Composite

Stir casting is preferred for the manufacturing of this composite to ensure the uniform distribution of particulate matter also to minimize the formation of pores in the structure. Being a low cost manufacturing technique compared to others stir casting gives an upper hand to minimize the cost incurred in the production process. Scrap Aluminium from cans were melted in graphite crucible at 750ºC and the slags were removed to have a good quality melt. Coconut shell ash particles at 50 microns size were preheated at a temperature of 450 ºC to remove the moisture content and then added to the molten metal to prepare a set of composite samples. The molten metal was stirred at a stirring speed of 500 rpm for 10 min to have a uniform distribution of reinforcement particles. The composite melt was then poured into a preheated permanent Mould of 20mm in diameter and 150mm length and allowed to solidify at atmospheric conditions.

CHAPTER 4: BORON CARBIDE REINFORCED ALUMINIUM COMPOSITE

4.1 Properties of Constituent Phases.

4.1.1 Boron Carbide

Owing to the extreme hardness and improved mechanical properties Boron carbide finds variety of applications in Engineering. With Vickers Hardness in the range of 30GPa and above it competes with other harder materials like Diamond, Cubic Boron Nitride etc.[12] It is extensively used as industrial grade particulate reinforcement for Metal Matrix composites as powdered Boron Carbide has improved wettability with metal matrices. Apart from Composite applications Boron carbide finds its use in Machining operations as Cutting tools, Nozzles used for Abrasive Jet Machining, Polishing operations , Honing , Lapping. Processing of Precious Stones and Diamonds, Automotive Components Prone to Extreme wear and friction like Brake Pads, Armored trucks etc.

4.1.2 Preparation of B4C Reinforced Aluminium Composite

Stir casting is used for the manufacturing of this composite to ensure the uniform distribution of particulate matter also to minimize the formation of pores in the structure. Being a low cost manufacturing technique compared to others stir casting gives an upper hand to minimize the cost incurred in the production process. Scrap Aluminium from cans were melted in graphite crucible at 750ºC and the slags were removed to have a good quality melt [4]. Purchased B4C particles having 50 micron particle size were preheated at a temperature of 450 ºC to remove the moisture content and then added to the molten metal to prepare a set of composite samples. The molten metal was stirred at a stirring speed of 500 rpm for 10 min to have a uniform distribution of reinforcement particles. The composite melt was then poured into a preheated permanent Mould of 20mm in diameter and 150mm length and allowed to solidify at atmospheric conditions.

Fig 4.1 (a) B4C (b) CSA (c) Scrap Aluminium Can

CHAPTER 5: WIRE CUTTING OF COMPOSITES TO FORM SPECIMEN

5.1 Wire cut Electro-discharge Machining

It is an advanced metal cutting process which uses the principle of metal erosion due to electric discharge. Here the tooling which consists of wire which is controlled by a CNC controller is made to traverse along X, Y and Z axes. Wire cut EDM is mostly preferred for precision machining and contour machining operations. ASTM G99 standard [13] pertaining to Pin on Disc Tribometer for size of specimens is met using this Wire cut EDM process.

Fig 5.1 Wire Cut EDM

Fig 5.2 Specimen (ASTM G99 standard)

CHAPTER 6: TRIBOLOGICAL TESTING

6.1 Pin on Disc wear testing machine

The manufactured specimens cut according to ASTM G99 standard is fed into the Pin on disc wear testing machine. The sensors in the Machine has the capability to sense and record the normal force and frictional force in a real time basis which is used by the computer to calculate coefficient of friction in real time basis.

For the wear test the specimen is forced to rub against an EN31 standard steel disc [13] which can be rotated at different speeds for different time intervals to match our different parameters like Sliding distance, Time and sliding velocity and applied load. Wear rate in g was measured using the help of highly accurate weighing machine (4 digit accuracy) by taking mass before and after the wear test.
For Wear tests with EN31standard hardened Steel the hardness of the test specimen should be less than 65 HRC.

Testing involves conversion of the required Parameters like Sliding Velocity , Sliding distance into inputs via Speed in RPM as well as Sliding time. The Following formulae are used for that Purpose,

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

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

N = Speed of the disc in RPM.

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

S = Sliding distance in m

$v =$ Sliding velocity in m/s

Pin on disc Tribometer accepts sliding time in minutes so we convert the sliding time in seconds to minutes and inputs the data to Tribometer.

6.1 (a) And (b) Pin on disc Tribometer

The Equipment set up is depicted in Fig. Specimen conforming to ASTM G99 Standard was clamped into the bridge of Tribometer. Since any irregularities in the bottom surface would result in error in measurement, Fine grade emery papers were used to rub and evenly face the specimen end surfaces. Test conditions are given in Tables for Measuring wear loss as well as Coefficient of Friction. 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 [15]. Acetone was used as cleaning agent to remove dusts from Specimen before and after measurement. The Pin on Disc Tribometer meter uses a dedicated Dynamometer to measure the frictional force, with the application of normal loads in the form of weights; the software computes coefficient of friction on areal time basis.

6.1.1 Specifications for Pin on Disc testing

1	Pin dimensions	3,4,5,8,10, &12 mm and Length 40 mm and 10 mm ball with separate holder.
2	Disc size	50mm to 75 mm max diameter (55 mm optimum we give along with the equipment),10mm thickness.
3	Disc rotation speed	0-1200 rpm
4	Wear track dia. mean	30 to 60 mm maximum
5	Load	100 grams– 8 kg; 100 grams to 1 kg steps of 50 grams
6	Frictional force	0-10 kg
8	Power	415,50Hz,3 phase,63 amps fuse
9	Display	Rpm, Coefficient of Friction, Load.
10	Protection	Short-circuit and earth leakage breaker

Table 6.1 Specifications for Pin on Disc testing

CHAPTER 7: DESIGN OF EXPERIMENT

7.1 Test for Wear loss.

Since wear loss was a highly small parameter it was concluded that to reduce the error in measurements a repetition of 3 observations was required for a single test run and to average out the observations to finalize the results. For Testing the wear loss and effect of factors affecting wear loss, Taguchi L9 design method was used. For designing the experiment Minitab Software were used. In order to simplify the Tests two input variables via Reinforcement (wt %) Applied Load (L) as well as Sliding distance (S) was selected with reference to Literature survey. Numbers of levels of input factors were set to be 3 and those levels were obtained from literature survey [4]. For wear testing on Al/B4C Composite, Design of Experiment Table from Minitab Software is shown in Table.

Reinforcement (wt%)	Applied Load(L) - N	Sliding distance (S) - m	Wear loss (g)
0% B4C	5	500	
0% B4C	10	1000	
0% B4C	15	1500	
2.5% B4C	5	1000	
2.5% B4C	10	1500	
2.5% B4C	15	500	
5% B4C	5	1500	
5% B4C	10	500	
5% B4C	15	1000	

Table 7.1 Design of Experiment –Al/B4C Wear test

Similar Experiment Design was also Chosen for Al/CSA Composite as described in table.

Reinforcement (wt%)	Applied Load(L) - N	Sliding distance (S) - m	Wear loss (g)
0% CSA	5	500	
0% CSA	10	1000	
0% CSA	15	1500	
2.5% CSA	5	1000	
2.5% CSA	10	1500	
2.5% CSA	15	500	
5% CSA	5	1500	
5% CSA	10	500	
5% CSA	15	1000	

Table 7.2 Design of Experiment –Al/CSA Wear test

Specimens for Both tests were named in systematic way to avoid errors while measurement and experimentation as shown in table.

Composites	Reinforcement and Composition (wt%)	Specimen
Aluminium/ Boron Carbide	Pure Al/ Alloy	AB1,AB2,AB3
	Al/ 2.5 wt% B4C	AB4,AB5,AB6
	Al/ 5 wt% B4C	AB7,AB8,AB9
Aluminium/ Coconut Shell Ash	Pure Al/ Alloy	AC1,AC2,AC3
	Al/ 2.5 wt% CSA	AC4,AC5,AC6
	Al/ 5 wt% CSA	AC7,AC8,AC9

Table 7.3 Specimen Nomenclature

7.2 Test for Coefficient of friction

The input variables selected for finding out the trend in coefficient of friction were Sliding velocity v (m/s) and Reinforcement (wt%) as per relevant literature review ,and a suitable table was proposed for the experiment as shown in Table. Same Tabulation was used for both Types of Composites vis Al/B4C as well as Al/CSA. Levels of sliding velocity were selected on the basis of literature review as well as Pin on disc machines specifications.

Reinforcement (wt %)	Sliding velocity (m/s)	COF
0	1	
0	1.5	
0	2	
2.5	1	
2.5	1.5	
2.5	2	
5	1	
5	1.5	
5	2	

Table 7.4 Test for Coefficient of friction

CHAPTER 8: RESULTS AND DISCUSSIONS – WEAR LOSS

8.1 Observations for Al/B4C Composite for Wear loss

Sl. No.	Specimen	Reinforcement (wt %)	Load (N)	Sliding distance ,S (m)	Avg. Wear loss for 3 sets of Observations (g)
1	AB1	0	5	500	0.0028
2	AB2	0	10	1000	0.0031
3	AB3	0	15	1500	0.0042
4	AB4	2.5	5	1000	0.0012
5	AB5	2.5	10	1500	0.0014
6	AB6	2.5	15	500	0.0015
7	AB7	5	5	1500	0.0002
8	AB8	5	10	500	0.0005
9	AB9	5	15	1000	0.0009

Table 8.1 Observations – Al/B4C Wear test

One of the Tribological characteristic of Al-B4C composite which is wear loss is recorded at various levels of input parameters via Reinforcement (wt%), Applied Load (N) and Sliding distance (S). 9 Samples consisting 3 different compositions were tested against 3 different levels of load via 5N,10N,15 N as well as Sliding distances 500m, 1000m and 1500m . Each test run was repeated for 3 times and average wear loss was recorded.

8.2 Observations for Al/CSA Composite for Wear loss

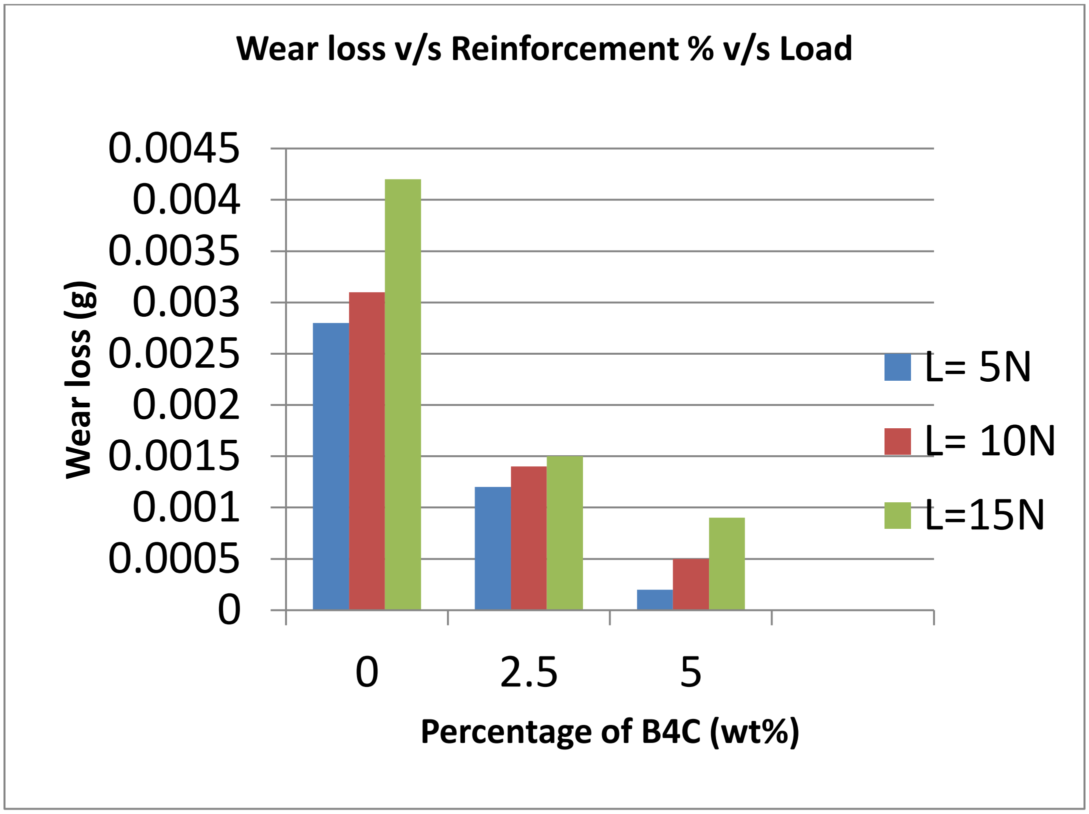
In order to compare the Performance of Both types of composites it is imperative that the test conditions need to be identical, So similar values of Load (N), Reinforcement (wt%) and Sliding distances (S) were used for testing. Table shows the observations recorded for Al/CSA composite.

Sl. No.	Specimen	Reinforcement (wt %)	Load (N)	Sliding distance ,S (m)	Avg .Wear loss for 3 sets of Observations (g)
1	AC1	0	5	500	0.0028
2	AC2	0	10	1000	0.0032
3	AC3	0	15	1500	0.0045
4	AC4	2.5	5	1000	0.0019
5	AC5	2.5	10	1500	0.0023
6	AC6	2.5	15	500	0.0025
7	AC7	5	5	1500	0.0011
8	AC8	5	10	500	0.0013
9	AC9	5	15	1000	0.0015

Table 8.2 Observations – Al/CSA Wear test

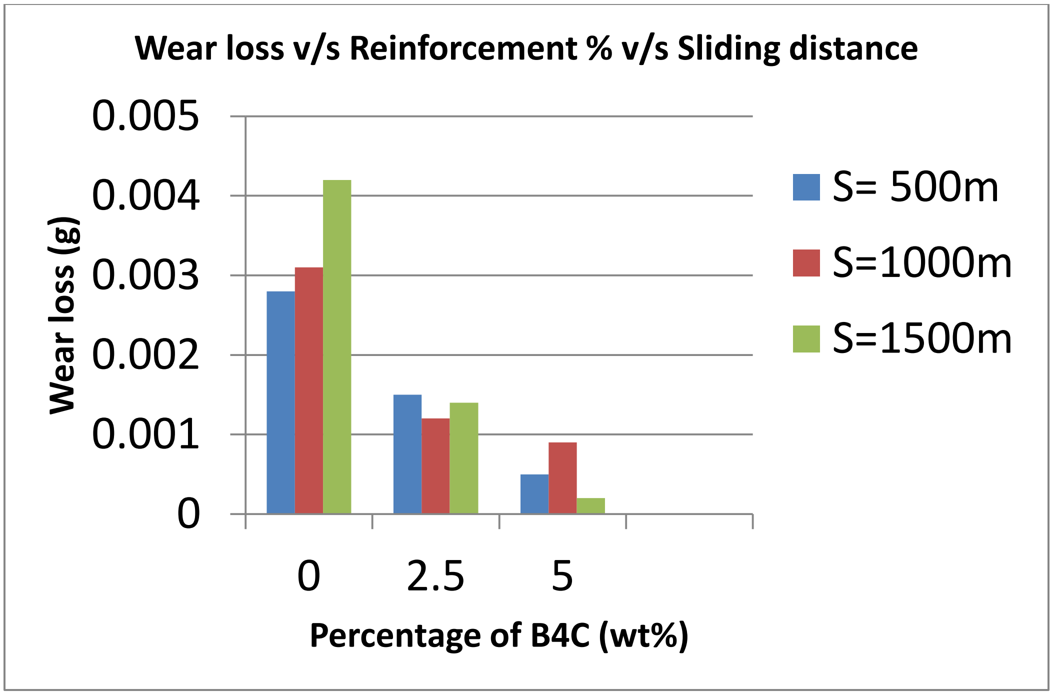
8.1.1 Analysis of Results – Al/B4C Composite – Wear loss

Graphical Analysis was performed on the obtained observations and the following Graphs were plotted.



Graph 8.1

Analysis showed that within each composite type having the same constituents (same reinforcement wt%) there is a considerable increase in the wear loss with respect to increase in Applied load (L) in Maximum wear loss was recorded for Unreinforced Aluminium alloy at 15 N applied load which was 0.0042g ,at the same load conditions wear loss observed for 2.5 wt% reinforced composite showed a wear loss of 0.0015 g and 5 wt% reinforced composite showed 0.0009 g. Indicating the Percentage reduction of wear loss corresponding to maximum load 15N ,amounting to 78.57% compared to Unreinforced Aluminium alloy at same load conditions.

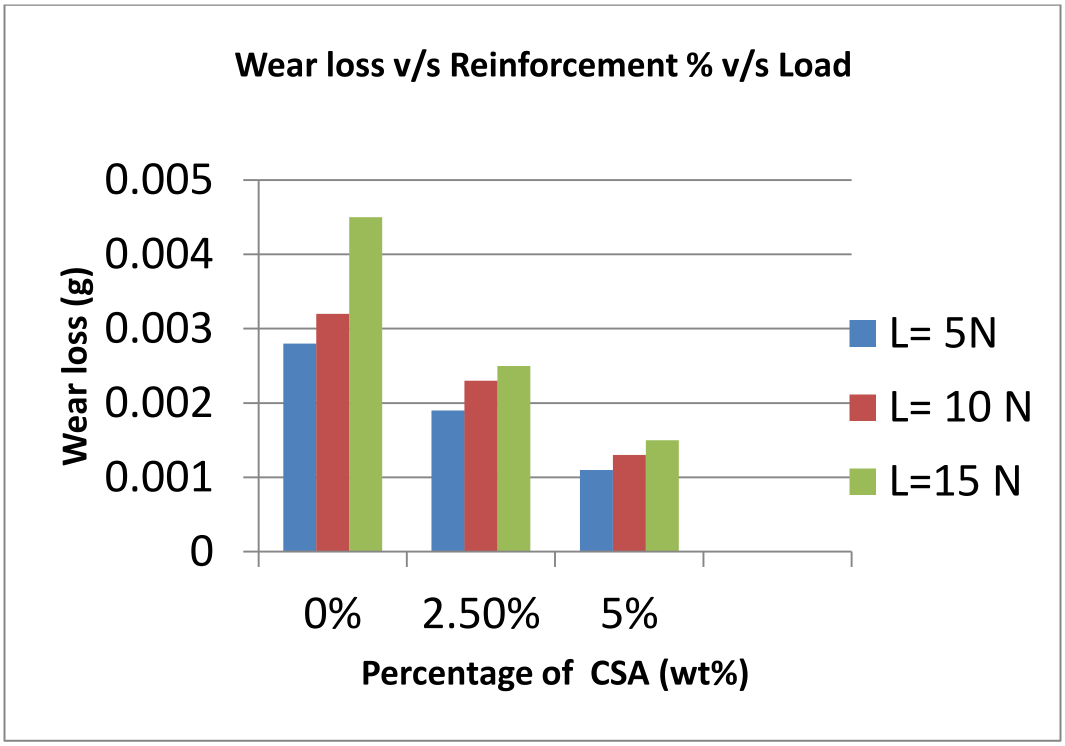


Graph 8.2

The trend obtained for Wear loss with increasing sliding distance within similar type of constituents was random. This was probably due to predominant effect of load on the wear loss on specimen as suggested by the graph 8.1. The observation across different constituent reinforcement proportions showed gradual reduction in wear losses as the proportion of Boron Carbide increases.

8.2.1 Analysis of Results Al/CSA Composite –Wear loss

As shown in Graph 8.3, Within a specific composition of constituent phase (say 5wt%) with the increase in Applied load, wear loss increased. The trend observed was similar to that of the Al/B4C composite.

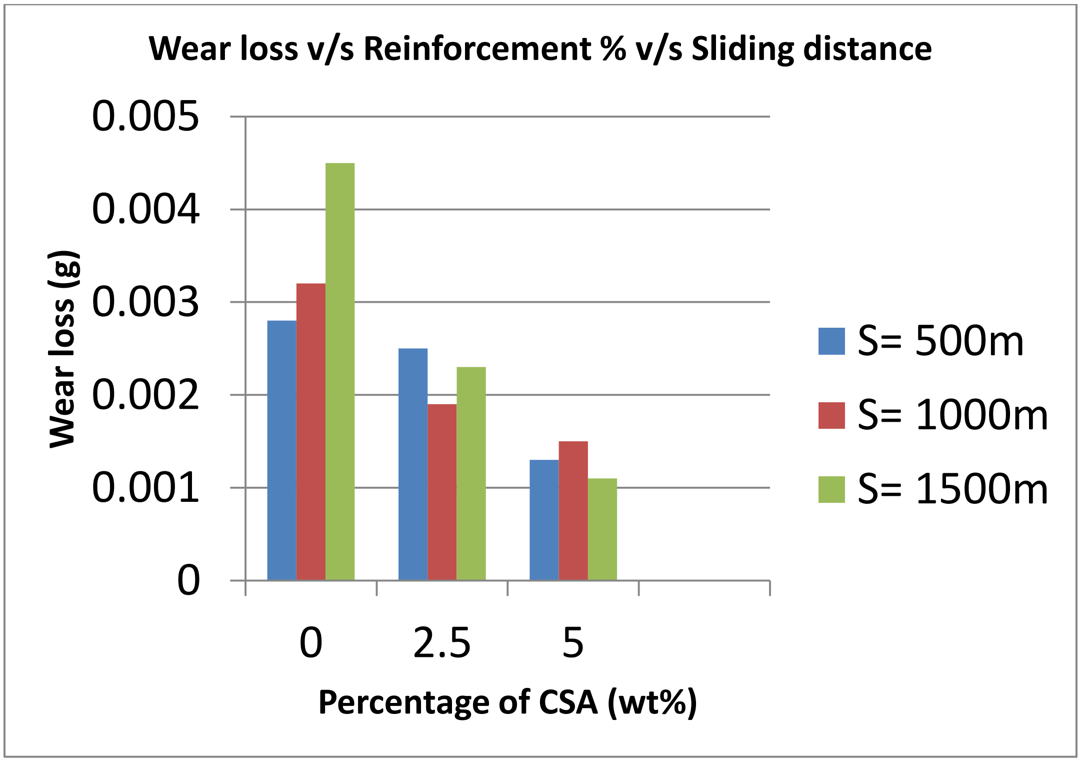


Graph 8.3

Also with the increase in reinforcement wt% it showed reduction in wear loss. Maximum wear loss was recorded for Unreinforced Aluminium Alloy at 15 N Applied load which was 0.0045g and for the same load conditions wear loss recorded for 2.5 wt% CSA/Al, 5 wt% CSA/Al were 0.0025g and 0.0015g respectively. Percentage reduction of wear loss corresponding to max load conditions (15N) were obtained to be 66.67%.

Least wear loss of 0.0011g was observed for highly reinforced Al/CSA composite (5wt%).Trend observed for wear loss v/s reinforcement wt% v/s sliding distance was found random as shown in

Graph 8.4. But overall pattern of pattern of wear loss across different reinforcements (0%, 2.5%, 5%) was reduction in wear loss as reinforcement wt% increases.



Graph 8.4

CHAPTER 9: RESULTS AND DISCUSSIONS – COEFFICIENT OF FRICTION

9.1 Observations for Al/B4C Composite for Coefficient of Friction

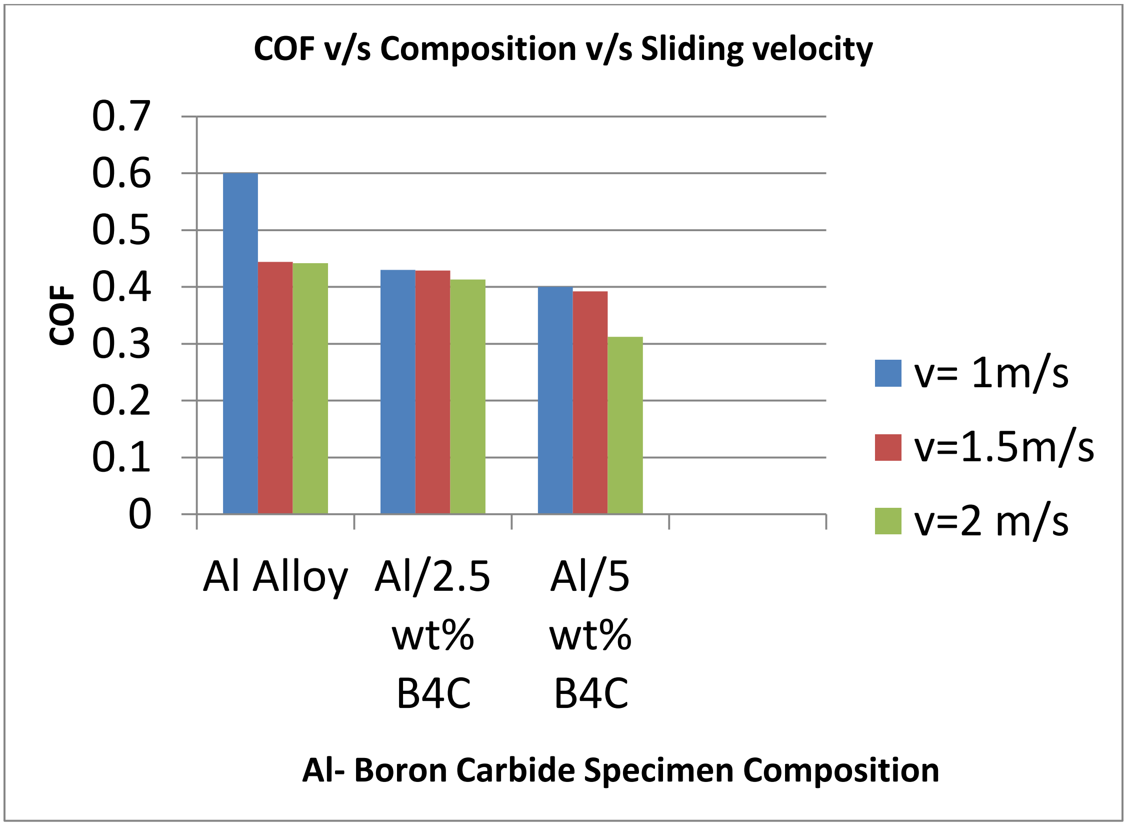
Coefficient of friction refers to the property of a material surface by which it opposes relative motion. It's a dimensionless number correlated with the amount of frictional force a surface can offer. COF is obtained by taking the ratio of Frictional force and Normal reaction. Unreinforced Aluminium can have COF in the range of 0.4 to 0.6 [] . The variation of Coefficient of friction was considered with respect to the percentage of reinforcement and sliding velocity (v)[]

Sl.No.	Specimen	Reinforcement (wt%)	Sliding velocity(m/s)	COF
1	AB1	0	1	0.60005
2	AB2	0	1.5	0.44412
3	AB3	0	2	0.44187
4	AB4	2.5	1	0.42988
5	AB5	2.5	1.5	0.42903
6	AB6	2.5	2	0.4131
7	AB7	5	1	0.39988
8	AB8	5	1.5	0.39207
9	AB9	5	2	0.31206

Table 9.1 Observations for COF – Al/B4C Composite

For a standard time of 15 minutes and Applied Load of 10N , coefficient of friction was recorded for different sliding velocities. Average coefficient of friction generated on the Pin on Disc software in real time basis was recorded for each test run.

9.1.1 Analysis of Results – Al/B4C Composites –Coefficient Of Friction



Graph 9.1

The Graph 9.1 shows that highest coefficient of friction of 0.60005 was recorded for unreinforced Aluminium with least sliding velocity (1m/s) with increase in sliding velocity across all reinforcement proportions. With increase in Sliding velocity coefficient of friction was found to be reducing with respect to both reinforcement percentages as well as sliding velocity. Explanation for this was attributed to the clogging of particles within the pin – disc interface causing a rolling movement which reduces the effective frictional force between pin and disc. Least coefficient of friction of 0.31206 for Al/B4C was observed for 5 wt% reinforcement (Max) and 2 m/s sliding velocity (Max).For Al/B4C composite under same conditions (1m/s Sliding velocity) 5wt% Composite showed 33.36% reduction in COF compared to that of Unreinforced Aluminium Alloy.

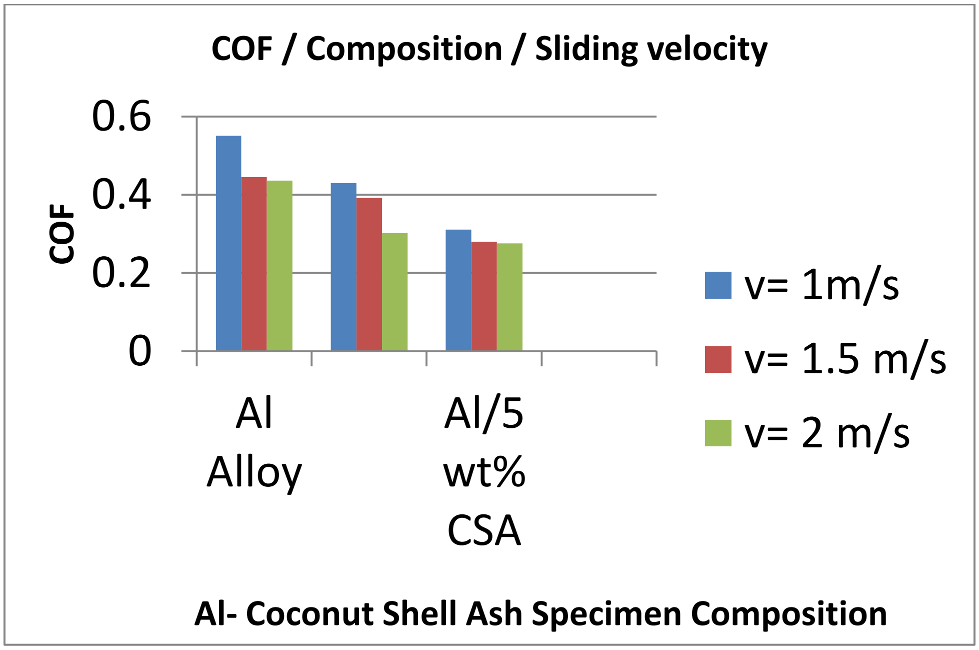
9.2 Observations for Al/CSA Composite for Coefficient of Friction

Sl.No.	Specimen	Reinforcement (wt %)	Sliding velocity(m/s)	COF
1	AC1	0	1	0.55091
2	AC2	0	1.5	0.44521
3	AC3	0	2	0.43633
4	AC4	2.5	1	0.42988
5	AC5	2.5	1.5	0.39207
6	AC6	2.5	2	0.30206
7	AC7	5	1	0.31102
8	AC8	5	1.5	0.27979
9	AC9	5	2	0.27531

Table 9.2 Observations for COF –Al/CSA Composite

Al/CSA composite specimens were tested in the same conditions to compare the results i.e. with varying sliding velocities 1m/s, 1.5 m/s and 2 m/s for 15 minutes.

9.2.1 Analysis of Results – Al/B4C Composites –Coefficient Of Friction

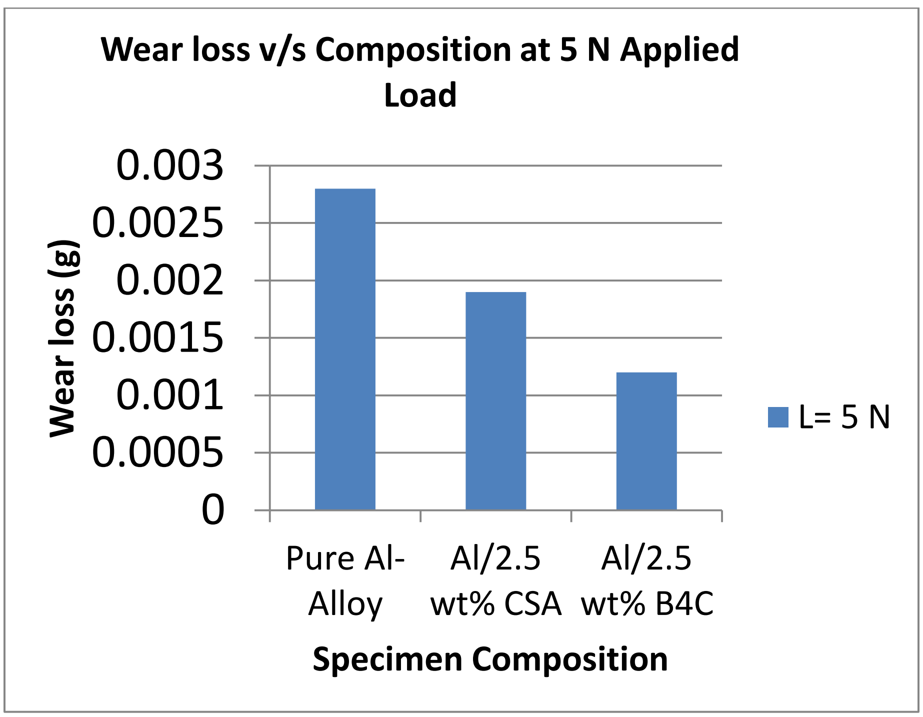


Graph 9.2

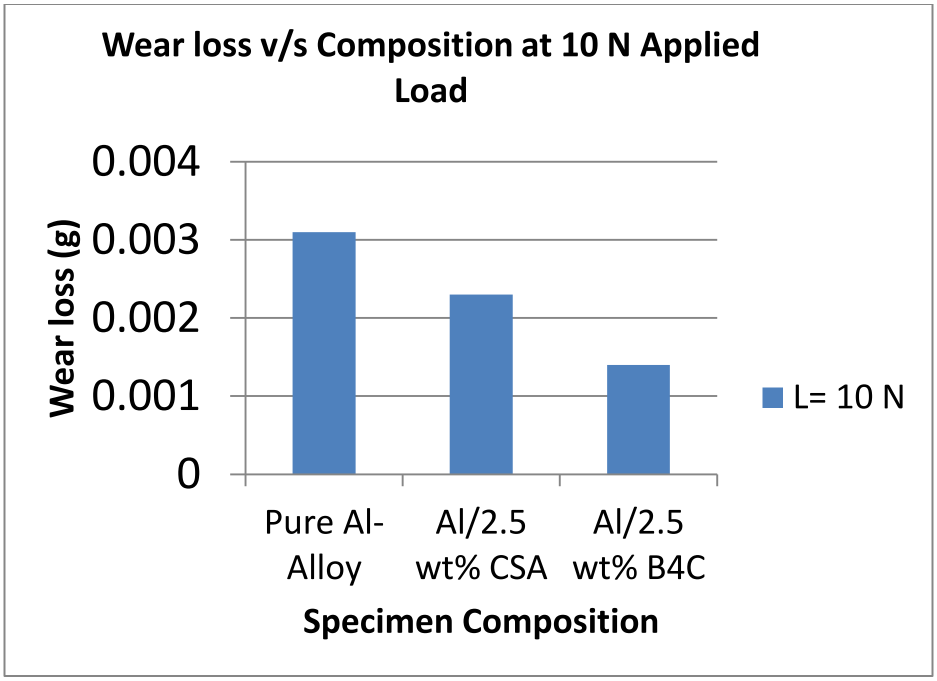
Analysis of the Graph 9.2 showed significant reduction in Coefficient of friction as both Sliding velocity and reinforcement percentage increased. Maximum COF (0.55091) was obtained for Unreinforced Aluminium and least for 5 wt% CSA/Al composite (0.27531). Effect of solid lubricating property of Coconut Shell Ash particles as referenced in the literature review was also attributed to this reduction in Coefficient of friction.[1]. The percentage reduction of COF under similar test conditions (2m/s) was determined as 36.9%.

CHAPTER 10: COMPARISON OF TRIBOLOGICAL PERFORMANCE BETWEEN Al/B4C AND Al/CSA

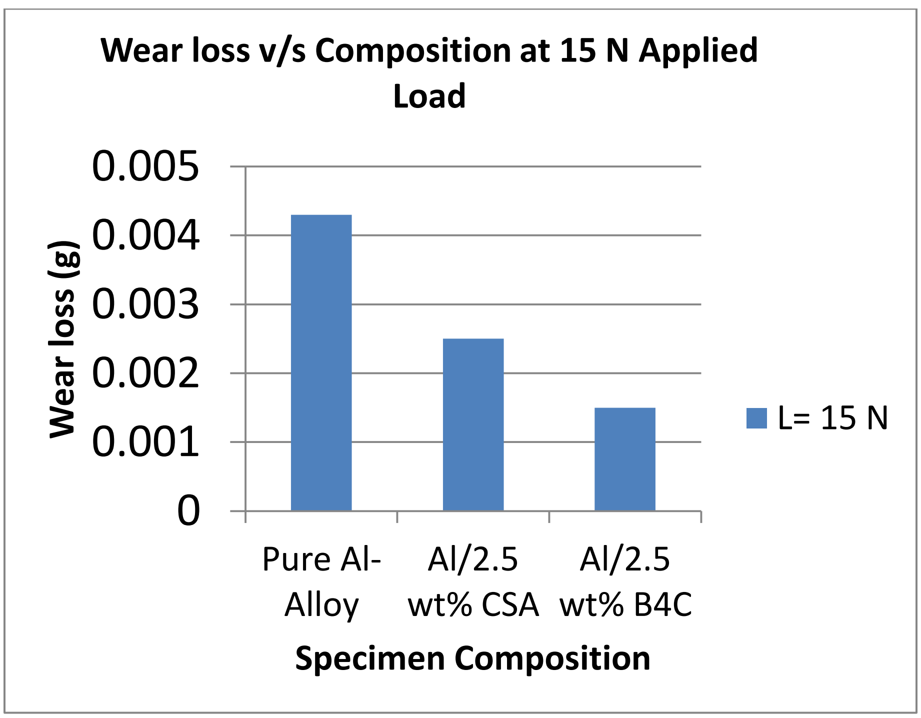
Applied load was found to be the parameter which showed dominant correlation with wear loss in the similar fashion across all composite types. Following Graphs 10.1, 10.2, 10.3 shows the variation of wear loss at constant applied loads in comparison with different constituent percentages. For Each applied load, Better wear resistance characteristics was obtained for the composite reinforced with Boron carbide [7] followed by Coconut Shell Ash. Higher hardness of Boron Carbide compared to locally sourced Coconut Shell Ash is attributed as reasoning.



Graph 10.1



Graph 10.2



Graph 10.3

Overall the Wear Performance of Materials in study can be summarized in the order of Pure Al-Alloy, Al/CSA and Al/B4C with latter being more resistant to abrasive wear. Maximum recorded wear losses for Pure Al-Alloy was 0.0045g, 0.0025 g for Aluminium and 0.0015g for Al/B4C composite(66.6% reduction). Minimum recorded wear loss for Pure Al-Alloy was 0.0028g, 0.0011g for Al/CSA and 0.0002g for Al/B4C composite (60.7% reduction).

Coefficient Of friction table showed inferences that the coefficient of friction for Al/CSA was most favorable compared to that of Al/B4C as well as Pure Al-Alloy. At each Individual level Al/CSA showed lesser COFs as compared to similar reinforced Al/B4C composite attributed by the solid lubricating property of Coconut Shell Ash [1]. Minimum recorded COF for CSA/Al was 11.77% lower than corresponding Al/B4C composite (at max reinforcement wt %).

CHAPTER 11: TEST FOR DENSITY

Densities of the measured Specimen were calculated with the help of weighing machine and vernier caliper for precisely measuring specimen dimensions for volume measurement. Average density of scrap Al-alloy was determined as 2.612 g/cm^3 and that of Al/B4C composite was 2.52 g/cm^3. For Al/CSA composite density recorded was 2.59 g/cm^3. Density didn’t show much variation among three types of material but with the introduction of reinforcements composites were made marginally lighter than the monolithic Aluminium alloy.

CHAPTER 12: CONCLUSION

After performing Tribological testing the following conclusions were obtained.

1. Applied load was the predominant input variable that affected the wear loss of material. Wear loss was stretched in the order of 78.57% with the increase in applied loads from 5N to 15N.
2. Densities of the Composites were marginally lower compared to that of the Al-Alloy. A maximum 3.5% reduction in the density was observed in Al/B4C composites in comparison with Al-Alloy. Al/CSA was slightly heavier than Al/B4C Composites.
3. Wear loss was reduced with the increase of reinforcement wt%. Data showed wear loss was reduced to the range of 60% in Al/B4C compared to unreinforced Aluminium alloy.
4. Material which offers least Coefficient of friction was identified to be Al/CSA Composite. COF in Al/CSA was minimized to the range of 11.77% compared to that of Al/B4C.
5. The direct correlation of COF with sliding velocity was concluded across different compositions.

Overall the improvement of mechanical properties of Aluminium with introduction of both industrial and locally sources bio-reinforcement was observed. It was concluded that with the usage of scrap Aluminium cans environmental pollution effects and material wastage could be minimized.

CHAPTER 13: SCOPE OF FUTURE WORKS

Only one potential agricultural waste material was used in the current project work. Materials like Rice husk ash, bagasse ash, bamboo ash etc. [4]. can also be used as potential bio-particulate reinforcement for composite materials. The Percentage of reinforcement was limited to 5wt% in the current study; more research work could be done with the values beyond 5wt%. A statistical Optimization study could be conducted with suitable software with more samples and experiment runs to find further correlations between wear loss and parameters like sliding velocity, sliding distance, specimen temperature etc.

CHAPTER 14: GANTT CHART

	11/21	12/21	01/22	02/22	03/22	04/22	05/22	07/22	08/22	09/22
Literature Review	*	*	*	*	*	*	*	*	*	*
Planning	*	*								
Fabrication			*	*	*					
Testing						*	*	*	*	
Analysis									*	*
Scope for future work										*

CHAPTER 15: REFERENCES

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