VISVESVARAYA TECHNOLOGICAL UNIVERSITY
JNANA SANGAMA, BELAGAVI - 590 018

PROJECT REPORT ON

"FABRICATION OF ALUMINIUM - CARBON NANOTUBE - COCONUT SHELL ASH COMPOSITE BY STIR CASTING PROCESS"

Submitted in Partial fulfillment of the requirements for the degree of

BACHELOR OF ENGINEERING
IN
MECHANICAL ENGINEERING
For the Academic Year 2019-2020

Submitted by

PREETHI R KARPOOR 1CR16ME056
NAMRATA SAH 1CR16ME048

Under the guidance of

Prof. Prashant S Hatti
Assistant Professor
Dept. Of Mechanical Engineering
CMR Institute of Technology
Bengaluru - 560 037

DEPARTMENT OF MECHANICAL ENGINEERING
CMR INSTITUTE OF TECHNOLOGY
(Accredited with A+ by NAAC, Affiliated to VTU Belagavi)
#132, AECS Layout, IT Park Road, Kundalahalli, Bengaluru - 560 030

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Bengaluru - 560 030

CERTIFICATE

This is to certify that the Project work titled **"Fabrication of Aluminium-Carbon Nanotube-Coconut Shell Ash Composite by Stir Casting Technique"** has been succesfully completed by **Ms.PREETHI R KARPOOR**, bearing USN **1CR16ME056**,and **Ms.NAMRATA SAH**, bearing USN **1CR16ME048**, bonafide student of **Visvesvaraya Technological University** in partial fulfillment of the requirements for the degree of **BACHELOR OF ENGINEERING** in **MECHANICAL ENGINEERING** awarded by **VISVESVARAYA TECHNOLOGICAL UNIVERSITY**, Belagavi during the Academic Year 2019-2020. It is certified that the corrections/suggestions indicated for Internal Assessment have been incorporated in the report deposited in the Department Library. The Project report has been approved as it satisfies the academic requirements in respect of Project work prescribed for the said degree.

(Prashant S. Hatti)	**(Dr. Vijayanand Kaup)**	**(Dr. Sanjay Jain)**
Signature of the Guide	**Signature of the HOD**	**Signature of the Principal**

External Viva

Name of the examiners **Signature with date**

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DECLARATION

We, **PREETHI R KARPOOR** & **NAMRATA SAH**, bearing USN **1CR16ME056** & **1CR16ME048** respectively , bonafide students of CMR Institute of Technology, Bengaluru hereby declare that the Project work titled **"Fabrication of Aluminium-Carbon Nanotube-Coconut Shell Ash Composite by Stir Casting Technique"** has been carried out by us and submitted in partial fulfillment of the course requirements for the degree of **BACHELOR OF ENGINEERING** in **MECHANICAL ENGINEERING** awarded by **VISVESVARAYA TECHNOLOGICAL UNIVERSITY**, Belagavi during the Academic Year 2019-2020. The work done in this project report is original and has not been submitted for any other degree in any other University.

PREETHI R KARPOOR
1CR16ME056

NAMRATA SAH
1CR16ME048

Place : Bengaluru
Date :

ACKNOWLEDGEMENT

It is our proud privilege and duty to acknowledge the kind of help and guidance received from several people in preparation of this report. Apart from our own, the success of this report depends largely on the encouragement and guidelines of many others. It would have not been possible to prepare this report in this form without their valuable help, co-operation and guidance.

We would like to express our deep sense of gratitude to our Principal **Dr. Sanjay Jain**, CMR Institute of Technology College, Bangalore for his motivation and for creating an inspiring atmosphere in college by providing state of the art facilities for preparation and delivery of this report.

Our sincere thanks to **Dr. Vijayananda Kaup**, Head of Department of Mechanical Engineering, for his whole-hearted support in completion of this project.

We are highly indebted to our guide **Prof. Prashant S Hatti,** Assistant Professor, CMR Institute of Technology for being our pillar of support, despite our incessant prodding, and for standing by us, watching us over with a hawk-eye in every step and turn of the project. This piece of writing will not do justice to the kind of backbone he has been for us!

We would also like think **Prof. Harish P**, who has ever so graciously supported us with his work. Also, Our heartfelt gratitude to all the Faculty of Dept. Of Mechanical Engineering who have supported us through thick and thin in the three years of our journey.

Last but not least, we would like to put forward our heartfelt acknowledgement to all our classmates, friends and all those who have directly or indirectly provided their overwhelming support during our project work and the development of this report.

ABSTRACT

Aluminium is one of the most versatile metals to have been used in the history of metallurgy and manufacturing. While Aluminium, on it's own strength, has managed to retain it's unmatched utility in various applications, the benefits that Composites bring to the table cannot be denied. That being said, Carbon Nanotubes are an excellent candidate for using in conjunction with Aluminium given it's proven versatility. In this project, along with the aforementioned strong composite of Aluminium - Carbon Nanotubes , Coconut Shell Ash, an excellent bio-degradable agro-waste has been introduced to fabricate a composite of Aluminium - Carbon Nanotubes - Coconut Shell Ash by the process of stir-casting. The composite was prepared by adding high purity Aluminium (98%) , 0.2 % of Carbon Nanotubes (weight percentage) and 2,4,6,8 and 10 % of Coconut Shell Ash (weight percentage). Hardness of the composite cast models thus obtained were determined using Brinell Hardness Test while wear behaviour was determined using dry sliding pinion disc wear test.

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CHAPTER 1 : INTRODUCTION

1.1 Preamble

Composite Materials have remained an unending endeavour since the dawn of manufacturing. Engineers and Scientists are forever on the lookout for materials that can do everything and beyond. The plethora of properties that individual materials provide can be harnessed in a more versatile way when combined in appropriate proportions. This project, particularly this chapter, is an exordium of the same. It intends to give a glimpse of the relevant concepts and ground norms that are essential in picturing our end goal - Fabrication of a Novel Material that is far superior than it's existing counterparts!

Given that objective, the constituents in focus include Aluminium, Carbon Nanotube and Coconut Shell Ash. While the main target still remains in 'making' or 'fabricating' a composite material and trying to explore it's properties, this chapter is an attempt to encapsulate the comprehensive profile of the materials as well as the Fabrication and Testing methods involved.

Thus, it is only imperative that we start off in understanding our pre-requisites by understanding the material constituents, their multi-faceted properties and what makes their candidature as a mixture so intriguing to be explored and then further about fabrication and testing activities as well the whole chronology of our venture.

1.2 Pre-Requisites' Layout

The next few chapters aim to convey the necessary pre-requisites in the following order :

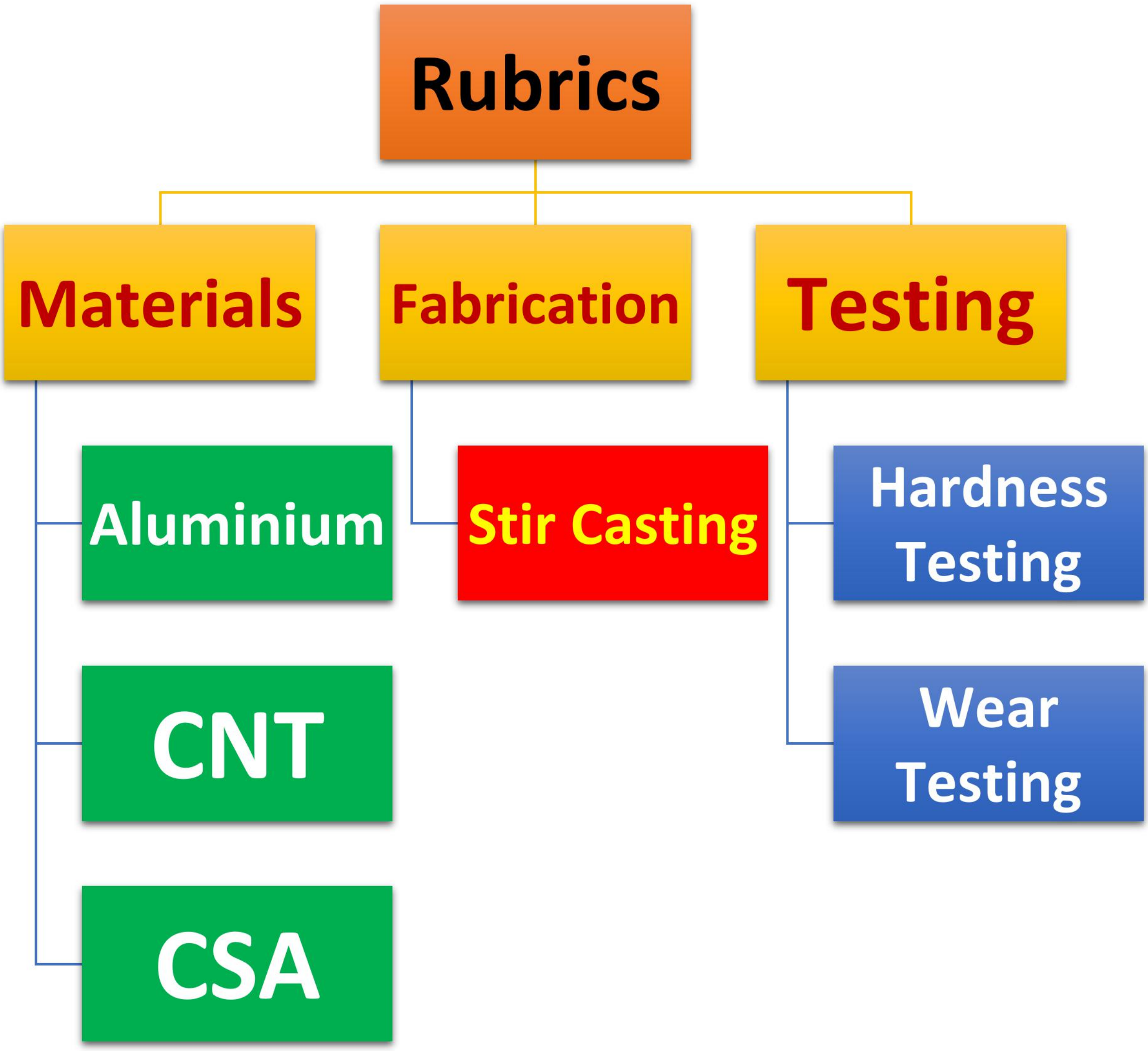

Fig 1 : Rubrics for Introduction

As evident from the illustration, further few chapters will be an attempt to introduce the various aspects of fabricating a composite from Aluminium, Carbon Nanotubes and Coconut Shell Ash.

CHAPTER 2 : CONSTITUENTS & THEIR PROPERTIES

As we begin our attempt to fabricate the composite, it is essential to understand the constituents of the same first. Thus, as we intend to fabricate Aluminium - Carbon Nanotube - Coconut Shell Ash composite, this chapter gives a glimpse of the materials as well as what makes their utility value high.

2.1 Aluminium : Endless benefits, Versatile Use

Aluminium is an extremely versatile metal with a number of advantages, it is recognized for being both lightweight and flexible. It can be cast, melted, formed, machined and extruded meaning that it can be manufactured into a variety of shapes and then subsequently fabricated to suit a whole variety of uses.

Due to its extreme versatility and strength, the use of Aluminium is becoming more popular, especially with the advantages it has to offer. A known lightweight metal, it has a specific weight of approximately 2.71 g/cm3. It's about a third of the weight of steel, which makes it easier and cheaper to transport than most other metals.

The strength of aluminium can be adapted using varying alloying elements to provide better benefits including higher strength or easier formability. Because of its lightweight nature, corrosion resistance and ease of fabrication, aluminium sheets are the firm for projects like vehicle panelling, artwork, building cladding and kitchen fitting among other applications

Aluminium is a corrosion resistant metal that naturally generates a protective coating. The coating formed is extremely thin and is generated when aluminium comes into contact with an oxidizing environment. This protective aluminium oxide layer helps protect the surface of the metal from corrosion. Additionally, getting surface treatment such as painting or anodising can further improve the overall corrosion resistance of the metal.It is an excellent conductor of heat and electricity.

Although aluminium is not as conductive as copper it is approximately a third of the weight meaning that an aluminium wire with half the weight of a copper wire would have the same amount of electrical resistance. As a result, it is the chosen material for power transmission lines. It is also an excellent conductor of heat and is used as heat sinks in a variety of applications such as LED lights, electrical products, computer motherboards, etc.

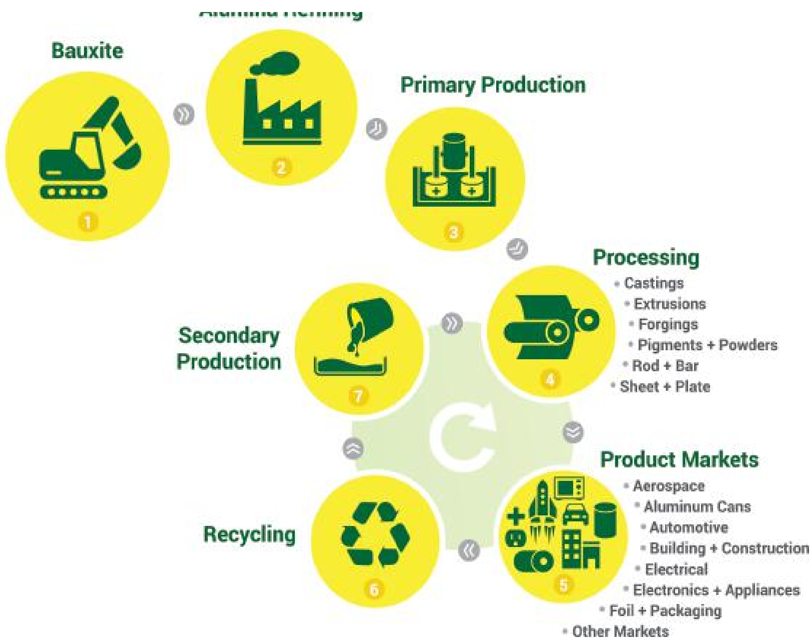

Fig 2 : Multi- faceted capabilities of Aluminium

2.2 Carbon Nanotubes : The Revolution

Carbon nanotubes (CNT) are an important new class of technological materials that have numerous novel and useful properties. Recently, immense interest has grown in materials research on CNTs because of their high mechanical properties.

CNT reinforced in aluminium matrix composites are been experimented considerably. The composites if obtained with right composition and enhanced mechanical properties will have great potential applications in the aerospace and automotive industries where most of the components are light weighted and possess high stiffness and strength.

2.2.1 Types of Carbon Nanotubes

Single Walled Carbon Nanotubes (SWCNT)

The structure of an ideal single-walled Carbon Nanotube is that of a regular hexagonal lattice drawn on an infinite cylindrical surface, whose vertices are positions of Carbon atoms.

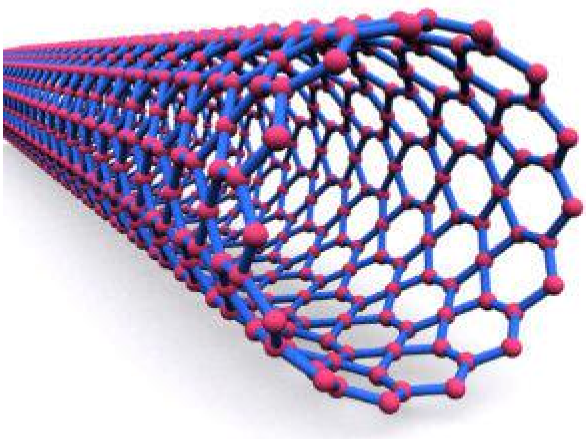

Fig 3 : A representation of a single-walled CNT

Multi Walled Carbon Nanotubes (MWCNT)

Multi-walled carbon nanotubes(MWCNTs) are a special form of carbon nanotubes in which multiple single-walled carbon nanotubes are nested inside one another.

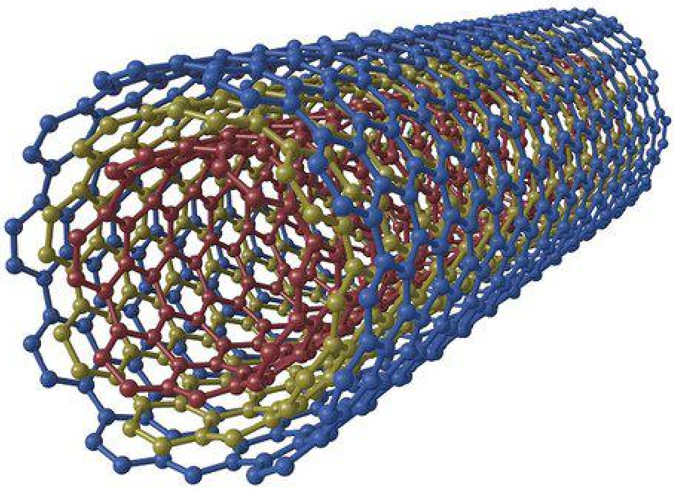

Fig 4 : A representation of a multi-walled CNT

Although MWCNTs are still classed as a 1D form of Carbon, the unique properties that are seen in single-walled Carbon nanotubes are not as prominent. The reason for this is the higher probability of defects occurring. These disadvantages are however offset by the increased dispersability of MWCNTs and the reduced cost in synthesis and purification of these materials.

Comparison between Single Walled and Multi-walled CNT

Property	Single Walled CNT	Multi-walled CNT
Structure	Single Graphene cylinder Well characterized structure	Several concentric Graphene cylinders Many structural defects
Strength	Lower tensile strength	Exceptional tensile strength
Chemical corrosion	Less resistant	More resistant
Size/Aspect Ratio	Small size of the order of 0.5 to 1.5 nm High Aspect ratio	Larger size of the order of 100nm Low aspect ratio
Manufacture	Easier to produce	Costly and difficult to produce on large scale
Purity	Lack of purity	Negligible purity
Synthesis	Controlled conditions needed for bulk synthesis	Bulk synthesis is convenient
Dispersability	Low	High

Table 1 : Differences between SWCNT and MWCNT

2.3 Coconut Shell Ash : The Future ?

Coconut Shell Ash is one of the low density and inexpensive agricultural waste which is abundantly available throughout the tropical countries in large quantities as solid waste and it exhibits superior physical and mechanical properties.

While Coconut Shell is an agricultural residue from the Coconut processing industry, Approximately 15kg of coconut shell is obtained from every 100 kg of coconut.
It can be utilized highly efficiently in the development of composite materials suitable for various applications.

In very few research works agricultural wastes were used as reinforcing material. In particular in the case of Coconut shell pyrolised coconut shells are used as reinforcing materials.

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Al_2O_3	CaO	Fe_2O_3	K_2O	MgO	Na_2O	SiO_2	MnO	ZnO
15.6	0.57	12.4	0.52	16.2	0.45	45.05	0.22	0.3

Table 2 : Chemical composition of Coconut Shell Ash(CSA)

It mainly comprises of oxides like SiO_2, Al_2O_3,MgO,Fe_2O_3. The hard oxides present in the ash make it suitable to be used as reinforcement in Aluminium because its wear resistance and hardness can be improved without much compromise on the density of the matrix.

CHAPTER 3 : FABRICATION PROCESS

Stir casting is a liquid state method for the fabrication of composite materials, in which a dispersed phase is mixed with a molten matrix metal by means of mechanical stirring. Stir Casting is the simplest and the most cost effective method of liquid state fabrication. The stir casting set-up is shown in the following Figure.

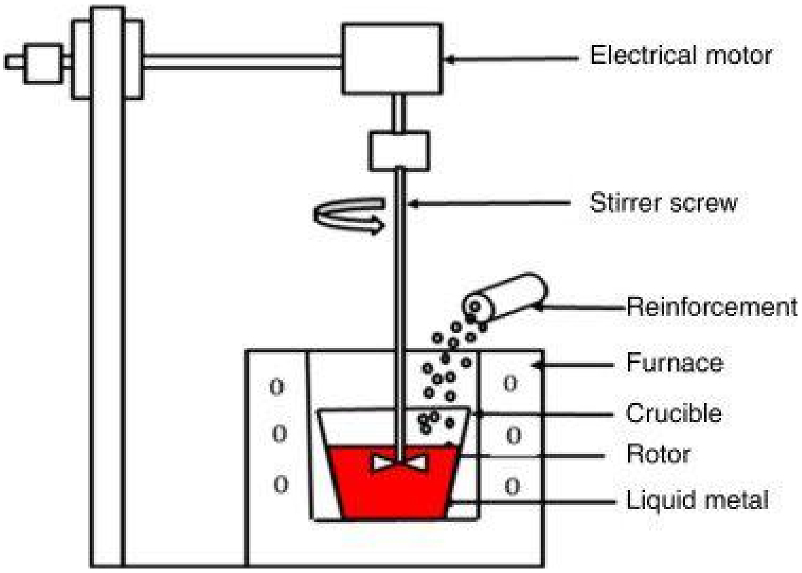

Fig 5 : Stir Casting Process Setup

Stir casting is a suitable processing technique to fabricate aluminum matrix composites and hybrid aluminum matrix composites as it is an economical process and preferred for mass production. involves stirring of melt, in which the melt is stirred continuously which exposes the melt surface to the atmosphere which tend to continuous oxidation of aluminum melt. As a result of continuous oxidation, the wettability of the aluminum reduces and the reinforcement particles remain unmixed. Al_2O_3 is a very stable chemical compound, which cannot be reduced under normal conditions and the wettability of melt remains unchanged

CHAPTER 4 : TESTING METHODS

Testing is the inevitable stage that leads to successful market establishment of any given product. From Human thoughts to Large Engineering products, testing is the most important stage to establish any idea or product. Similarly, in metallurgy as well, a multitude of tests are conducted on any given product before they can be commissioned. They intend to check the Physical, Chemical, Mechanical Properties of a product and evaluate it's long term viability.

In the course of this project, we intend to test the Hardness and Wear properties of the Aluminium - CNT - CSA Composite thus fabricated by Brinell Hardness Test and Pinion Disc Wear Test respectively.

4.1 Hardness Test

4.1.1 *What is hardness?*

Hardness is defined as the resistance of a material to permanent deformation such as indentation, wear, abrasion, scratch. Hardness is resistance to plastic deformation of the metal and it is measure by the depth of the indentation. The hardness test is preferred because it is simple, easy, and relatively nondestructive.

4.1.2 What is a Hardness Test?

The hardness test is a mechanical test for material properties which are used in engineering design, analysis of structures, and materials development. The principal purpose of the hardness test is to determine the suitability of a material for a given application, or the particular treatment to which the material has been subjected. The ease with which the hardness test can be made has made it the most common method of inspection for metals and alloys.

4.1.3 Brinell Hardness Test

Brinell Hardness Test is one of the most important hardness tests in the engineering industry and metallurgy. It is used when the surface of the metal is very rough to use another hardness test on it.

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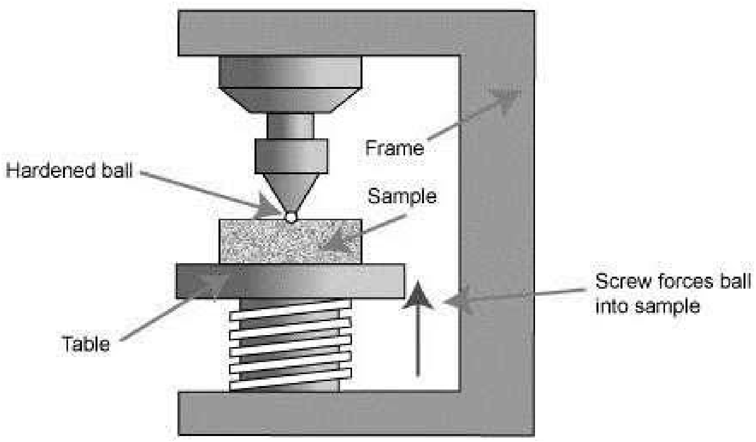
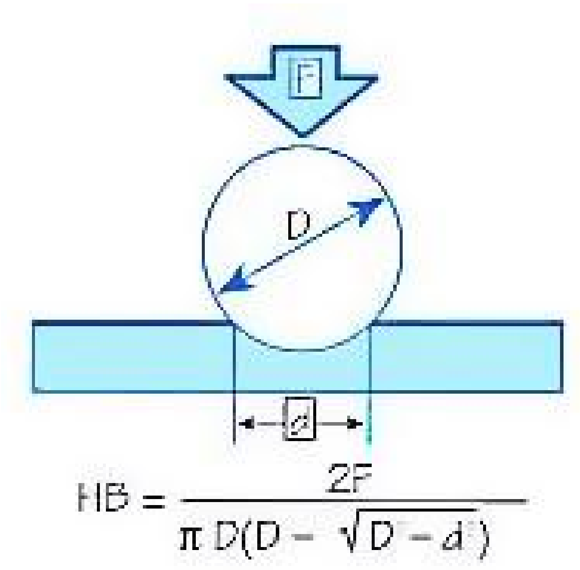


Fig 6 : Brinell Hardness Test Apparatus

The above diagram depicts Brinell hardness testing machine equipped with various loads and multiple ball indenters. A load selecting knob is used to change the size of the load. The lever is used to move metal samples in an upward and downward direction. Metal samples are placed over the anvil and a lamp is fixed on the machine column to observe the process.



- ✓ D = Ball diameter
- ✓ d = Impression diameter
- ✓ F = Load
- ✓ HB or BHN = Brinell Hardness Number

Fig 7 : Test Method Illustration

The Brinell method applies a predetermined test load (F) to a carbide ball of fixed diameter (D) which is held for a predetermined time period and then removed. The resulting impression is measured with a specially designed **Brinell microscope** or **optical system** across at least two diameters – usually at right angles to each other and these results are averaged (d).

4.2 Wear Test

4.2.1 Why wear testing?

Wear test is carried out to predict the wear performance and to investigate the wear mechanism.

Two specific reasons are as follows:

1. From a material point of view, the test is performed to evaluate the wear property of a material so as to determine whether the material is adequate for a specific wear application.
2. From a surface engineering point of view, wear test is carried out to evaluate the potential of using a certain surface engineering technology to reduce wear for a specific application, and to investigate the effect of treatment conditions (processing parameters) on the wear performance, so that optimized surface treatment conditions can be realized.

4.2.2 Pin-on-Disc Wear Testing

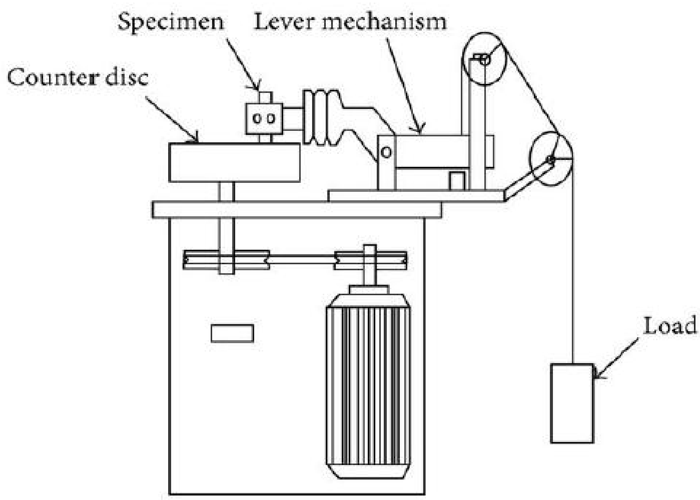


Fig 8: Schematic diagram of Pin-on-disc setup

Ina pin-on-disc wear tester, a pin is loaded against a flat rotating disc specimen such that a circular wear path is described by the machine. The machine can be used to evaluate wear and friction properties of materials under pure sliding conditions. Either disc or pin can serve as specimen, while the other as counter-face. Pin with various geometry can be used.

CHAPTER 5 :AIM & OBJECTIVES

5.1 Problem Statement

Reinforced Aluminium Composites are one of the most popular class of Novel Materials that have been deployed in use far and wide in most industrial and manufacturing activities. Similarly, Carbon Nanotubes (CNT) and Coconut Shell Ash (CSA) have too proven their mettle as effective additions to Aluminium in creating composite materials that have displayed excellent characteristics compared to the main metal on it's own. However, what has remained unexplored is how the combination of all three - Aluminium, Carbon Nanotubes and Coconut Shell Ash - would yield a composite which is further superior to earlier composites of Aluminium-Carbon Nanotubes and Aluminium - Coconut Shell Ash. The aim of this project is to fabricate such a composite of Aluminium- Carbon Nanotube - Coconut Shell Ash by using the highly economical and commercial method of Stir Casting. In addition, testing properties like Hardness and Wear is done with aim to characterize the composite, testing it's validity for future commercial exploitation.

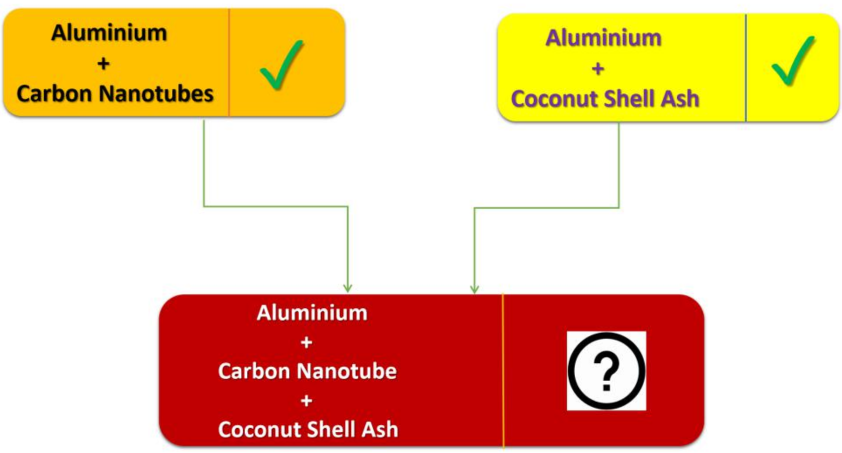


Fig 9 : Summary of the Project Aim

5.2 Motivation

The intent of doing this project is a small part of a very large goal that is more a continuous process than a nearsighted aim.The use of Metal Matrix Composites in various Manufacturing sectors like Automotives, mining etc is based on requirements of weight reduction and pursuit of high efficiency and performance.

The Automotive Industry, for instance, is always on the look out for systems that are subjected to increasingly restricted fuel economy requirements, thereby also demanding improved comfort and safety in parallel. To meet such requirements, manufacturers are turning to light weight products with high efficiency.

Aluminium Metal Matrix Composites with their high strength, high specific stiffness and low weight properties (among other characteristics) can be used in long term applications in which system weight reduction is a vital requirement

In addition, it has also been well recognized in the recent years that Carbon Nanomaterials in the form of Carbon Nanotubes have outstanding potential with reference to their mechanical and chemical properties thereby motivating their use in composite materials as a fibrous reinforcement agent.

Alongside, in an attempt at overcoming limitations of high production cost, there has been growing interest in researchers to explore the possibility of using suitable agro waste products as secondary reinforcements in composite fabrication. Particularly in India, which is one of the largest agricultural based economies, it is only obvious that the availability and utilization potential is exponentially high. Coconut shell being a very commonly available agro-waste product is an interesting (and abundantly available) component to be considered and worked on.

Having accounted for all the above factors, they were enough of a motivation for us to do this project that is not just a engineering-driven process but more as a community contribution.

5.3 Objectives

The primary objectives of this project are listed and justified as follows :

- **Study of Existing Industry trends on use of composites**

As an impetus to begin with, it is crucial to analyse the existing industry trends and understand what is the need of the hour. With the rapid strides that the world, in particular the industries are making, it is crucial to study the long term requirements and directed technical effort must be taken to innovate what would be relevant even in decades to come.

- **Study of Existing Aluminium Based Composites**

With the almost rife use of Aluminium in every aspect of human life, the next step would be to understand how existing systems have made use of Aluminium as well as it’s composites. Only this can give a clear picture of what the next step should be.

- **Identification of Potential Composite Constitution as well as viable fabrication method**

Once decided upon Aluminium as the focus point, it is now important to select what are the potential primary, secondary, tertiary etc reinforcement materials - combinations that will compliment Aluminium in forming a composite of excellent properties.

- **Fabrication of Aluminium- Carbon Nanotube - Coconut Shell Ash Composite by Stir Casting Technique**

Having chosen Carbon Nanotubes and Coconut Shell Ash based on Literature Surveys, fabrication of the composites to be done in a Stir Casting Furnace employing scientific processes that will aid further studies on the same. Fabrication process chosen on the basis of Literature Survey as well.

- **Testing of the thus fabricated Aluminium - CNT - CSA Composite's Hardness Properties by Brinell Hardness Test**

It is crucial to test the properties of any product or or any composite once its fabricated. This is detrimental to further implementation of the product on a large scale like in industries etc. In view of the same, mechanical properties like Hardness can be tested with the Brinell Hardness Test.

- **Testing of the Aluminium - CNT - CSA Composite's Wear Properties by Dry Sliding Pinion Disc Wear Test**

Similarly, Wear properties of the composite is tested with Dry Sliding Pinion Disc wear testing methodology.

- **Comparative Assessment of thus tested properties of Aluminium - CNT - CSA Composite with previously studied Aluminium - Carbon Nanotubes and Aluminium - Coconut Shell Ash Composites**

Having studied how Aluminium - Carbon Nanotubes , how Aluminium - Coconut Shell Ash Composites are making big strides in their respective domain of studies, and now on fabricating the Aluminium - Carbon Nanotube - Coconut Shell Ash composites, performing comparative assessments will also give us data that can be studied further

- **Project completion with evaluation of further scope of extension of work with such Aluminium based composites**

Further scope of work is suggested to be discussed.

CHAPTER 6 : LITERATURE SURVEY

The Literature Survey of umpteen number of research papers and other related material were undertaken as a part of this project. A few papers that were our main basis' along with our key takeaway's is described in this chapter of the report.

1. **Title** : *Study of microstructure and wear properties of novel aluminium-modified fly-ash composite*

Authors: Bijayani Panda, Vishwanatha A.D, Niranjan C.A, Harisha P, Chandan K R and Rakesh Kumar

Description : The referred paper deals with the study of structural and mechanical properties of a composite of Aluminium reinforced with different weight fractions of modified fly ash(FA). The preparation of modified FA powder involved heating FA with graphite and magnesium in Nitrogen atmosphere at suitable ratio and temperature. The composite was prepared by melting AA 1200 aluminium and adding modified FA in a stir furnace and studied for different properties

Key takeaways:

(1) Hardness of the composite was found to increase with increase in the quantity of modified FA.

(2) The wear rate of the composite increased with increase in amount of modified FA up to 6% by weight fraction beyond which the rate decreased.

(3) The increase in wear rate can be explained as a result of segregation of particles thereby weakening the bonding between particles.

(4) The decrease in wear rate could be possibly attributed to the increase in abrasive wear mechanism as particles separated during the wear test.

2. **Title:** *Characterization of Coconut Shell Ash for Potential Utilization in Metal Matrix Composites for Automotive Applications*

Authors: P.B Madakson, D.S Yawas and A.Apasi

Brief Description:

The referred paper primarily deals with spectroscopic and microscopic analysis of coconut shell ash to identify various characteristics. The various methods revealed that Coconut shell ash possesses nearly similar chemical phases and other functional groups as other reinforcements that have been used in Metal Matrix Composites (MMC)

Key takeaways :

(1) XRF studies showed the presence of hard constituents like SiO_2, Al_2O_3, MgO etc which are reinforcements in MMC's

(2) Coconut Shell Ash can withstand high temperatures and hence can be used in production of light weight MMC's.

3. **Title** : *Microstructure and Hardness Behaviour Study of Carbon Nanotube in Aluminium Nanocomposites*

Authors : Prashant S. Hatti, K. Narasimha Murthy and Anupama B. Somanakatti

Brief Description : The referred paper investigates the effect of Carbon Nanotube(CNT) fraction in Aluminium(Al)-CNT composites on the microstructure and hardness of CNT-reinforced Al matrix composites. Tungsten ball and Aluminium oxide ball were used for same composition of Al-CNT composites. The ball milled powders were then sintered and scanned using SEM. Further, hardness tests was conducted for the nano-composite samples for different loads.

Key takeaways :

(1) From Brinell hardness test it was observed that highest hardness occurred in 1.3 % by weight CNT reinforced Al composite for both 60 and 100Kgf loads.

(2) The alumina ball-milled samples have slightly higher improvement in hardness compared to tungsten ball milled samples.

(3) Microstructural analysis indicated that CNT was succesfully reinforced into the Al matrix.

4. **Title** : *Development of Novel Stir Cast Aluminium Composite with modified Coconut Shell Ash Filler*

Authors : Bijayani Panda, Niranjan C A, Vishwanatha A D, Harisha P, Chandan K R, Rakesh Kumar

Brief description : The referred paper is concerned with the study of Coconut Shell Ash(CSA) as a suitable candidate in reinforcement for metal-matrix composites useful automotive and aerospace applications. In the work described in the paper, coconut shell powder was burnt to form ash which was then treated in an inert atmosphere with magnesium and graphite. A composite of Aluminium with CSA was then prepared for different weight fractions of CSA, the microstructure of which was then further studied using optical microscopy and SEM.

Key takeaways :

(1) XRD analysis showed that the CSA powder was mainly composed of SiO_2. After furnace treatment of CSA, additional peaks of MgO, MgO_3Si, Mg_2Si and SiC were observed.

(2) Microstructural observation showed that there was some amount of segregation of particles in all samples while no defects were observed.

(3) Wear rate of the composites decreased till 4 wt. % of modified CSA addition. With further increase in reinforcement, the wear rate increased.

5. **Title** : *Wear and compression behavior study of carbon nanotube in Aluminium Nano composites*

Authors : Prashant S. Hatti , Dr.K. Narasimha Murthy, Anupama B. Somanakatti

Brief description: The referred paper describes the study of Carbon Nanotube(CNT) reinforced in Aluminum matrix which were fabricated by powder metallurgy. Ball milling method with two different ball materials viz tungsten ball and aluminium oxide ball was employed for effective mixing of CNT's in Aluminium powder. The powder mixtures were sintered and microstructural analysis was done for both ball milled powder and sintered specimen.

Key Takeaways :

(1) The alumina ball milled specimens were observed to have high compressive strength and improved wear behaviour compared to tungsten ball milled specimens.

(2) Alumina ball milled samples with 1.3 wt. percentage CNT reinforced composites had improved compression and wear behavior.

(3) The wear behavior of the CNT/Al Nanocomposites was successfully tested and the obtained results proved the efficient reinforcement of CNT in the aluminium matrix.

(4) The results from Wear test and the Compression test indicate that the alumina ball milled CNT/Al nano composites have higher ductility with wear behavior and when compared to pure aluminium.

6. **Title** : *Fabrication of Aluminum Matrix Composites by Stir Casting Technique and Stirring Process Parameters Optimization*

Authors : Mohit Kumar Sahu and Raj Kumar Sahu

Brief description : The referred article rigorously explored the effect of stirring parameters in stir casting process of fabricating Aluminium Matrix Composites(AMC). Optimal values of stirring parameters were presented which could benefit researchers in the development of AMCs and Hybrid AMCs.

Key Takeaways :

(1) The range of stirring speed may vary depending upon the properties of the reinforcements and matrix material, wettability and chemical properties from 200 to 1000 rpm.

(2) For multistage impeller stirring 1000 rpm has suggested as optimal value. But in case of single stage impeller stirring 550 rpm gives an optimal speed of stirring, as higher speed causes excessive tabulation.

(3) The fabrication of Hybrid AMCs and AMCs by stir casting route by optimal selection of parameters provides high strength, low cost and light weight composites.

7. Title : *Comparison of Mechanical Properties of Coconut Shell Ash and SiC Reinforced Hybrid Aluminium Metal Matrix Composites.*

Authors : Poornesh M., Johnson Xavier Saldanha, Jevy Singh, Gavin Manuel Pinto, Gaurav

Brief description : In the referred paper, a comparative study of properties of composites prepared by reinforcing pure aluminium metal with varying percentage of Coconut Shell Ash and SiC particles, was carried out. Stir casting process was used to fabricate the composites which were then studied for mechanical properties like hardness, density etc.

Key takeaways :

(1) Inclusion of ash and ceramic particles has a significant influence on the mechanical properties but will make the composites brittle.

(2) The density of the composites produced with only CSA as reinforcements showed an decreasing trend with the increase of the content of the reinforcements

(3) Hardness test revealed that with the increase of the content of ash in the mix, the hardness increases.

(4) The Ultimate Tensile Strength of the composites increased with trivial with the increase of percentage of Coconut Shell Ash

8. **Title** : *Mechanical and Tribological behaviour of Aluminium AL6061-Coconut Shell Ash(CSA) composite using stir casting pellet method*

Authors: P. Lakshmikanthan, Dr. B. Prabu

Brief Description : The referred paper is focused on synthesis and determination of mechanical and tribological properties of aluminium alloy Al6061-Coconut Shell Ash (CSA) MMC synthesized by Stir casting Pellet method. Varied weight fractions of CSA particles were introduced to form Composites. Characterization of the composites was carried out using scanning electron microscopy, EDAX, tensile test,hardness test and wear test.

Key Takeaways :

(1) Mechanical and tribological properties of composites are better at a lower amount of CSA reinforcement.

(2) Results of tested specimens indicated that 6% CSA reinforced composite has the maximum tensile strength, maximum hardness and minimum wear.

(3) CSA particles act as barriers to the dislocations when load is applied

(4) The co-efficient of friction and friction force of the composites increases gradually with the increase in amount of reinforcement.

(5) EM image shows that this stir casting- pellet method ensures even distribution of the fine reinforcement particles in the matrix.

CHAPTER 7 : METHODOLOGY

The Aluminium- Carbon Nanotube - Coconut Shell Ash composite, as mentioned earlier, has been fabricated by Stir Casting Technique. The following sections aim to give the most crystal clear picture of the whole process - from the component profiles to the fabrication and testing details.

7.1 Materials

With Aluminium being available in various alloys, namely Al-1000 series to Al-7000 series, for our study, we have chosen Aluminium with 98% Purity. The Physical Properties of Aluminium Alloys can be understood from the following table :

		Numerical values
Yield stress	(MPa)	280
Ultimate tensile strength	(MPa)	327
Strength coefficient	K (MPa)	447
Strain hardening exponent	n	0.095
Young's modulus	(GPa)	68
Percent elongation	A (%)	12
Hardness	Hv50	95

Table 3 : Properties of Aluminium Alloys

While the previous sections have already detailed the clear advantage of using Multi Walled Carbon Nanotube (MWCNT), the properties of the same are illustrated via the following table :

S. No.	MWCNT standards	Description	Characterization Method
1	Production	Chemical vapour	Proprietary method
2	Available form	Black powder	visual
3	Diameter	Outer diameter: 10–30 nm	TEM, SEM
4	Length	10 μm	SEM, TEM
5	Nanotubes purity	98+% & above pure carbon	TGA, RAMAN
6	Bulk density	0.04–0.06 g/cm^3	Pycnometer

Table 4 : Characterization of Multi Walled Carbon Nanotube

Coconut Shell Ash was produced by first creating a powder of the coconut shell and then burning that at high temperatures to produce the Coconut Shell Ash.

Fig 10 : Coconut Shell Powder

Fig 11 : Coconut Shell Ash

7.2 Preparation of Samples for Casting

Next,the plan is to fabricate 5 different casting models that had varying percentages of Coconut Shell Ash and Carbon Nanotubes. The proportions of the same for each sample is represented as follows :

Samples	% of CNT	% of CSA
Model 1	0 %	2 %
Model 2	0.2 %	2 %
Model 3	0.2 %	4 %
Model 4	0.2 %	6 %
Model 5	0.2 %	8 %
Model 6	0.2 %	10 %

Table 5 : Sample Composition

Since stir- casting method was used for fabrication, there was no pre-mixing of constituents involved.

7.3 Sand Mould Preparation

The actual fabrication process was carried out as follows :

- Sand Moulds were prepared by ramming green sand in the cope and drag. Appropriate Sprues and runners are provided to ensure ventilation and smooth flow of metal.

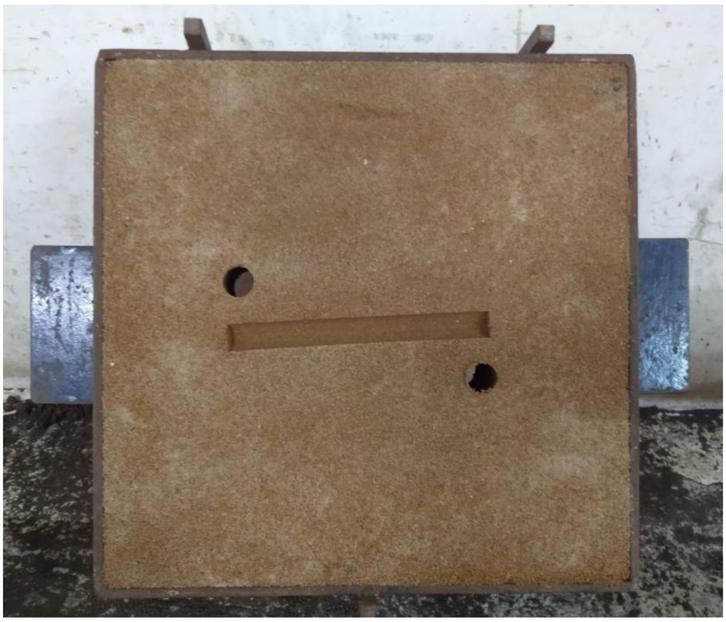


Fig 12 : Cope of the mould

Fig 13 : Drag of the mould

7.4 Stir Casting Process

The following Ceratherma furnace was used in the preparation of the composites.

Fig 14 : Furnace Setup for Stir Casting

The sequence of events for further fabrication is as follows :

- Aluminium is taken in measured quantities depending on the sample proportion pre-decided and melted at 670ºC in the Stir Casting Furnace.
- The method of Double Stir Casting is used here as explained in the next steps.
- First, the reinforcement mixture comprising of Degassing Agent + Carbon Nanotubes + Magnesium + Coconut Shell Ash to be Added stepwise in appropriate pre-determined quantities at 600ºC. All whilst continuous stirring is going on.
- This mixture is stirred for a duration of about 3 minutes.

- The heat of the mixture is then increased further by 100ºC above the melting point I.e. to around 800ºC .

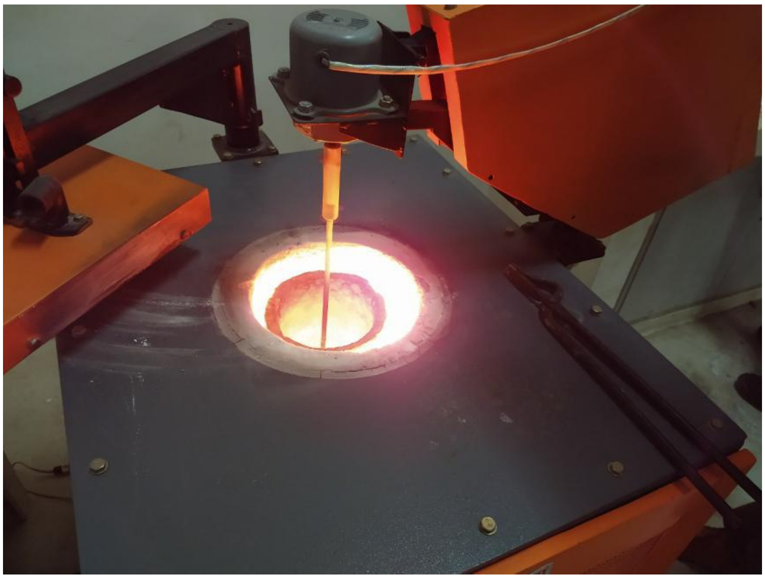


Fig 15 : Photograph of the Stir Casting Process

- The mixture is again stirred about 3 minutes and then poured into the sand moulds prepared.
- Once the mixture cools down and sets, it is taken out of the moulds and machining is done.

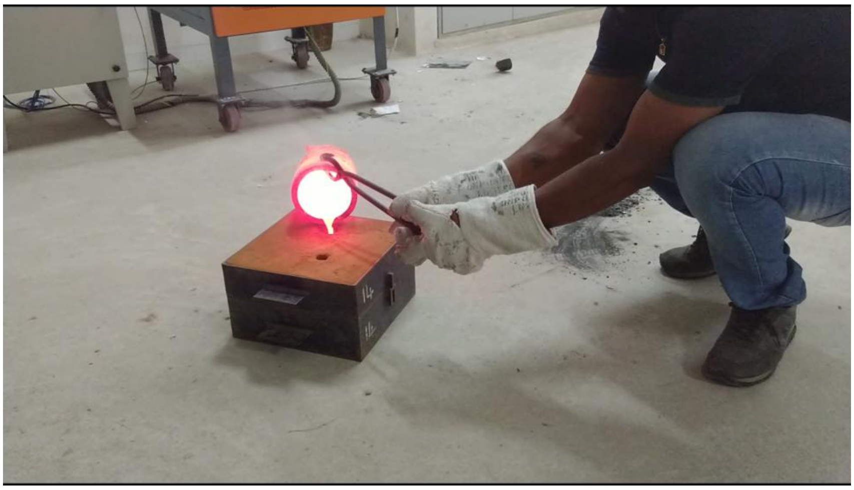


Fig 16 : Photograph of the mixture being poured into the moulds

- Machining is done on the lathe using brazen carbide tipped tool to provide a smooth finish to the components so that they may be subjected to further studies.

7.5 Casting Models

While six different models were prepared for different compositions of Aluminium - Carbon Nanotubes - Coconut Shell Ash - all through sand moulding, a picture of one of the model prior to machining - for visualization purpose is represented as follows :

Fig 17 : Cast Model of the Aluminium - Carbon Nanotube - Coconut Shell Ash Composite

7.6 Calculations

7.6.1 Preliminary Calculations on Material Composition and Weight

Preliminary calculations were performed to obtain the values of material composition and weight of the different casting models.

COMPOSITION	QUANTITIES OF EACH COMPOSITE (gm)		VOLUME OF COMPOSITE 'V' (cm^3)	DENSITY OF COMPOSITE 'ρ_{comp}'(g/cm^3)	WEIGHT OF COMPOSITE '$W_c = V \times \rho_{comp}$' (gm)
Aluminium + 2 % CSA	Aluminium	207.642 g	79.12 cm^3	2.678 g/cm^3	211.88 gm
	CNT	0 g			
	CSA	4.238 g			
Aluminium + 0.2 % CNT + 2 % CSA	Aluminium	207.37 g	79.12 cm^3	2.68 g/cm^3	212.04 gm
	CNT	0.42408 g			
	CSA	4.2408 g			
Aluminium + 0.2 % CNT + 4 % CSA	Aluminium	201.302 g	79.12 cm^3	2.6558 g/cm^3	210.127 gm
	CNT	0.42025 g			
	CSA	8.405 g			

COMPOSITION	QUANTITIES OF EACH COMPOSITE (gm)		VOLUME OF COMPOSITE 'V' (cm^3)	DENSITY OF COMPOSITE 'ρ_{comp}'(g/cm^3)	WEIGHT OF COMPOSITE '$W_c = V \times \rho_{comp}$' (gm)
Aluminium + 0.2 % CNT + 6 % CSA	Aluminium	195.466 g	79.12 cm^3	2.6338 g/cm^3	208.386 gm
	CNT	0.417 g			
	CSA	12.503 g			
Aluminium + 0.2 % CNT + 8 % CSA	Aluminium	189.701 g	79.12 cm^3	2.6118 g/cm^3	206.646 gm
	CNT	0.4133 g			
	CSA	16.532 g			
Aluminium + 0.2 % CNT +10 % CSA	Aluminium	184.005 g	79.12 cm^3	2.5898 g/cm^3	204.905 gm
	CNT	0.4098 g			
	CSA	20.49 g			

Table 6 : Preliminary Calculation of Material Composition and Weight of Models

CHAPTER 8 : PLAN FOR COMPLETION

Having described the background, necessary tools as well as the methodology of Fabrication of Aluminium- Carbon Nanotube - Coconut Shell Ash Composites by Stir Casting Technique, the next obvious step is TESTING.

As we approach the end of this project, we aim to conclude this project with the following 7 point plan :

1. Conduct Hardness Testing on the Aluminium-CNT-CSA Casting models by Brinell Hardness Testing Method
2. Conduct Wear Testing using Pinion Disc Wear Test
3. Compare the results thus obtained with Hardness and Wear Characteristics of Similar composites like Aluminium + CNT and Aluminium + CSA
4. Use Plots for clearer inferences of the stark or weak differences between the composites' characteristics
5. Results to be Drafted
6. Final Conclusion of the Project to be drawn up
7. Future Scope of this work to be discussed

Fig 18 : 7 Point Plan for Project Completion

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