PROJECT REPORT ON

Design and Analysis of Brake Liners and its Materials

submitted in partial fulfillment of the requirements of the degree of

Bachelor of Engineering

by

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CERTIFICATE

This is to certify that the project entitled **"Design and Analysis of Brake Liners and its Materials"** is a bonafide record of the Project work done by **"Kaustubh K. Chile (TU5F1819028), Gaurang S. Kargutkar (TU5F1819034), Aniket P. Gandhi (TU5F1819053), Karan P. Naik (TU5F1819021)"** in the year 2021-22 of the Department of Mechanical Engineering submitted to the University of Mumbai in partial fulfillment of the requirement for the award of the degree of **"Bachelor of Engineering"** in **"Mechanical Engineering".**

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DECLARATION

We declare that this written submission represents my ideas in my own words and where other ideas or words have been included, We have adequately cited and referenced the original sources. We also declare that we have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. We understand that any violation of the above will be cause for disciplinary action by the institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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Abstract

This project presents research work on new alternative materials for brake pads. A new asbestos free brake pad was developed using an agro waste material using sawdust as filler material and phenolic resin as binder along with other ingredients. This was with a view to exploiting the characteristics of sawdust which are largely deposited as waste around sawmills in replacing asbestos which has been found to be carcinogenic, also replacing the epoxy resin with the phenolic resin since it decreases Thermal conductivity. A brake pad was produced using sawdust as a filler material following the standard procedure employed by the manufacturers. The sawdust was sieved into sieve grades of different sizes. The sieved sawdust was used in production of brake pad in ratio of 60% sawdust, 15% Brass, 5% graphite, 7% silicon carbide and 13% phenolic resin using compression moulding. The properties examined are hardness, compressive strength, density, ash content, wear rate and water absorption. Thermal Analysis was also carried out using ANSYS along with Force acting on the brake pad. The achieved result of this work is to be compared with that of commercial brake pads (asbestos based) and it should be able to match with the properties of Asbestos-based brake pads. So that sawdust as reinforcer and phenolic resin as binder can be used in production of asbestos-free brake pads.

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List of Abbreviations and Notations

α	- Coefficient of Thermal expansion
μ	- Coefficient of friction
ρ	- Density of Friction Material
θ	- Angular Dimension of Brake pad

MMC	- Material Matrix Composition
CAD	- Computer Aided Design
MAT Journal	- Journal of Mechanical and Mechanics Engineering
IJMTR	- International Journal of Modern Trends in Engineering and Research
PMC	- Polymer Matrix Composites
ASTM	- American Society for Testing and Materials
BHN	- Brinell Hardness Number
HRC	- Hardness Rockwell C

Chapter 1

Introduction

Fig 1.1 Brake Pad

Brake is a supreme part of all the automobiles and machineries without which we cannot imagine them to be completed. They are exploited to reduce the speed and to control the motion of so many things around the globe. Brakes are framed with leverage, some moving parts and an important one is lining material to have frictional effect; those are utilized to absorb kinetic energy and transform it into other forms. In mechanical brakes, braking has been applied by efficacious utilization of brake lining materials applied on brake shoes. A brake is said to be more effective, if it assimilates m47ore kinetic energy and dissipates it into heat or other form.

Brake linings are formulated with comparatively slushy but stringy and heat-resistant material having a higher tribological properties. Brake linings are the molded form of an adhesive material with minute shots, to have frictional effect. Asbestos is used as a base material to furnish a combining effect of all the materials. Asbestos is consisting of six naturally materialized silicate minerals ,these all minerals have in familiar their characteristics of asbestos like, they have around 1:20 aspect ratio, thin muscular crystals, with each visible fiber consisting of number of minute structure known as "fibrils" that can be revealed by abrasion and other processes. Asbestos and their composites have been used from several decades with varying compositions, which has good tribological and mechanical properties.

Nevertheless, due to health hazards analogous with handling and application of asbestos, there is scope for development of alternative friction lining material

1.1 Background

History records the use of many kinds of friction materials for brakes. For example,wagon brakes used wood and leather. In fact, many current brake materials still contain organic-based materials, like polymers and plant fibers. Emerging. railroad technology in the 1800's required brake materials to perform under high loads and speeds. Friction experiments were conducted with iron brake shoes in the 1870's. The first brake lining materials were woven, but in the 1920's these were replaced with molded materials that contained chrysotile asbestos fibers, a plentiful mineral. Resin-bonded metallic linings were introduced in the 1950's, and by the 1960's so-called 'semi-mets' were developed [1].

In recent times, coconut shells based brake pad were produced with a formulation of grinded coconut shells (filler), epoxy resin (binder –matrix), iron chips (reinforcement), methyl ethyl ketone peroxide (catalyst), cobalt naphthenate (accelerator), iron and silica (abrasives), and brass (friction modifier). Also an investigation was carried out on the use of banana peels to replace asbestos in brake pads with phenolic resin (phenol formaldehyde) as binder. The resin was varied from 5 to 30 %weight in an interval of 5 %weight. Most recently,pulverized cow hooves based brake lining was developed as replacement for asbestos for automobile application This Project therefore aimed to develop brake pads from agro waste material composite of sawdust with a view to investigate the functional properties as compared with the commercial brake pad[2].

1.2 Main Characteristics of Friction Materials

- Maintain a sufficiently high coefficient of friction with the brake disc.
- Not to decompose or break down in such a way that the friction coefficient with the brake disc is compromised, at high temperatures.
- Exhibit stable and consistent coefficient of friction with the brake disc.
- Wear resistant.
- Able to dissipate heat to the surroundings.
- Having sufficient fade resistance.
- Induce less squealing action and should be operated over different atmospheric conditions [7].

1.3 Classification of Friction Materials

In the past, asbestos reinforced fiber friction material was widely used because of its excellent comprehensive performance such as low density, high mechanical properties, high melting point, high friction coefficient, and less wear rate on disc. It has been proved recently that asbestos is carcinogenic to human respiratory organs and cannot be used as a friction material. Based on the type of matrix material, brake friction materials can be divided into:-

- Metallic - the main friction material is steel, copper, or some other metal; the pad is characterized by high resistance and thermal conductivity; cooperation with a cast iron disc results in deep scratches and cavities in the material (due to adhesion), and may lead to undesired noise and rapidly progressing corrosion.

- Semi-Metallic – the friction material is a mixture of metals and organic materials, which provides decent friction and high thermal conductivity; similarly to metallic pads, wear may be more rapid, as well as noise during braking and corrosion.

- Non-Asbestos Organic or Ceramic – the main component in this case is an organic material usually reinforced with aramid, glass or ceramic fiber; this design ensures high durability, resistance to high temperature, low wear rate, lightweight and quiet operation; however, due to the complexity of the production process, this type of solutions may be very expensive, and because of high hardness, the material may be brittle.

- Carbon-Carbon – structure of the pad is similar to that of ceramic pads, yet its properties are more desirable, namely: high coefficient of friction, resistance to increased temperatures and wear, small weight; this type of brake pad works best in elevated temperatures, that is why it is often used in sport cars; manufacturing costs, compared to conventional brake pads, are very high.

- Eco-friendly - one of the main components (additives) in these type of brake pads are plant-based materials, usually waste material obtained in the production of, for example, food; brake pads with this type of material have various properties, usually favorable ones [17].

1.4 Problem Statement

In recent times, the Brake pads which are made up of Sawdust composite uses epoxy resin as binder but it has been seen that epoxy resin has a high heat resistance. Which makes the heat dissipation difficult, also it is observed that it takes long curing time as compared to other resins and it costs very high. It also causes respiratory illness. Hence there is a need to develop a material with a new binder.

1.5 Objectives

The Research has the following objectives as mentioned below:-

1. To increase the thermal conductivity of the brake liner for proper heat dissipation.
2. To decrease the overall cost of Fabrication.
3. To reduce the weight of the Brake Pad.
4.To increase its resistance towards water and moisture.

1.6 Scope

1. By Manufacturing of this Brake liner there is increase in the Thermal efficiency of BrakePads by increasing its Thermal Conductivity.
2. To Fabricate a brake liner with minimum wear rate.
3. To achieve good Braking in wet region since this Brake Pad will have High Resistance
4. Approach towards eco-friendly Brake liners.

Chapter 2

Review of Literature

The following chapter has discussed the literature survey over the last three decades for Design and Development of various Brake Pads using Different Material Compositions . We have found some proposed literature surveys given below.

S.S.Lawal, Katsina Bala (2017) has published paper on 'Development and Production of Brake Pad from Saw Dust Composites'.This paper presents research work on new alternative materials for brake pad.A new asbestos free brake pad was developed using an agro waste material of sawdust along with other ingredients.The Process used was Compression Moulding.Various Tests such as Brinell hardness test, Ash Content Strength, Compressive Strength, were done. The results showed that sawdust has properties comparable to that needed for use as brake pad material to replace asbestos in the manufacture of brake pads since it gave results which are within the range for brake pad manufacture.[2]

K. Naresh Kumar, Dr. K. N. S. Suman (2017) has published a technical paper on 'Review of Brake Friction Materials for Future Development'. As per this paper the wear rate mainly depends on the type of friction material used, pressure applied on the pads, friction material temperature, friction material contact area, friction material finish, heat removal rate, ability to operate over various atmospheric conditions and fade resistance. The result showed that the Selection of optimum wt% of the fiber is essential for the designer to achieve better wear and frictional propertiesBy increasing the aspect ratio of fiber, flexural strength of the composite increased and compressive strength decreased while the coefficient of friction (μ) and wear rate of composite first increased and then decreased at selected load and speed [3].

U. Elakhame, **et.al (2014)** has published a paper on 'Development and Production of Brake Pad from Palm Kernel Shell Composites'. This Article refers to the Development and Production of Asbestos free Brake pad using Palm Kernel which the Compression Moulding process. In this Paper after preparation of Raw Materials of the specified Composition various tests were performed by taking Components of Different Sieve sizes. From this Research paper we conclude that, the Compressive strength, hardness, densities and porosity of the produced samples were seen to be decreasing with increase in sieve grade while there oil soak, water soak, wear rate and percentage charred increased as sieve grade increased. Based on the above test properties of these brake pads composite using palm kernel shell as filler can be effectively used as an alternative to existing fillers, such as asbestos, in brake pad composites.[4]

S.S.Lawal, Katsina Bala, et.al (2019) has published a paper on 'Production and Testing of Brake pad composites made from Cashew nut shell and Plant gum binder'. This paper presents a new asbestos free brake pad composites developed from agro waste material based on cashew nut shells, Nigerian plant gum along with other ingredients such as brass, graphite and silicon carbide. Brinell hardness, Compressive Strength, Wear Rate and Coefficient of friction test were conducted on the specimen. Hence, it can be concluded that the cashew nut shells and Nigerian Gum Arabic along other ingredients can be used for the production of asbestos free composites for automobile brake pads.[5]

Bashar DAN-ASABE, et.al (2012) has published an article on 'Material Selection and Production of a Cold Worked Composite Brake pad**'**. This paper entails the selection and production of composite brake pad with varied constituent's composition.The main materials for this research are coconut shell powder, cast iron fillings, silica, epoxy (liquid resin), catalyst and accelerator. It concluded that the higher the percentage of grounded coconut powder the lower the breaking strength, impact hardness and compressive strength, and vice-versa respectively. They are far less dense (lighter) than the other compositions and models[6].

Ritesh Sharma has proposed a Research on ' Fabrication, Characterization, and Machining of Novel brake pad material'. In this study Wear characteristics and Machinability of Al/SiC/Carbon fiber MMCs has been taken into consideration. In this paper the challenge of present materials for a variety of applications: the advent of the technological era has brought the requirement of new material. That was to find or create the new material various material systems have been invented by the researches.MMCs is the one of the most prominent systems in the past few decades, where new material is fabricated by the mixing of two or more constituents.[7]

S. H. Gawande, et.al (2020) has published an article on 'Study on wear analysis of substitute automotive brake pad materials'. The objective of this work is to study the wear analysis of brake pad in braking operation to estimate the weight loss and wear rate of different brake pad materials used in automotive applications. In this work the Tribological characteristics like wear rate of different materials has been investigated and compared for their use as Brake pad material.[9]

Mr. Vikram S.Yendhe, et.al (2015) has published a study on 'Development of fly ash based automotive brake lining''. An attempt has been made through this research to incorporate more than 50% of fly ash particles in automotive brake lining friction composites. The developed compositions are 50–60% lighter than current commercial brake linings for similar friction, wear and temperature performance under dry and wet conditions. Fly ash particles were found thermally resilient enough not to decompose at typical braking temperature[8].

J. ABUTU, et.al (2018) has published a paper on 'An overview of Brake pads production using Non-Hazardous reinforced materials'. An overview of brake pad production using non–hazardous reinforcement materials is carried out with assessment of various production methods and mechanical and tribological properties produced from these non–hazardous materials.A comprehensive review of application of non–hazardous reinforcement materials as possible replacement for asbestos has been highlighted in this study. The physical, mechanical and tribological properties of these brake pads compared favorably with the commercial brake pad [10].

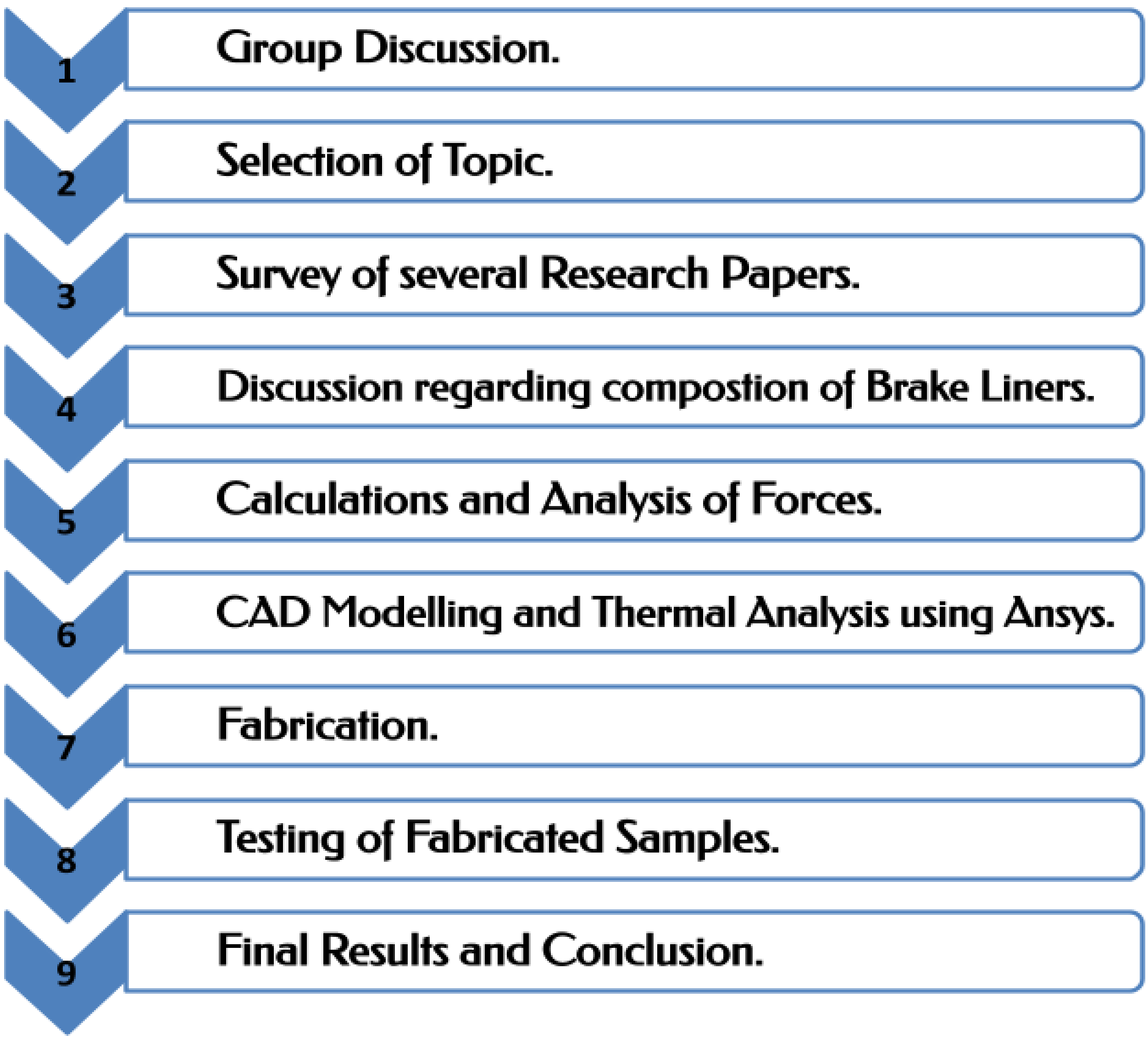
B. Praveenkumar, et.al (2019) has published an article on 'Case Studies on the Applications of Phenolic Resin-Based Composite Materials for Developing Eco-Friendly Brake Pads'. This Research paper consists of applications of Phenolic Resin-Based Composite Materials as Brake pad material. In this paper, six case studies of the tribological performance of eco-friendly polymer matrix composites (PMC) utilizing phenolic resin are presented. The study showed that Fly ash, bagasse ash, palm kernel fiber, natural fiber, basalt fiber, flax fiber and Shellfish powder are useful ingredients to eliminate harmful ingredients like asbestos, lead, antimony trisul-phide from the brake pad [11].

Chapter 3

Methodology

The project started by proposing a methodology which states the complete process from analyzing the problem statement to the Brake Pads Fabrication. Whole process is disintegrated into steps and explained accordingly.

Flowchart for design and analysis of Brake is shown below:



3.1 Problem Statement

In recent times, the Brake pads which are made up of Sawdust composite uses epoxy resin as binder but it has been seen that epoxy resin has a high heat resistance. Which makes the heat dissipation difficult, also it is observed that it takes long curing time as compared to other resins and it costs very high. It also causes respiratory illness. Hence there is a need to develop a material with a new binder.

3.2 Preliminary Search

Brake pads manufacturers utilize approximately 2000 different materials which have different effects of the final product. An average brake pad consists of from 10 to 20 different substances. Selecting the right composition for the brake pad and predicting its impact on the final products is a difficult task. It requires tremendous amounts of research and abundant experience[12]. The materials used in the production of brake pads can be classified in terms of different criteria such as :-

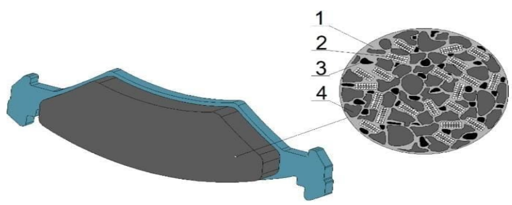


Fig 3.2 Brake pad friction material structure:

1- binder, 2- reinforcement, 3- filler, 4- abrasive [1]

The binder is the flu that holds all the components of the pad. This substance must be characterized by high and stable coefficient of friction, resistance to high and rapidly changing temperatures, and low mass. Also, the material must not react with any other component of the pad, as this might lead to changes in overall material characteristic or cause delamination of the composite and greatly limit the efficiency of the braking system.The binder is usually made from epoxy or silicone resin [12].

The reinforcement is a fibrous material which improves the binder's mechanical properties. Different types of reinforcement materials have a significant impact on the durability and resistance of the brake pad, therefore, the selection cannot be random[12]. Fillers are used to fill up the empty spaces between the other components of the brake pad. They can make up for up to 10% of the brake pad volume, which is why using the right substance is so important. Most common fillers include vermiculite, perlite, mica, barium sulfate,and calcium carbonate[12].

Abrasives are used for modifying (increasing or decreasing) the coefficient of friction. Additives such as steel,cast iron, flame resistant oxides and silicates or quartz,due to their hardness, are used for increasing the coefficient of friction between the brake pad and disc, and therefore increasing the operating life of the pad[12].

3.3 Initial Concept

This is about initializing the work by taking into consideration various design parameters and constraints. The primary aim is Fabrication and testing of brake liners from sawdust composite using phenolic Resin as binder material. The main constraint is to combine all the demerits of asbestos free and asbestos base materials with comparable properties. Therefore, the main challenge for the designer is to develop a brake friction material which is intended to serve its effective braking performance and be eco friendly in nature The developed Brake pad should have High coefficient of friction, Low wear rate of Disc, Environmentally friendly raw materials, etc. This puts tremendous demands on the material selection process. To fulfill so many demands friction materials are made from many constituents and hence are termed composite

3.4 Material Selection for Friction Material

The developed Brake pad should have High coefficient of friction, Low wear rate of Disc, Environmentally friendly raw materials, etc. In order to design a Brake pad, various parameters have to be considered which includes environmental conditions and technical requirements. The materials that are to be used in production of friction material of the Brake pad includes sawdust, steel powder, silicon carbide, graphite and Phenolic resins.

Phenolic resin was selected as the binder as it increases the thermal conductivity of the brake liner for proper heat dissipation. Saw Dust is used as a reinforcer. Graphite is used as a filler because of its excellent conductivity of heat, high Thermal stability, exceptional chemical resistance and mechanical properties . Silicon carbide is used as the abrasive because of its very good chemical, thermal and mechanical properties. Brass is used as lubricant for the production of the braking pad because of its moderate water absorption (less than 3%), good abrasion resistance, high bearing strength and good heat capacity.

The Composition used in the brake pad friction lining in this project is shown in Table 1

TABLE 3.4 :- MATERIAL WEIGHT PERCENTAGE OF THE SAMPLES

Materials	**Weight Percent (%)**		
	A	**B**	**C**
Sawdust	45	55	60
Phenolic Resin	13	13	13
Graphite	5	5	5
Silicon Carbide	22	17	7
Brass	15	15	15

3.4.1 Mechanical Properties of Friction Materials

3.4.1 Phenolic resin Powder:-

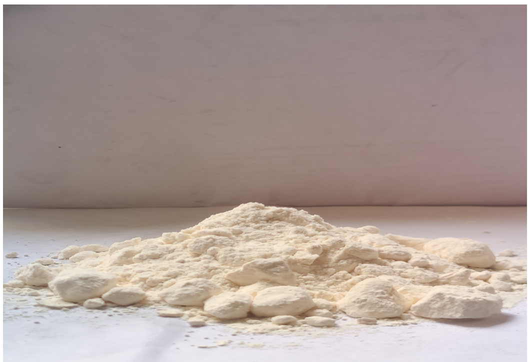


Fig 3.4.1 Phenolic resin Powder

TABLE 3.4.1.1 :- MECHANICAL PROPERTIES OF PHENOLIC RESINS

Property	**Metric Unit**
Maximum Operating Temperature	140 °C
Tensile Strength	90 MPa
Flexural Strength	152 MPa
Water Absorption 24 hrs	1.8 %
Density	1.34 g/cm³

3.4.2 Silicon Carbide Powder:-

Fig 3.4.2 Silicon Carbide Powder

TABLE 3.4.2 :- MECHANICAL PROPERTIES OFf SILICON CARBIDE

Mechanical Properties	
Density	3.1 g/cm³
Porosity	0%

Color	Black
Flexural Strength	550 MPa
Elastic Modulus	410 GPa
Poisson's ratio	0.14
Compressive Strength	3900 MPa
Hardness	2800 Kg/mm^2
Fracture Toughness	4.6 MPa.m½
Maximum Use Temperature	1650 ` C

3.4.3 Graphite Powder :-

Fig 3.4.3 Graphite Powder

TABLE 3.4.3:-MECHANICAL PROPERTIES OF GRAPHITE

Property	Commercial Graphite
Bulk Density (g/cm^3)	1.3 - 1.95
Porosity (%)	0.7 - 53
Modulus of Elasticity (GPa)	8 - 15
Compressive Strength (MPa)	20 - 200
Flexural Strength (MPa)	6.9 - 100
Coefficient of Thermal Expansion (*10^6 °C)	1.2 - 8.2
Thermal Conductivity (W/m.K)	25 - 470
Specific Heat Capacity (J/kg.K)	710 - 830
Coefficient of Friction	0.1 (increases with Temperature change)

3.4.4 Saw Dust:-

Fig 3.4.4 Saw Dust

TABLE 3.4.4 :-MECHANICAL PROPERTIES OF SAW DUST

Mechanical Properties		
Density	210 g/cm³	
Thermal Conductivity	0.324 W/m.K	
Specific Heat Capacity	800 J/kg.K	
Poisson's ratio	0.18 - 0.35	
Shear Modulus	4.24 - 2.72 MPa	

3.4.5 Brass Powder:-

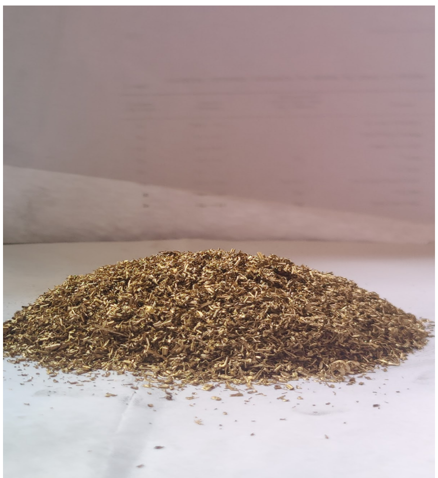


Fig 3.4.5 Brass Powder

TABLE 3.4.5:- MECHANICAL PROPERTIES OF BRASS

Mechanical Properties	
Thermal Conductivity	123 W/m.K
Coefficient of Thermal Exp.	20.8
Density	8.73 g/cm³

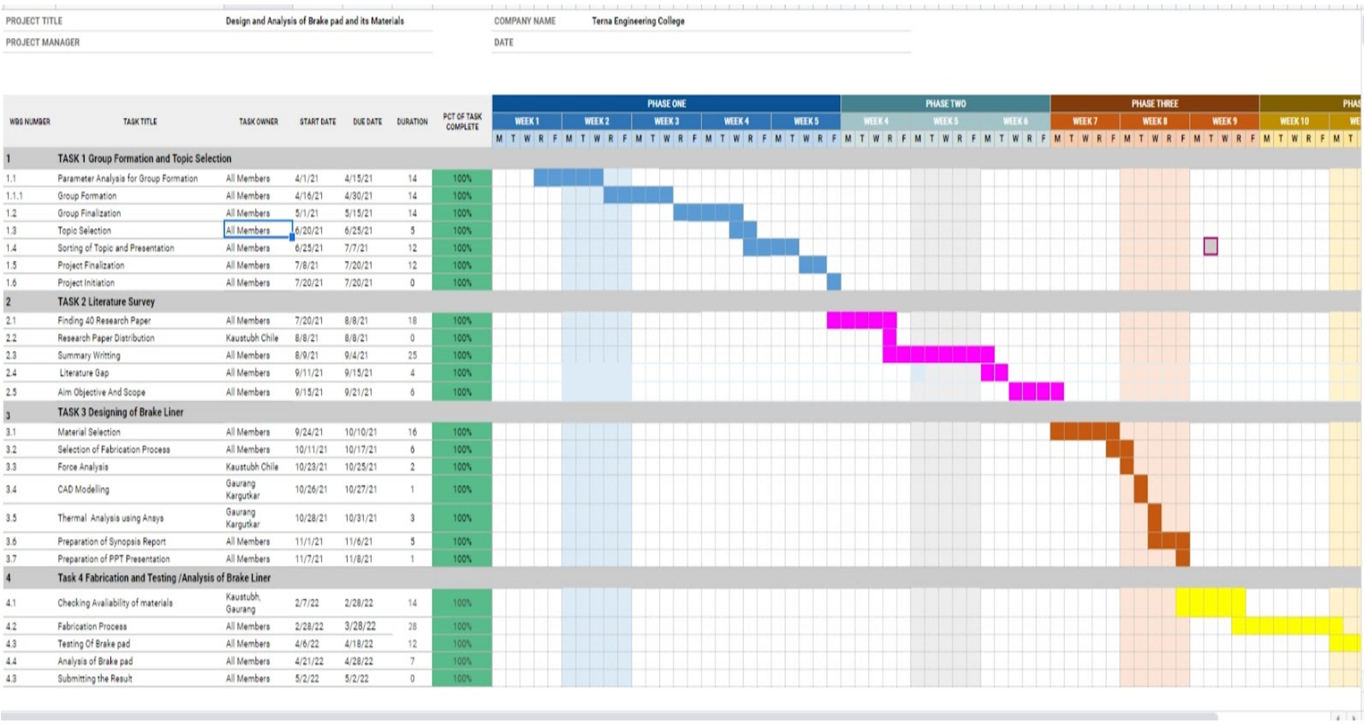
3.5 Technique of Fabrication

The Various techniques used for fabrication of brake pad are Compression Moulding, Diffusion Bonding ,Stir Casting and Liquid Infiltration method. From various Research papers it is concluded that the Compression molding Process is the most widely used for the purpose of fabrication of brake pad because of its Low cost and its ability to mould itricates parts easily.

Compression Moulding is a method in which the molding material, generally preheated, is first placed in an open, heated mold cavity. The mold is closed with a top force or plug member, pressure is applied to force the material into contact with all mold areas, while heat and pressure are maintained until the molding material has cured. The process employs thermosetting resins in a partially cured stage, either in the form of granules, putty-like masses, or performs. Compression molding is a high-volume, high-pressure method suitable for molding complex, high-strength fiberglass reinforcements.

The sawdust will be cleaned and sun-dried for about one week to remove the moisture content. The sawdust will be grounded into powder using a ball milling machine and then sieved into different sieve sizes. Production of the brake pad consists of a series of unit operations including mixing, cold and hot pressing, cooling, post-curing and finishing. The samples will be produced using a compression molding machine after the mould was impregnated with the various composition and sieve grades of different sizes of sawdust, brass, graphite, silicon carbide and phenolic resin were added together. The various compositions are presented in Table 1. The combinations will be properly dried and mixed in a mixer for 20 minutes to achieve a homogenous state and then transferred to a mould kept in a hot platen press at temperature of 150 °C at a pressure of 100kN/cm² for 2 minutes. After removing it from the hot press, the brake pad will be cured in an oven at a temperature of 120 °C for 8 hours. The product will be then allowed to cool at room temperature and then subjected to various tests to determine its functional characteristics as presented[1].

3.6 GANTT CHART



PROJECT TITLE	Design and Analysis of Brake pad and its Materials	COMPANY NAME	Terna Engineering College
PROJECT MANAGER		DATE	

WBS NUMBER	TASK TITLE	TASK OWNER	START DATE	DUE DATE	DURATION	PCT OF TASK COMPLETE
1	TASK 1 Group Formation and Topic Selection					
1.1	Parameter Analysis for Group Formation	All Members	4/1/21	4/15/21	14	100%
1.1.1	Group Formation	All Members	4/16/21	4/30/21	14	100%
1.2	Group Finalization	All Members	5/1/21	5/15/21	14	100%
1.3	Topic Selection	All Members	6/20/21	6/25/21	5	100%
1.4	Sorting of Topic and Presentation	All Members	6/25/21	7/7/21	12	100%
1.5	Project Finalization	All Members	7/8/21	7/20/21	12	100%
1.6	Project Initiation	All Members	7/20/21	7/20/21	0	100%
2	TASK 2 Literature Survey					
2.1	Finding 40 Research Paper	All Members	7/20/21	8/8/21	18	100%
2.2	Research Paper Distribution	Kaustubh Chile	8/8/21	8/8/21	0	100%
2.3	Summary Writting	All Members	8/9/21	9/4/21	25	100%
2.4	Literature Gap	All Members	9/11/21	9/15/21	4	100%
2.5	Aim Objective And Scope	All Members	9/15/21	9/21/21	6	100%
3	TASK 3 Designing of Brake Liner					
3.1	Material Selection	All Members	9/24/21	10/10/21	16	100%
3.2	Selection of Fabrication Process	All Members	10/11/21	10/17/21	6	100%
3.3	Force Analysis	Kaustubh Chile	10/23/21	10/25/21	2	100%
3.4	CAD Modelling	Gaurang Kargutkar	10/26/21	10/27/21	1	100%
3.5	Thermal Analysis using Ansys	Gaurang Kargutkar	10/28/21	10/31/21	3	100%
3.6	Preparation of Synopsis Report	All Members	11/1/21	11/6/21	5	100%
3.7	Preparation of PPT Presentation	All Members	11/7/21	11/8/21	1	100%
4	Task 4 Fabrication and Testing /Analysis of Brake Liner					
4.1	Checking Avaliability of materials	Kaustubh, Gaurang	2/7/22	2/28/22	14	100%
4.2	Fabrication Process	All Members	2/28/22	3/28/22	28	100%
4.3	Testing Of Brake pad	All Members	4/6/22	4/18/22	12	100%
4.4	Analysis of Brake pad	All Members	4/21/22	4/28/22	7	100%
4.3	Submitting the Result	All Members	5/2/22	5/2/22	0	100%

Chapter 4

Design and Analysis of Brake pad

4.1 Design and CAD Modeling of Brake pad

Designing of brake pad includes designing of backplate along with design of friction pad. There are predefined specific dimensions that are needed to be given to the brake pad. Therefore there is no calculation for designing the brake pad, instead a CAD Model is made which signifies the shape ,size and dimensions of the brake pad.

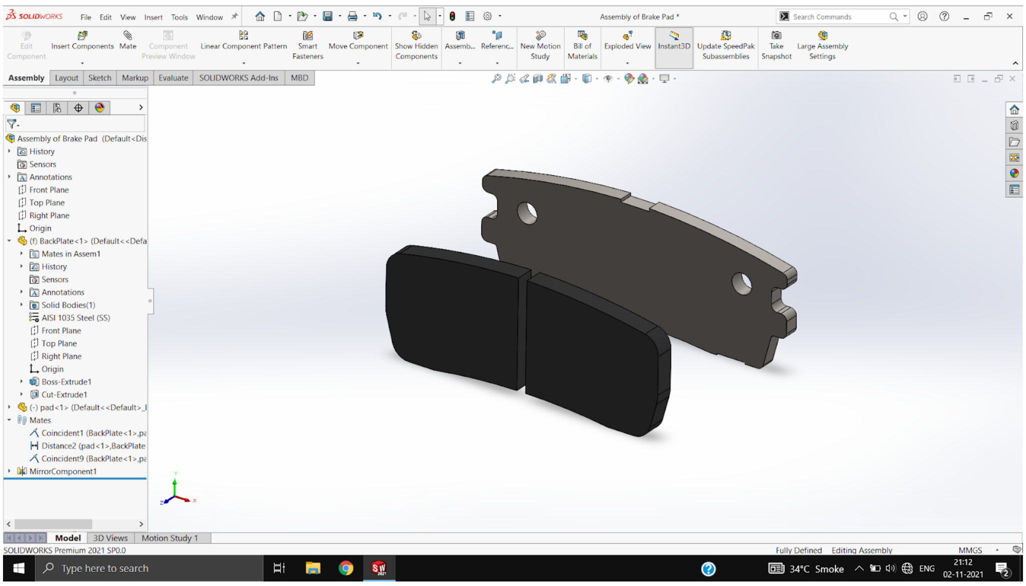


Fig 4.1 Exploded View of Brake pad Assembly

4.1.1 CAD Model of Backplate :-

A Backplate is a metallic part which is attached to the friction material/brake pad to provide support to it when the braking action takes place. These components provide a shield from brake dust and water, reducing corrosion of suspension parts. Usually a backplate is 105 mm to 110 mm in length and has a thickness upto 5 to 8 mm.It is mainly made up of steel.

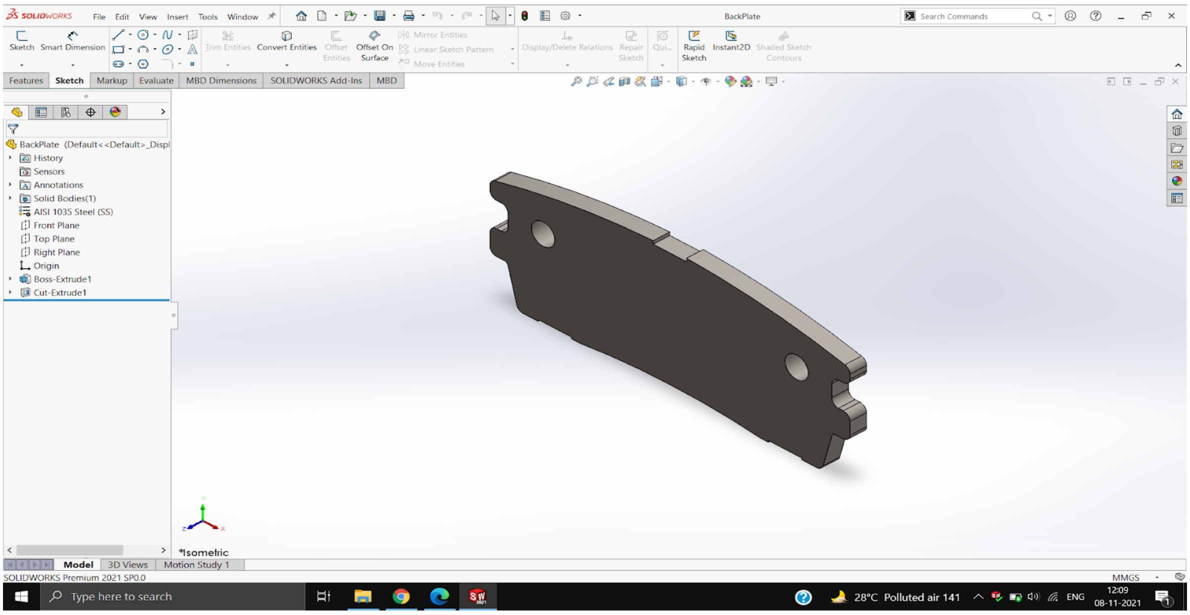


Fig 4.1.1 CAD Model of Backplate

4.1.2 CAD Model of Friction Pad/Brake Pad :-

A friction pad is one of the most important parts of the braking system. The friction pad is used to generate controlled friction for braking or power transfer application. Its composition is mentioned in Table 3.4. It has a Thickness of 6 mm to 10 mm.

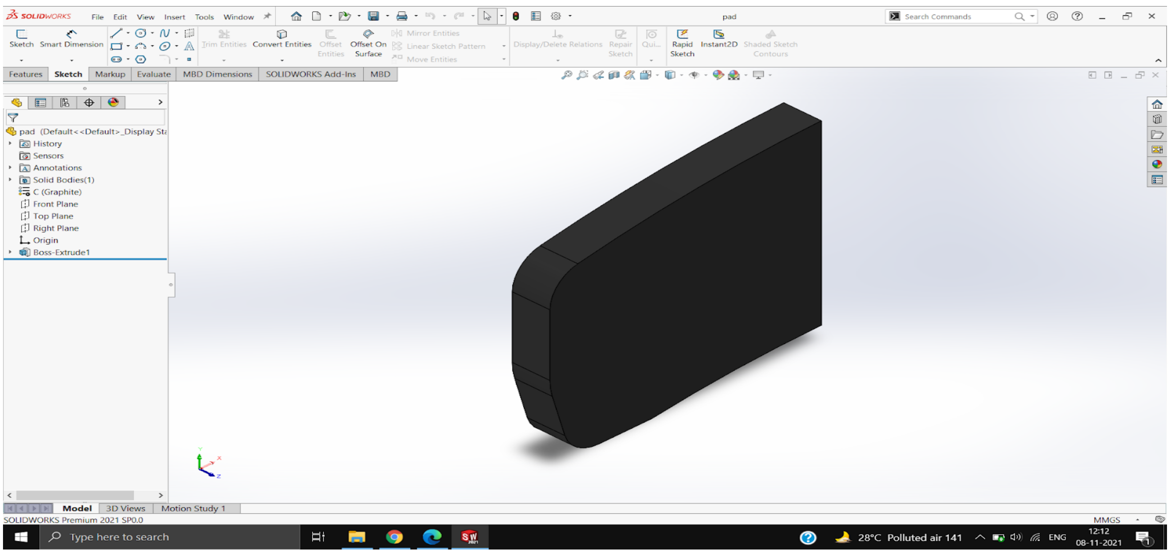


Fig 4.1.2 CAD Model of Friction Material

4.1.3 Assembly of Brake pad:-

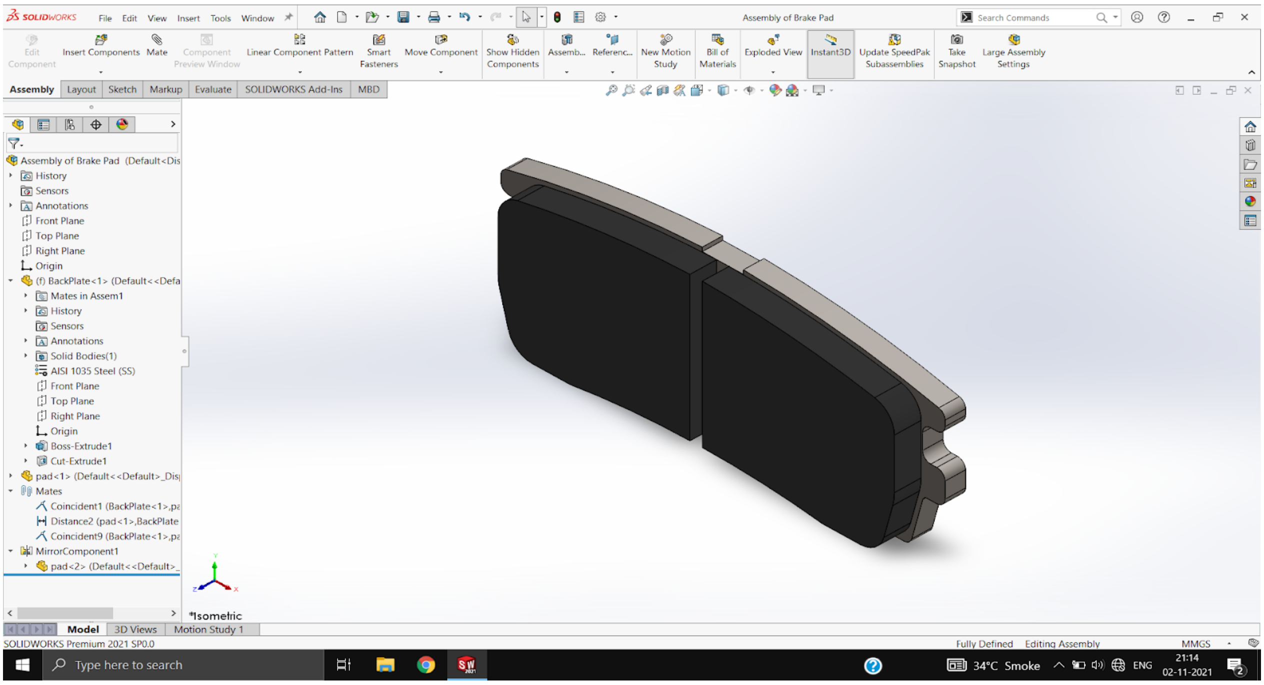


Fig 4.1.3 Assembly of Brake Pad

4.1.4 Drafting Of Brake Pad Assembly:-

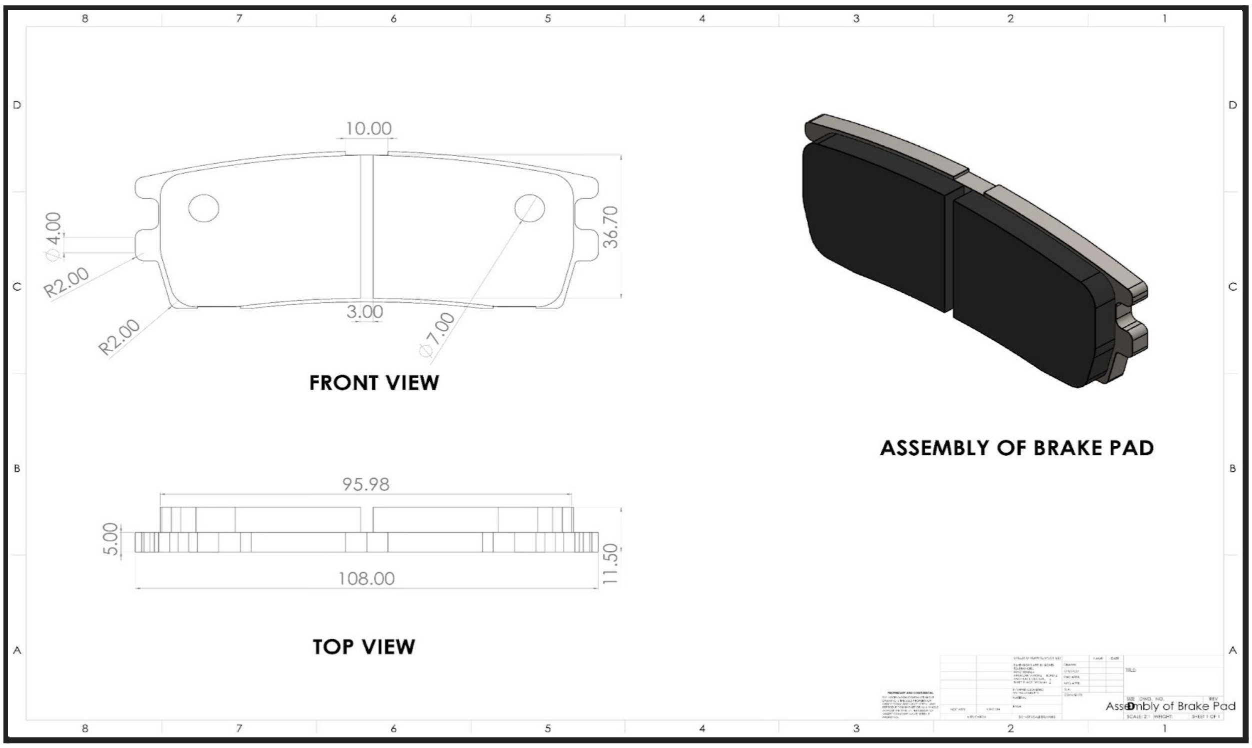


Fig 4.1.4 Drafting of Brake pad Assembly

4.2 Force Analysis and Calculation

Whenever braking action takes place on a Brake pad , two types of forces act on it i.e a normal force and a tangential force.

1. Clamping Force(Normal Force):-Clamping Force (F_n) is the force pressing each brake pad against the disc.

2. Braking/Frictional Force(Tangential):-Braking Force (F_b) is the tangential friction force acting

between the brake pads and disc.

$$F_b = 2 . \mu . F_n$$

Where: μ is the coefficient of friction between the pad and the disc

Due to this Braking force , braking torque acts due to which the braking action takes place.

$$T_b = F_b . Re$$

Where Re is the effective disc radius

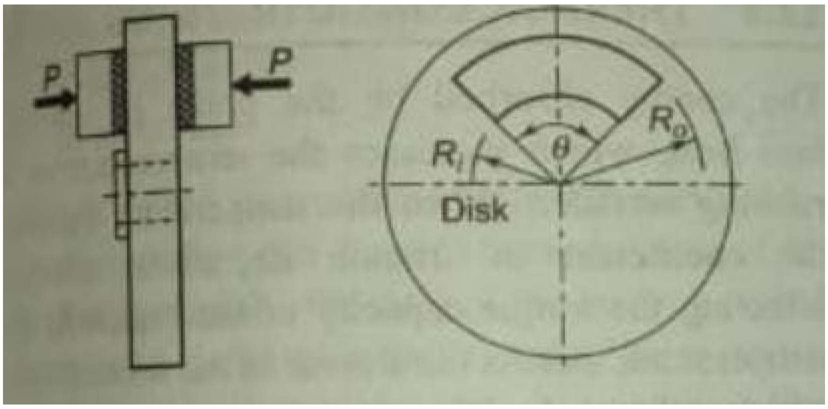


Fig 4.2 Disc Brake with Forces acting on Brake pad[13]

The Dimensions of the Brake pad are as follows :-

R_o= Outer radius of pad (mm) = 230 mm
R_i= Inner radius of pad (mm) = 200 mm
θ = Angular dimensions of pad (radians)
= 0.521 radians

- The Area of the Brake pad is given by :-

$A = \theta*\pi*(R_o^2 - R_i^2) / 2\pi$
$= \theta*(R_o^2 - R_i^2) / 2$
$= 0.521*((230)^2 - (200)^2) /2$
$= 3360.45$ mm

- The Clamping force or Actuating force P is given by:-

P = Average Pressure * Area of pad
= 2 * 3360.45 ...(Assuming Standard value of Average Pressure = 2)
= 6720 kN

- The Frictional Force is given by:-

$F_r = \mu * P$

$= 0.35 * 6720.9$ ...(Assuming the value of μ between the Standard coefficient of friction for Brake pads i.e 0.3-0.4)
= 2352.315 N
= 2.352 kN

Since the area of pad is comparatively small, it is assumed that pressure on friction lining is uniform

- Thus, by Uniform Pressure Theory, the friction radius is given by:-

$R_f = 2*(R_o^3 - R_i^3) / 3*(R_o^2 - R_i^2)$

$= 2 *((230)^3-(200)^3) / 3*((230)^2-(200)^2)$
$= 215.34$ mm

- The Brake Torque capacity of the disc brake is given by:-

$T_b = \mu * P * R_f$
$= 0.35 * 6720.9 * 215.34$
$= 506.547 *10^3$ N
= 506.547 kN

4.3 Thermal Analysis using Ansys

The energy absorbed by the brake is converted into heat, which increases the temperature at the rubbing surfaces. When the temperature increases the coefficient of friction decreases, adversely affecting the torque capacity of the brake At high temperature, there is rapid wear of the friction lining which reduces the life of the lining. Therefore, the temperature rise should be kept within permissible range. These types of variations are studied using FEA for Thermal Analysis using ANSYS WORKBENCH 2021.

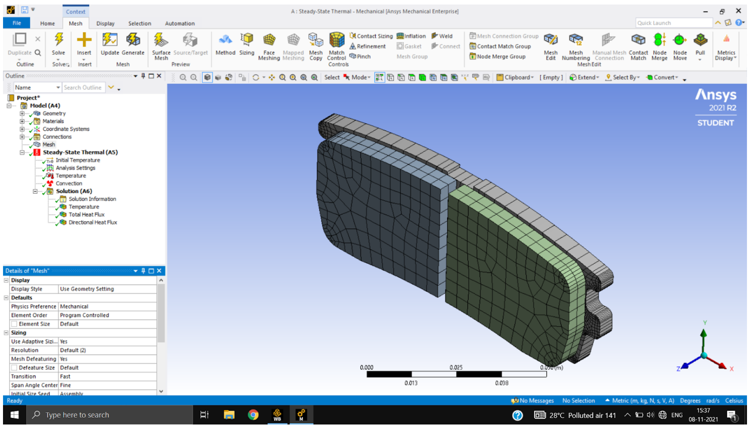


Fig 4.3.1 Mesh Model Of Brake pad

Then thermal analysis was carried out to find out the temperature distribution throughout the pad for one braking cycle. The model was divided into 1625 number of elements, and 11749 number of nodes. Fig.4.3.2 shows the temperature distribution on the brake pad generated due to braking. It is seen that the temperature obtained from the analysis of the existing brake pad is almost equal to that calculated theoretically.

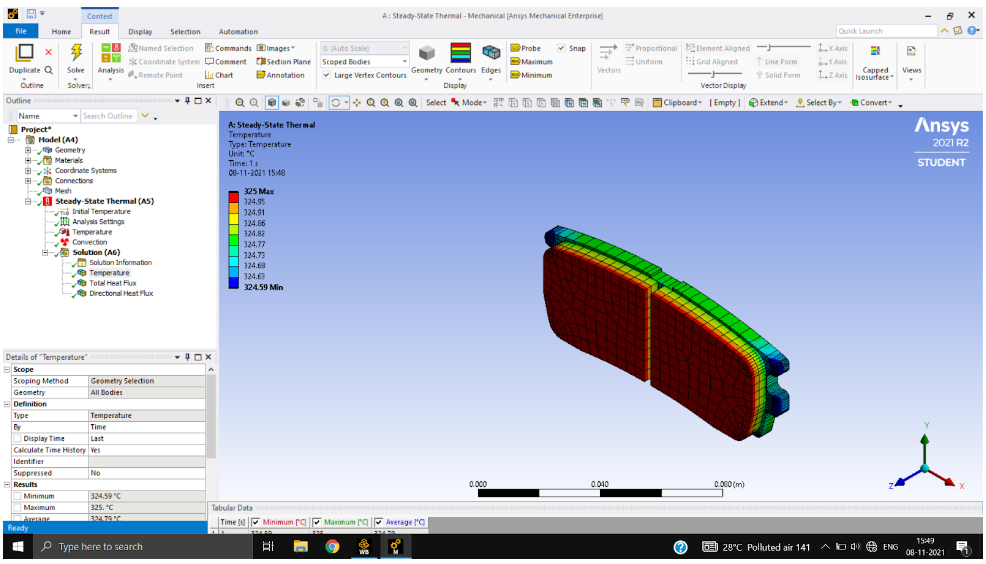


Fig4.3.2 Temperature Distribution on Brake Pad

The maximum temperature reached is about 325-350 °C at the surface of brake pad and it is observed that due to convection the heat dissipates more from the backplate and it reaches to the minimum temperature of 324.5 °C .

Similarly, Steady State Heat flux generated in brake pad is shown in Fig.4.3.3. The maximum Heat flux generated in the brake pad is 5048.6 W/m² and minimum Heat flux is 5.5084 W/m².

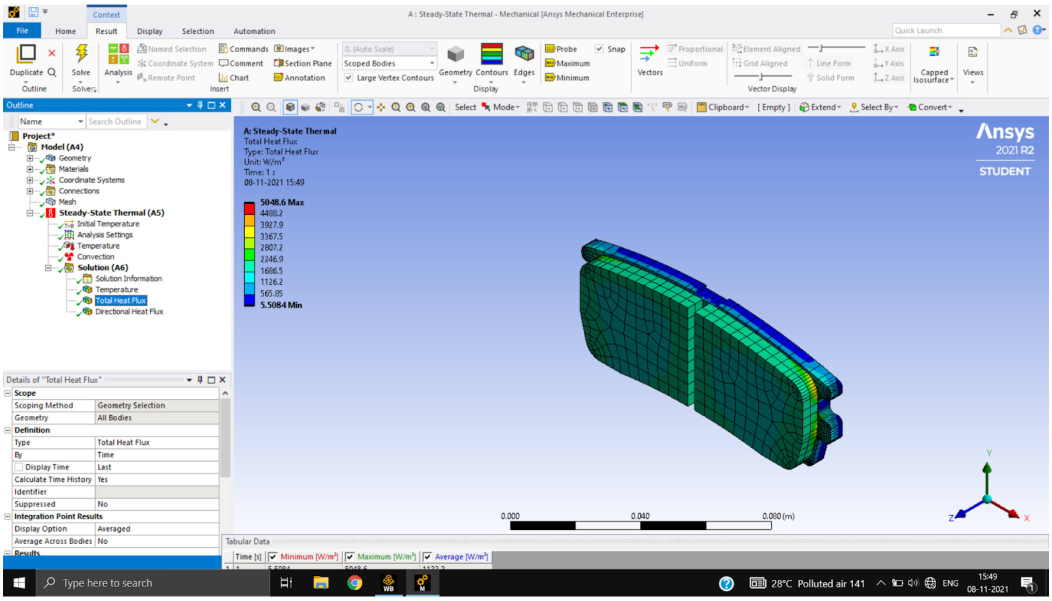


Fig 4.3.3 Steady State Heat flux on Brake pad

4.4 Testing

4.4.1 Brinell hardness test

The resistance of the composites to indentation will be carried out using the Brinell hardness testing equipment of BS240, a Tensometer (M500-25kN, hardened steel ball of diameter D to indent the test specimen. Based on ASTM specification, a steel ball of D = 10 mm diameter steel ball was used, and the load applied P was kept stable at 3000 kgf. The diameter of the indentation, d, will be measured along two perpendicular directions, using an optical micrometer screw gauge. The mean value will be used to obtain the Brinell Hardness Number (BHN) using.

$$BHN = 2*P / \pi*D*(D - \sqrt{(D^2 - d^2)})$$

where P = applied load, D = diameter of hardened steel ball, d = diameter of indentation[2].

4.4.2 Density test

The density of the samples will be determined by weighing the samples on a digital weighing machine and their volumes will be determined by viewing their mass properties in Solidworks. The density was determined using an equation.

$$\text{Density, } \rho = M / V$$

where M = mass of test piece (g), V = volume of the test piece (cm3).

4.4.3 Water absorption test

The samples will be weighed on a digital weighing machine and soaked in water at room temperature for 24 hours. The samples will be then removed, cleaned and weighed. The water absorption rate will be calculated thus:

$$\text{Water Absorption} = ((M2 - M1) / M1) * 100 \%$$

where M1= mass of the sample (g), M2 = mass of the sample after absorbing water (g)[2].

Chapter 5

Development of Prototype/Brake pad

5.1 Fabrication of Brake pad

5.1.1 Acquiring Raw materials:-

1. **Graphite Powder:-**
   1 kg of Graphite powder was acquired from 'Jitendra & Company' for a price of 100 Rs per kg.

Fig 5.1.1(a) Graphite Powder

2. **Silicon Carbide Powder:-**
   1 kg grams of Silicon carbide was acquired from 'Universal Trading Corporation' for a price of 130 Rs per kg.

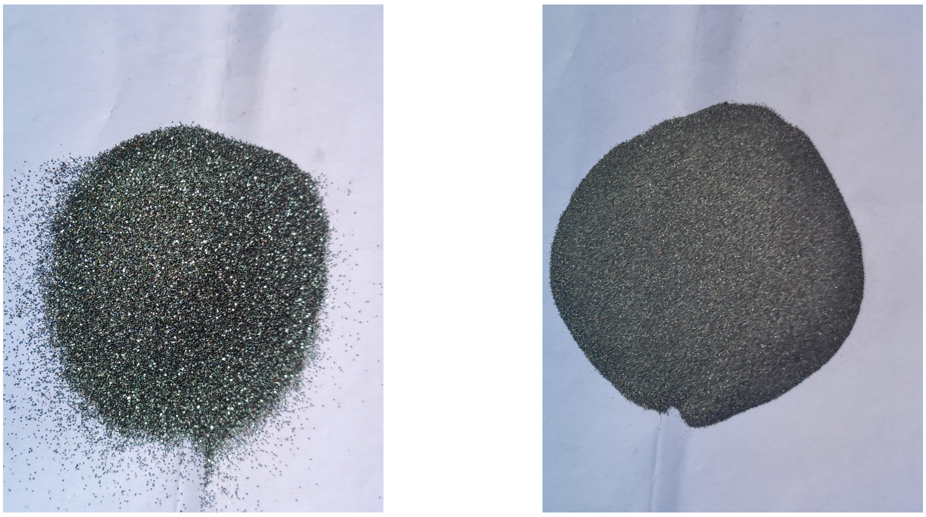


Fig 5.1.1(b) Silicon Carbide Powder

3. **Sawdust :-**

   1 kg of Sawdust was collected from nearby Wooden carpentry Shop for free of cost.

Fig 5.1.1(c) Saw Dust

4. **Brass Powder and Phenolic resin:-**
   Brass Powder and phenolic resin in powdered form was acquired from the Manufacturer named 'SSS Brothers'.

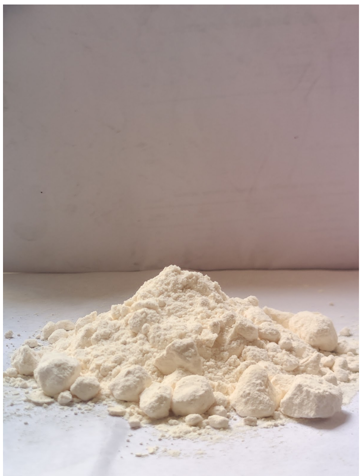


Fig 5.1.1(d) Phenolic Resin Powder

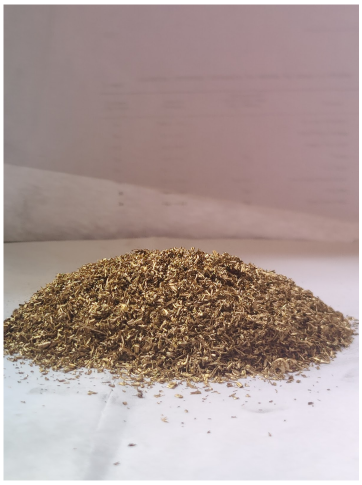


Fig 5.1.1(e) Brass Powder

5.1.2 Fabrication of Backplate

Backplate will be Manufactured by 'SSS Brothers' using Laser cutting method of the shape specified in the CAD Model. It is made up of MS Steel. The Cost of Backplate per piece is 200 Rs.

5.1.3 Blending of Rawmaterials

All the five raw materials were first sun dried and then blended or mixed properly with the help of a hand blender and Blending Machine in all 3 different proportions given in the previously mentioned table.

5.1.4 Molding of Friction Material

The blended friction material was transferred into a self adjustable mould then was hand pressed using a pressing Machine at a pressure of 110 kg/cm2 for a period of 15 minutes . After the molding of friction material it was dried for 2-3 hours. Once the friction material was ready it was then bolted with the MS backplate and joined with an adhesive named 'Araldite'.

5.2 Result and Discussion

On the basis of different proportions of weight percentages three different types of Compositions of Brake Pads were made. Figures 5.3.1, 5.3.2, 5.3.3 shows the produced samples of the Brake pad with three different compositions respectively.

Fig 5.2.1 Sample A

Fig 5.2.2 Sample B

Fig 5.2.3 Sample C

Table 5.2(a) shows the results of the Brinell hardness, density, water absorption, wear rate.

TABLE 5.2(a) :- Results of various properties of produced brake pads

Sample	Weight (grams)	Brinell Hardness (BHN)	Density (g/cm^3)	Water Absorption (%)
A	180	320	3.74	1.11
B	181	284	3.79	0.55
C	183	-	3.89	0.54

The Weight of Samples A, B and C are 180 gm, 181 gm and 183 gm respectively, considering the Backplate weight which is 100 gm per sample. The Weight of the samples was weighed using a Digital Weighing Machine of Swisser Company. From the readings it is observed that with the increase in quantity of sawdust in the overall composition the weight of brake pad sample increases.

5.2.1 Brinell Hardness Test

The results of Brinell hardness test on the given samples as shown in Table 5.2(a) indicates that sample A has the highest hardness value due to the increase in percentage of Silicon carbide which results in increased bonding ability with Phenolic resin and increases the overall strength. It is observed that the hardness values decrease with increase in Sawdust proportion, since we can notice that Sample C having the highest sawdust proportion could not bear a load of 3000 kgf. Thus it is necessary to have an appropriate proportion of sawdust in the composite.This values are quite higher than the commercial and other experimental brake pads.

Sample A

Sample B

Sample C

Fig 5.2.1(a) Tested Samples of A, B and C respectively

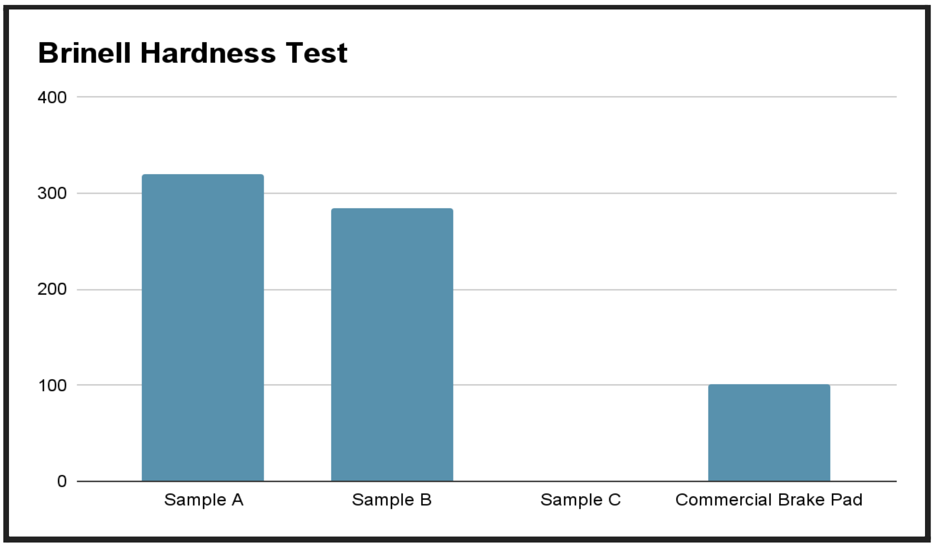


Fig 5.2.1(b) Chart representing comparison of Hardness of all samples

5.2.2 Density Test

From Table 5.2(a) it is also observed that the density of the sample changes with the change in the proportions of Sawdust and silicon carbide in the composition.The density of the sample was calculated by dividing mass of each sample friction material with its volume calculated using solidworks. The volume of friction material sample was taken as 21.334 cm^3. The change in density can be attributed due to the difference in the density of Sawdust from the other raw materials. The sample B having Moderate Percentage of Sawdust and Silicon Carbide has the modest density value which is as a result of appropriate combination of Sawdust and Silicon Carbide particles with other Raw materials creating more homogeneity in the entire phase of the composite body. The density values of the samples are quite high in comparison to commercial brake pads.

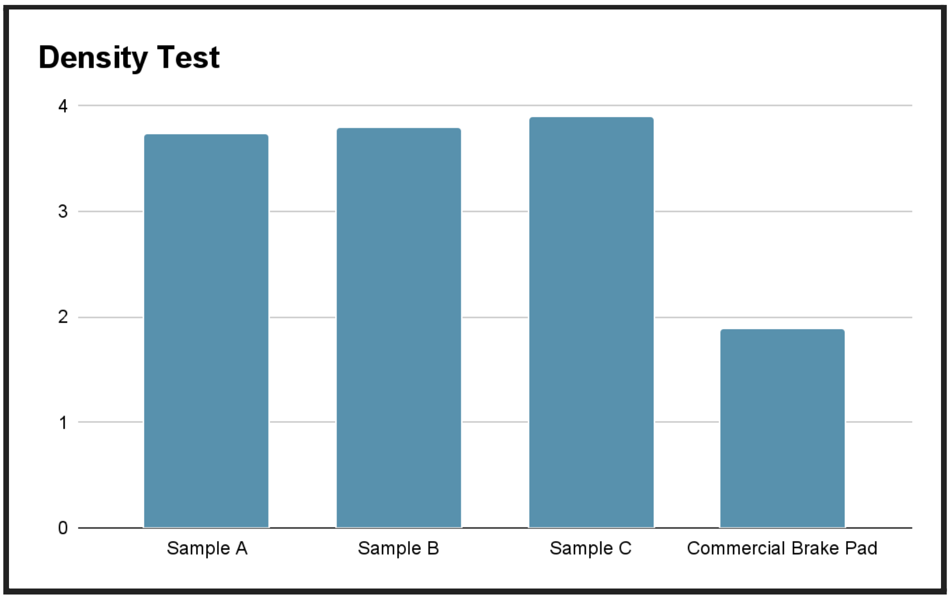


Fig 5.2.2 Chart representing comparison of Density of all samples

5.2.3 Water Absorption Test

From Table 5.2(a) it is observed that the water absorption rate decreases as the sawdust proportion increases and silicon carbide proportion decreases which can be attributed to the decrease in the pore size due to increasing density. These results are consistent with the samples A, B and C. It can be seen from the result that sample C having the highest sawdust proportion gave the best property as a result of a very good dispersion of sawdust particles which led to a better interfacial bonding of the Phenolic resin and the sawdust particles. The water absorption rate values of Sample B and C are much better than the value of commercial brake pads[25].

Fig 5.2.3(a) Samples for Water absorption

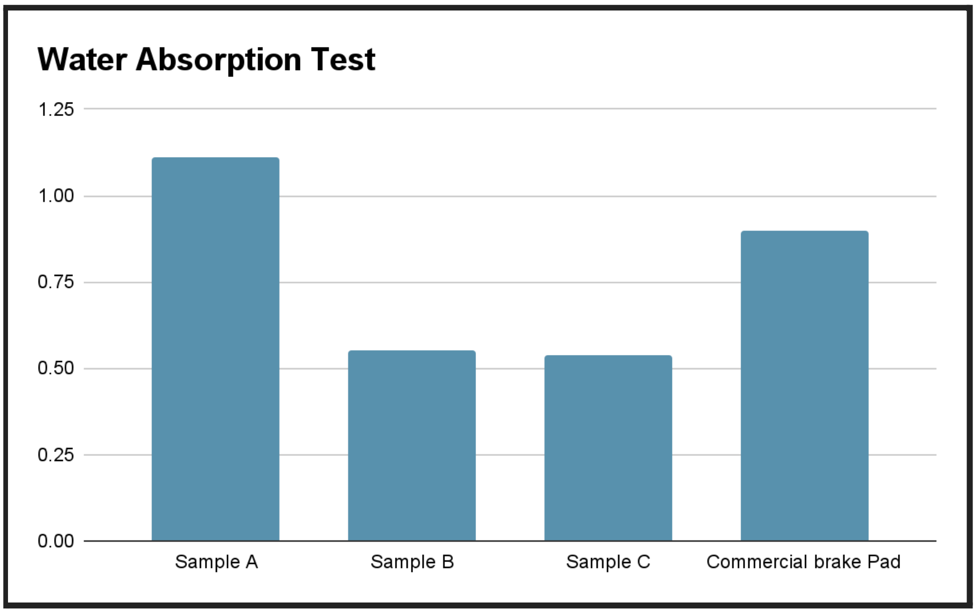


Fig 5.2.3(b) Chart representing comparison of water Absorption of all samples

The above Performed test and research indicates that sample B having appropriate composition of all the raw materials have the properties comparable to the commercial brake pads. A comparison of the results of the properties of developed sawdust brake lining and commercial brake pad (asbestos based) is shown in Table 5.2(b)

TABLE 5.2(b) :-Summary of result findings compared with asbestos based brake pad

S/N	Property	Commercial Brake pad (asbestos based)[2]	Experimental Brake Pad (sawdust based)
1	Weight (gm)	250-300	181
2	Hardness(HB)	101	284
3	Density	1.89	3.74
4	Water Absorption (%)	0.9	0.55

5.3 Bill of Material

TABLE 5.3 :- Bill of Material

Sr No	**Components**	**Quantity**	**Cost/piece(kg)**
1	**Backplate**	**14**	**200**
2	**Graphite Powder**	**1 kg**	**100**
3	**Silicon Carbide**	**1 kg**	**130**
4	**Brass Powder**	**500 gm**	**125**
5	**Phenolic Resin**	**500 gm**	**100**
6	**Sawdust**	**1 kg**	**Nil**
	TOTAL		**3255**

Chapter 6

Conclusion

From the Project the conclusion is made that the use of Non-Asbestos based brake pads is the need of the market. The overall cost of fabrication of brake pad can be reduced through utilization of cheap materials like industrial waste of Saw Dust Composites. All the tests have been conducted on the fabricated brake pad to ensure that it fulfills all the necessary requirements to replace Asbestos based brake pad in commercial vehicles. From the observation and discussion of this research work the following conclusions can be made:

1. Hardness and water absorption of the produced samples decreases with decreases in silicon carbide composition and increase in sawdust composition whereas Density of the samples increases with increase in sawdust composition
2. The sample B of Sawdust Composite had 55% and 17% weight percent of sawdust and silicon carbide gave the best properties out of all the 3 different compositions.
3. Hardness and Water Absorption Rate of sample B is much better than the commercial asbestos based brake pad .
4. Based on the above test properties of these brake pads composites using saw dust as reinforcer and Phenolic resin as Binder along with Silicon Carbide as abrasive can be effectively used as an alternative to existing Asbestos brake pad composites.

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