OPTIMIZATION OF BRAKE PAD USING COW HORN AS THE BASE MATERIAL

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DEPARTMENT OF INDUSTRIAL ENGINEERING

FACULTY OF ENGINEERING

UNIVERSITY OF BENIN

BENIN CITY

APRIL, 2024

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A DESIGN AND OPTIMIZATION PROJECT IS SUBMITTED TO THE DEPARTMENT OF INDUSTRIAL ENGINEERING, FACULTY OF ENGINEERING, UNIVERSITY OF BENIN, BENIN CITY, IN PARTIAL FULFILMENT OF THE AWARD OF BACHELOR OF ENGINEERING (B.Eng) DEGREE

APRIL, 2024

CERTIFICATION

This is certify that this fabrication work was carried out by **EKHORAGBON ENDURANCE** of the department of industrial engineering, faculty of Engineering, University of Benin, Benin city, Edo state. In accordance with the rules and registration of the University Benin for the award of Bachelor's Degree In industrial Engineering.

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DECLARATION

I, **EKHORAGBON ENDURANCE** declare that optimization of brake pad using cow horn as the base material is own work and that all source that I have used or quoted have been acknowledge by means of complete reference and that this work has not been submitted before for any other degree at any other university.

…………………………………..   …………………………………..

EKHORAGBON ENDURANCE   **DATE**

DEDICATION

This research work is dedicate to god almighty for the gift of life for making it possible for me to get this level of my academic pursuit, it is also dedication to my ever supportive parents and friend for their relentless support and sacrifice toward me.

ACKNOWLEDGEMENT

I give thanks to God almighty for the gift of life and his protect ion over my entire family. I am sincerely grateful to my supervisor, Engr. E. EBOJOH, Sir I am grateful for your patience, your support, your tolerance and your guidance on this project.

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ABSTRACT

The development and improvement of organic brake pads is the main goal of this project, which makes use of a special composite made of coconut shells. cow horn, graphite. and epoxy resin. Minitab 17 sonware is used for the optimization process to develop tests that will improve the brake pad's performance characteristics considering the composite matrix.

The project begins with the collection and preparation of coconut shells, followed by the incorporation of bone ash. graphite, and epoxy resin into a matrix. The synthesized material is then subjected to a series of comprehensive tests to evaluate its performance. The optimization phase of this projeet employs Minitab 17 software for designing experiments that systematically vary material composition and processing parameters to maximize performance. The software facilitates the identification of optimal combinations of coconut shell. bone ash, graphite, and epoxy resin proportions, as well as curing conditions, to achieve superior hardness, frictional properties. and resistance to water absorption.

The results shown that the optima component show consist of 36% coconut shell, 25% cow horn. 22% graphite, and 17% epoxy which would give friction coefficient of 0.5 and water absorption rate of 0.02 having an overall desirability of 0.99.

Here, the composite desirability (0.9963) is close to 1, which indicates the settings seem to achieve favorable results for all responses as a whole. The outcomes of this study have the potential to revolutionize the automotive industry by providing a sustainable and high-performance alternative to conventional brake pad materials, characterized by improved hardness, frictional propertics, and moisture resistance.

CHAPTER ONE

INTRODUCTION

1.1 Background of study

Materials are fundamental to all areas of modern life and technological advancement. Many modern technologies demand materials with unique combinations of properties that cannot be achieved using traditional metal alloys. This is particularly evident in the automotive industry, where materials like ceramics and polymers are often required (Country, 1991). One example is the brake pad, a critical component of the braking system, which must deliver high and stable friction under varying temperatures, loads, and wear conditions. Brake pad materials are embedded in the disc during the bedding process and must wear evenly while maintaining consistent performance. Issues such as seizure, excessive wear rates, and macroscopic fracture must also be avoided (Eriksson, 2000).

Brake pads function by converting the vehicle's kinetic energy into thermal energy through friction. Positioned within the brake calipers, the pads face the rotor, and when hydraulic pressure is applied, the caliper presses them against the rotor to slow or stop the vehicle. As the brake pads heat up during this process, they transfer material onto the rotor surface, creating the necessary friction. Historically, asbestos fibers were the dominant base material in brake pads and linings due to their durability and heat resistance (Sligleg & Miscwe, 2001). Asbestos was widely used in the construction and friction material industries beginning in the 1920s. However, due to its adverse effects on human health, non-asbestos organic (NAO) materials have since become the preferred alternative (Potash *et al.*, 2004; Stachowiak, 2004; Gurunath & Bigwe, 2007; Gramguly & George, 2007; Ibhodobe & Dagws Multi, 2009).

Today, the automotive industry aims to develop components that offer low fuel consumption, safety, environmental friendliness, convenience, and maximum efficiency (Far Sani & Shokuhfas, 2011). Despite its beneficial properties—such as sound absorption, heat and fire resistance, and low cost—asbestos is being phased out from applications where its dust could pose a health hazard (Elakhame *et al*., 2014; Roubic *et al*., 2008). This has prompted researchers to explore alternative materials such as baristas, mica, and cashew fiber for use as fillers in brake pad formulations (Chan & Stachowiak, 2004; Hee & Filip, 2005; Mohanty & Chugh, 2007).

Recent trends in scientific and engineering research focus on utilizing agricultural and industrial waste as alternative raw materials. This strategy not only reduces production costs but also contributes to environmental sustainability and foreign exchange earnings (Bienia *et al*., 2005; Aigbodun *et al*., 2013). One such promising material is cow horn, an agricultural waste product abundantly available in tropical regions. Cow horn particles exhibit desirable properties for brake applications, including high hardness, wear resistance, good acoustic insulation, and resistance to combustion and microbial degradation (Singh & Bhaskar, 2013).

According to Onyeneke and Anaele (2014), reliance on asbestos for brake pad and lining production increases manufacturing costs, which may ultimately affect retail prices. However, integrating local agricultural and industrial waste can significantly lower costs while meeting the required mechanical and chemical performance standards for automotive brake systems.

1.2 Statement of problem

Conventionally the use of asbestos for brake pad production poses a big threat to the human health because of it effect to human, asbestos dust during wearing can cause health related issues like cancer.it is important for a suitable replacement, the use of cow horn therefore ensure a safe and a healthy environment well as reducing cost. Asbestos has simple physical mechanical and biological properties.

1.3 Aim and Objectives

Aim

The aim of this project is to produce and optimize an automobile brake pad using cow horn as the base material as well as carrying test on its physical and mechanical test on the brake pads.

Objective

1. To determine the mixture ideal composition for making brake pad.
2. To develop mixture design matrix using expertise (minitablet).To produce the brake pad for individual runs.
3. To test for mechanical and morphological properties of the brake pad.
4. To produce brake pad with the optimal composition.
5. To achieve this aim, the object will be pursued to wind using cow horn and other organic material.
6. To create brake pad that prioritize the health and safety of the manufacturing personnel and the end user thus eliminating the harmful substance.

1.4 Scope of study

This research project is to develop brake pad using cow horn as the base material, cow horn, filler graphite and epoxy resin.

1.5 Significance

i. Asbestos brake pad known to have effect on human causing cancer of the lungs and the brain.so the use of cow horn eliminate that effect on humans ensuring a safe and healthy environment.

ii. Cow horn reduces the cost of expense in production as well as reducing the selling price of the brake pads to vehicle owners.

iii. The result from the properties of the developed cow horn brake pad and its optional friction formulation will serve as data, journal for reference material for researchers and industrialist.

iv. To produce a brake pad of optimal performance.

v. Its helps to create means of foreign exchange and serve as medium of employment.

CHAPTER TWO

LITERATURE REVIEW

2.1 Disc brake

In most disc brake systems, a set of brake pads is pressed against a rotating disc, generating heat through friction at the interface. This heat is then dissipated into the vehicle and surrounding environment before gradually cooling down. A basic disc brake setup includes terminology commonly used to describe its parts. The pad located closer to the center of the vehicle is known as the inboard pad, while the one farther away is the outboard pad. The side of the disc facing the vehicle is referred to as the inboard face, and the side facing outward is called the outboard face. Each pad also has an inner edge (closer to the center) and an outer edge (closer to the disc's rim).

A typical disc brake assembly consists of several major components: the brake disc (or rotor), pads, an underlayer, a back plate, shims, and the caliper. The part of the pad that first contacts the disc during braking is called the leading edge, while the part that leaves the disc last is known as the trailing edge. Disc brakes function by slowing the wheel's rotation through friction, created when brake pads are forced against the disc using calipers. This system converts kinetic energy into heat, which helps stop the vehicle.

Brake discs are usually made from cast iron, though in some high-performance applications, they may be constructed from advanced materials like reinforced carbon-carbon or ceramic matrix composites. These discs are attached to the wheel hub or axle. The caliper, which houses the brake pads, applies pressure through mechanical, hydraulic, pneumatic, or electromagnetic means. As the pads press against both sides of the disc, friction slows and eventually halts the wheel's movement. However, excessive heat buildup can reduce braking efficiency—a condition known as brake fade.

The development of disc brakes began in England in the 1890s. Frederick William Lanchester patented the first automotive caliper-type disc brake in 1902, which was successfully implemented in Lanchester vehicles. Compared to drum brakes, disc brakes are more effective because they dissipate heat more efficiently. A typical disc brake consists of a cast iron disc mounted to the wheel hub and a fixed caliper, which is usually attached to a stationary component like the axle casing or stub axle. The caliper is generally made of two parts, each housing a piston. Friction pads are placed between the pistons and the disc, held in place by pins and spring plates. Fluid passages within the caliper allow hydraulic brake fluid to move in and out of the pistons, and include additional passages for bleeding air from the system.

Disc brakes handle the majority of the work in stopping a vehicle. However, problems such as scarring can occur if the brake pads are not replaced once they're worn out. Cracking is another issue, particularly with drilled discs, which may develop cracks around the edges of holes due to uneven thermal expansion under extreme conditions. Although surface rust is common on cast iron discs, it typically doesn't affect performance. Occasionally, brakes may produce loud noises or high-pitched squeals, often caused by vibrations or resonance between the pads and discs (a phenomenon known as force-coupled excitation). Despite the noise, this squealing usually does not impact the braking effectiveness.

Problem occurred in disc brake

Brake discs are typically made from gray cast iron and can become damaged in a few common ways: scarring, cracking, warping, or excessive rusting. In many cases, repair shops may choose to replace the discs entirely rather than repair them, especially when the cost of a new disc is lower than the labor cost of resurfacing the original. However, replacing the discs isn't always necessary unless the disc has worn down to the manufacturer's minimum thickness limit or, in the case of ventilated discs, if severe rust has developed between the internal vanes.

Many major vehicle manufacturers recommend a process known as disc skimming (referred to as "turning" in the U.S.) to resolve problems like lateral run-out, vibrations, or brake noise. This procedure involves using a brake lathe to shave off a thin layer from the disc surface, removing minor imperfections and restoring even thickness. Skimming the discs when appropriate can help extend their usable life and improve braking performance.

Braking systems function through friction—hydraulic pressure forces brake pads against a cast iron disc (in disc brakes) or brake shoes against the inside of a cast iron drum (in drum brakes). When a vehicle slows down, the load shifts toward the front wheels, increasing the braking demand on them. The tangential force generated at the interface between the pad and the outer face of the rotor (FTRO) is equal to that on the inner face (FTRI), assuming both surfaces experience the same normal force and use the same friction materials. Advantage of disc brakes

i. Disc brakes requires less effort to stop the vehicle compare to drum brakes

ii. It also generates less heat compare to drum brakes for the same brakes torgue.

iii. It can also ease the maintenance as disc brakes is outside the wheel rim.

iv. It is the safer than drum brake in hand braking condition.

v. If worn out brake shoe are not charged at proper time, it can cut the brake drum

2.2 Disadvantage of disc brakes

i. They are more expensive when compared to drum brakes. The disc brake assembly has more part and much complex to them of drum brakes

ii. Whenever air remain in disc brake system. It can cause accident as the brake will not work effectively.

2.3 Drum brake

A drum brake is a brake that uses friction caused by a set of shoe or pad that press outward against a rotating cylinder shape part called a brake drum. The drum brake means a brake in the shoes press on the surface of the drum, most drum brake are used in heavy trucks and few cars, dirt bikes.

Drum brake are mostly applied to the rear wheels. Since most of the stopping force is generated by the front brake of the vehicle and the heat generated in the rear is less. They are mostly fitted as the parking (emergency)brake even when the rear wheel uses disc brake for the main brakes.

2.4 Drum brakes component

Backing plate: it serves as the base component which provides a base for the components. The backing plate also increase toughness of the whole setup support the housing and protect it from foreign material like dust, during a braking action, it asbestos the torgue so it also known as the torgue plate.

Brake drain: it’s made up generally from a special type of iron that is heat conductive and wear resistance it rotates the wheel and axle. When driver applies brake there is a lining pushes radially out against of the drum, the friction either slow or stop rotation of the wheel and axis.

Lining: it must be resistant to heat and wear and have a high friction co-efficient unaffected by fluctuations in temperature and humidity.

Brake shoe: these are major made up of two pieces of steel welded together. The friction materials are riveted to the lining table or attached with adhesive. The crescent shaped piece is the wed and contain holes and slots in different shape for return springs.

Wheel cylinder: one wheel cylinder operates the brake on each wheel. Two pistons operated operates the shoes one out each end of the wheel cylinder. the leading shoe is known as the primary shoe.

2.5 Structure of Drum brakes

Drum brakes are brakes system with brakes drum (rotors) which rotates with the wheels inside. each drum is brakes shoe fitted with brakes linings (friction material). Piston (pressure mechanisms) press against the drum from the inside to generate braking force, thus making it possible to decelerate and stop the vehicles.

2.5.1 How drum brakes work

When the driver steps on the brakes pedal, the power is amplified by brakes booster(servo.system) and changed into hydraulic pressure (oil pressure) by the master cylinders. The Pressure reaches the brakes on the wheels via tubing filled braking oil (brakes fluids). The delivered pressure pushes the piston the brakes of the wheels. The pistons press the brakes lining, which are friction material, against the inside surface of the brake drums which in turn decelerate the wheels, thereby slow down and stops the vehicle.

2.5.2 leading/traiting shoe type drum brake

Leading shoe is a term referring to the shoe that moves in the direction of rotation when it is being pressed against the drum. The other shoe is called the traiting (secondary)shoe, the leading shoe is pressed in the same direction as the rotation of the drums and this rotation helps to press the shoe against the drum with greater pressure for the stronger braking force. This is called the servo effect (self – boosting effect) which realize the powerful braking force of the drum brakes.

Structurally it has a wheel cylinder housing a piston with which hydraulic pressure is generated to push the shoes against the drum liner surface. The two shoes function a way they both become either the traiting shoe or leading shoe depending on whether the vehicle is travelling forward or backward, This is because drum brakes generate the same braking force in either direction. This type is used for the rear brakes of passenger car.

2.6 Brakes shoe

The brake shoe is the one of the key parts of an automobile which is directly related to the safety of driver, a brakes shoe is part of a braking system that caries the braking lining in the drum brakes used on the automobile or the brakes block in train brakes and bicycle brakes. A Brakes shoe is also known as advice which can be slow down railed cars. Brakes shoe and lining are riveted or glued to each other when we applied a brake, The shoe move and presses the lining against the inside of the drum between the lining and drum friction is produced the provides the braking effort. In modern vehicle, disc brakes are generally used but due to more effective as working of parking brakes we use the drum brakes instead of disc brakes.

2.7 Braking system studies

A braking system typically consists of two primary mechanisms: an automatic braking system and a pneumatic bumper system. These systems are commonly installed in four-wheeled vehicles and are managed by an intelligent electronic control unit known as the "automatic braking with pneumatic bumper system using proximity sensors" (Sagar B. Pawar *et al*., 2018).

According to Akshay Kumars *et al*. (2014), the implementation of electromagnetic brakes is crucial for enhancing the safety of heavy vehicles. These brakes aim to reduce the likelihood of road accidents by minimizing brake failure. Additionally, they contribute to lower maintenance costs by reducing wear and tear on traditional braking components.

Braking systems are mechanical devices that absorb kinetic energy to slow down or stop moving systems, typically through friction between brake components. The highest achievable deceleration, known as peak force, is a key performance measure. However, during regular braking, the system can generate high temperatures, which may lead to failure if not properly managed.

Before applying design modifications, researchers investigate various contact models to analyze the interaction between the brake pad and disc. Studies reveal that different modeling approaches result in significantly varied contact pressure distributions, highlighting the importance of accurate modeling for optimizing brake performance. This insight assists engineers in achieving more uniform pressure distribution, improving pad longevity, and enhancing customer satisfaction.

Rajendra Pohane and R.G. Choudhari (2014) developed a three-dimensional finite element model (FEM) to conduct both static and transient structural analyses of brake pads and discs. Their research compares the performance of solid and ventilated discs using identical materials and boundary conditions, evaluated through general-purpose FEM software. The study focuses on evaluating von Mises stresses and thermal stresses at the disc-pad interface.

M. Nouby, D. Mathivanan, and K. Srinivasan (2014) introduced an approach that combines finite element analysis with statistical regression to examine factors influencing brake squeal. Complex eigenvalue analysis (CEA) is used to predict unstable frequencies in braking systems. The FEM model is validated through experimental tests, and a relationship between brake squeal and brake pad geometry is established. Various geometric features—such as Young's modulus, back plate thickness, chamfer distance, slot width, and slot angle—are analyzed using the Design of Experiments (DOE) method. A mathematical prediction model is developed based on the most influential variables, and validation experiments confirm its accuracy.

Further research by V.M.M. Thilak, R. Krishnaraj, Dr. M. Sakthivel, K. Kanthavel, Deepan Marudachalam M.G., and R. Palani explores alternative lightweight materials for brake rotors. Their study evaluates hybrid composite materials, such as aluminum metal matrix composites and high-strength glass fiber composites, for their friction and wear properties. Transient thermoelastic analysis of disc brakes during repeated braking applications shows that S2 glass fiber is a suitable material. All analyzed stress values fall within acceptable limits, suggesting the material's viability for effective braking operations.

2.7.1 Types of braking system

Mechanical braking system

i. Drum braking

ii. Disc braking

iii. Band braking

iv. Pawl and Ratchet braking Electrical braking system

v. Dc injection types braking

vi. Eddy current braking

vii. Sharing dc bus types braking

viii. Regenerative braking

ix. Dynamic resistor types braking

Mechanical braking is commonly used in scooters, motorcycles, and other light motor vehicles where only a small amount of braking power is required. It also plays an essential role in power transmission systems, material handling, and various industrial applications. This type of braking system delivers force directly to the axle or wheel to gradually bring a moving system to a halt. Unlike electrical braking, mechanical braking primarily relies on a pedal mechanism. When the brake pedal is pressed, it causes the brake shoes to expand outward, pressing against the drum connected to the wheel. This friction slows down the wheel, eventually stopping the vehicle. Once the pedal is released, the brake shoes return to their original position through the action of a return spring.

In contrast, electrical braking reduces the speed of machines by manipulating magnetic flux and torque. It is commonly used for functional braking, allowing for smoother speed control in machines and systems. Electrical braking is user-friendly and provides comfortable operation, but it is not suitable for emergency or parking brake functions.

The operation of electrical braking systems relies on electromagnetic force (emf) acting on the brake components. When activated, electric current from a battery energizes an electromagnet mounted on the brake plate. This generates a magnetic field that triggers a cam mechanism, causing the brake shoes to expand and press against the wheel or drum. As a result, the vehicle or machine is brought to a stop through electromagnetic braking action.

2.7.2 Brake fade

It used to describe one of the conditions which result in reduced brakes torgue /line pressure gain for a given vehicle. There are also heat fade which result from change in the brake parameters caused by the energy dissipated at the lining drum interface; water fade also occurs as a result of the reduction in the lining coefficient of friction due to water contamination and washout describes fade due to any other cause (percy 1952, fleet owner 1966).

The brake torgues depends on the lining friction coefficient, the line pressure and the geometry of the brake. Heat fade can occur in two ways thermal distortion of the brake geometry and also change in the apparent coefficient of friction of the lining due to high temperatures. Heat fade is the most apparently influential, however there is no comparision between the two the temperature is controlled in the brake and towards developing fade resistant lining material (Weintraub & Bernard,1968, jacko *et al* 1968).

2.7.3 Fade and pedal effort

Whenever there is a decrease in the lining coefficient of the friction as a decreased gain in the system, thus greater pedal effort will be required to produce the same vehicle deceleration.

Gain is the as a ratio of an input to output variable or as a ratio of an output to input variable. Thus, it can have a pedal force/pedal force gain in g’s per pound.

It the ability to brake to reduce the vehicle speed up to a possible stop, to maintain a certain speed of the descending vehicle on a slope or to keep the vehicle on a slope.

E brakes =VW/BE *100

Where E brakes is the brakes efficiency %

VW is the total vehicle weight (Ibf) BE is the brakes effort (Ibf)

Brakes efficiency =divide the total vehicle weight by the brake effort, then multiply by 100

Brakes distance and stopping distance, the distance from the moment the driver presses the brake pedal to the moment the stops.

Stopping distance is the time taken until the driver to presses the brakes pedal the response time of the brake system and the distance travelling during the stopping time of the vehicle.

2.8 Principle of disc brakes

Disc brakes operate based on Pascal's Law of fluid pressure transmission. This principle, introduced by French mathematician Blaise Pascal, states that when pressure is applied to a confined, incompressible fluid, it is transmitted equally in all directions, maintaining a consistent pressure throughout the system. In simpler terms, applying pressure at one point in a static fluid results in an equal increase in pressure at all other points within the container. A common example of this is a hydraulic jack, where applying a small force at one end can lift a much heavier load due to the equal distribution of pressure.

In a disc brake system, when the brake pedal or lever is pressed, the connected push rod moves the piston within the master cylinder. This action compresses a return spring inside the master cylinder bore, generating pressure in the reservoir. A primary seal allows brake fluid to pass into the brake hoses, while a secondary seal ensures that the fluid remains directed toward the caliper.

The pressurized fluid travels through the brake hoses and enters the cylinder bore of the caliper assembly, where it forces the caliper pistons outward. As the piston moves, the sealing ring flexes in a rolling motion along with it. The caliper pistons then press the brake pads against the rotating disc (or rotor), generating friction that slows down or stops the disc's motion, and in turn, the vehicle.

When the brake is released, the piston ring helps retract the caliper piston back into the cylinder bore, returning both to their original positions. Simultaneously, the retraction spring moves the brake pads away from the disc. The return spring in the master cylinder also pushes the master cylinder piston back to its initial position, allowing the brake fluid to flow back into the reservoir through the hose and cylinder bore, resetting the system for the next operation.

2.8.1 Braking system and it’s classification

Brakes may be broadly described as the ones using friction, pumping, or electromagnetic types. A brake may be used for several operations and machines to generate necessary braking force to slow down a vehicle.

2.8.2 Frictional Braking System

Frictional brakes are the most commonly used type of braking systems and are generally categorized into two main types: "shoe" or "pad" brakes, which involve direct contact with a wear surface, and hydrodynamic brakes, such as parachutes, which use resistance within a fluid medium and do not rely on a physical wear surface. Although hydrodynamic brakes also function through friction, the term "friction brake" typically refers specifically to pad or shoe-based systems and excludes hydrodynamic types.

Friction (pad/shoe) brakes usually involve a rotating component that comes into contact with a stationary friction material. Common designs include band brakes, where shoes contract around the outer surface of a rotating drum; drum brakes, where shoes expand outward to press against the inner surface of a rotating drum; and disc brakes, where pads clamp onto a rotating disc. Although alternative brake configurations exist, these are less frequently used.

Drum Brakes: In drum brake systems, braking is achieved when brake shoes press against the inside surface of a rotating drum attached to the wheel hub. While this type of brake was common in older vehicles, it is still found today—particularly on the rear wheels of budget-friendly vehicles—due to its lower manufacturing cost. However, drum brakes tend to overheat more easily and wear out faster compared to modern disc brake systems.

Disc Brakes: Disc brakes are designed to slow or stop the rotation of a wheel using a brake disc (or rotor), which is usually made from cast iron or ceramic and is mounted to the wheel or axle. Brake pads, which are held within a caliper, are pressed against both sides of the disc through mechanical, hydraulic, pneumatic, or electromagnetic force. The friction generated between the pads and disc effectively slows or stops the wheel's rotation.

2.8.3 Pumping Braking System

Pumping brakes are commonly used in systems where a pump is already integrated into the machinery. For instance, in an internal combustion piston engine, braking can be achieved by cutting off the fuel supply, allowing the engine's internal pumping resistance to act as a braking force. Some engines are equipped with a special valve system known as a Jake brake, which significantly increases internal resistance and enhances braking power. Pumping brakes can either dissipate energy as heat or function as regenerative brakes, where the energy is stored in a pressure reservoir known as a hydraulic accumulator.

2.8.4 Electromagnetic Braking System

Electromagnetic brakes are frequently used in systems where an electric motor is already present. For example, many hybrid gasoline-electric vehicles utilize the electric motor not only to charge the battery but also as a regenerative braking system. In some diesel-electric locomotives, electric motors are used to produce electricity during braking, which is then dissipated as heat through resistor banks. Certain vehicles, like some city buses, may not have a main electric motor but instead use a secondary braking system called a "retarder," which operates like a generator with an internal short circuit to create resistance. Variations of these systems include eddy current brakes and electromechanical brakes—the latter being friction brakes activated by magnetic force, though commonly grouped under the term "electromagnetic brakes." Electromagnetic braking works by inducing an electromagnetic field that generates resistance, converting motion into either heat or electricity. In contrast, traditional friction brakes rely on the contact between two surfaces to decelerate the vehicle in a controlled way.

2.8.5 Need for safety brakes

1. Thruster brake system can’t hold the load drop in case of failures of couplings.

2. Thruster brake system can’t provide adequate braking force due to improper brake shoe alignment.

3. Thruster brake system is not able to hold the load if the gear box gets failure as thruster

brake is installed before the gear box.

4. if the connecting shaft is broken, the thruster brake system is not able to hold the load drop.

2.8.6 Basic component in a braking system

The brake system is composed of the following basic components: the energy supplying device, the control device, the transmission device the brake and additional retarder device, brake line (connecting different devices).

2.8.7 Brake parameter.

Brakes are commonly characterized based on several performance aspects:

Peak Force – This refers to the highest deceleration a brake can achieve. Often, this force can exceed the tire's traction capabilities, potentially causing the wheels to skid.

Continuous Power Dissipation – Since braking generates heat, brakes are designed to handle a certain amount of energy over time without overheating. The maximum rate at which a brake can dissipate heat without failing is its continuous power dissipation, which is influenced by factors like air temperature and airflow for cooling.

Brake Fade – As brakes heat up, their performance can decline, a phenomenon known as brake fade. Some brake types are more prone to this issue than others, but effective cooling can help reduce the impact of fade.

Smoothness – The consistency of braking force is important. Brakes that grab, pulse, or vibrate can lead to uneven stopping and skidding. This is especially critical in vehicles like trains, where low traction and lack of anti-skid systems can cause increased wear and discomfort.

Braking Power – A brake may be considered "powerful" if it produces a strong braking effect with minimal pedal force. However, this does not necessarily correlate with peak force or long-term performance and can sometimes be misleading.

Pedal Feel – This describes how the brake response feels to the driver, particularly how braking force increases with pedal movement. It is influenced by hydraulic or mechanical displacement and other design features.

Drag – When the brakes are not in use, some systems still experience slight contact or resistance due to system compliance or insufficient retraction of the brake pads from the disc or drum.

Durability – Friction brakes wear over time and need regular maintenance. This includes replacing brake pads or shoes and possibly resurfacing or replacing rotors or drums. Some high-performance materials offer stronger braking but may wear out faster.

Weight – Brakes add extra mass to a vehicle, often as unsprung weight on the wheels, which can negatively affect traction and handling. The term "weight" might refer to the brake components alone or include supporting structures as well.

Noise – While brakes usually produce some sound during operation, they can also generate louder noises like squealing or grinding, which may be distracting or indicate a maintenance issue.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter defines the materials and experimental procedures, which include the development of the Experimental Materials and method, the materials preparation, design of the mold, data analysis strategy for both production and testing stages, and the sequential execution of the experimental protocol. The focus of this concept is the production and optimization of a brake pad using coconut shell as the fundamental material, along with supplemental elements such as graphite, cow horn, and epoxy resin that act as binding agents.

3.2 Materials

The materials used in this production were all locally sourced. The materials were carefully selected to give the desire service requirement of the composite material. These materials include; Coconut shell locally source from home gowned coconut trees, graphite powder sourced from a factory located at Delta State, Nigeria, Epoxy resin from a chemical company in Port-Harcourt, cow horn from an abattoir in Benin City, Edo State.

S/N	MATERIAL	FUNCTION
1	Coconut Shell	Base Material
2	Cow Horn	Filler and friction dust
3	Epoxy Resin	Binding Agent
4	Graphite	Improves the friction coefficient

The starting phase of this project involved the collection of coconut shell from locally grown coconut trees. The shells were carefully dried to remove the moisture content in it and then grinded into fine powder using a grinding machine from a vendor at uselu market. The coconut shell powder was a key material for the brake composition. Cow horn was gotten from an Abattoir located at Ikpoba Hill, Benin City, Edo State. Graphite powder, another vital component used to enhance the friction properties was sourced from a factory in Warri, Delta State. The Graphite was procured in solid form and was grinded to powdered form. Epoxy resin and its hardener were essential binding agents, they were purchased from a chemical dealer in Port-Harcourt.

Figure 3.1 Broken coconut shell

Figure 3.2 Grinded coconut shell

Figure 3.3 Grinded Cow Horn Figure 3.4 Grinded Graphite

Figure 3.5 Epoxy Resin and the Epoxy Hardener

3.3 Tools and Equipment

The tools and equipment used for this production were gotten from the Production engineering laboratory and Foundry Shop, University of Benin. The tools/equipment are listed below;

- **Compression Mold and Die:** The mold is a critical tool in compression molding. It consists of two halves, a cavity, and a core, that define the shape and dimensions of the final part. The mold is typically made of metal, such as steel to withstand the high pressures and temperatures involved in the process. The mold was designed using 40kg mild steel. The closed sizes of mold; 255mm long, 160 mm wide and 50mm high. To get a good surface finish and a properly contoured mold surface, the mold was polished with abrasive papers, after polishing, it was greased with engine oil to prevent it from rusting.

Figure 3.6 Casting mold

➢ **Digital Measuring Scale:** This is a fundamental tool for accurately measuring and achieving the precise quantities of materials used. The measuring scale was used to take weight of all material used in grams (g), all the grinded samples and the weight of all the produced sample brake pad.

Figure 3.7 Measuring Scale

- **Measuring Cup:** The cup was a plastic container used in scooping the grinded materials to be measured on the measuring scale.

- **Mallet:** A strong cast iron was used as the mallet to hit the die and perform the compression that allows the sample brake pad to fall out of the mold.

- **Spatula:** This was used to properly mix the component together.

- **Bucket:** This was used to perform the water absorption test. The bucket served as a means of storage for the brake pad to be immersed in water for 24 hours.

Figure 3.8 Brake pad sample immersed in water

➢ **Inclined Plane Apparatus:** The inclined plane apparatus is commonly used in physics experiments to study various aspects of motion and forces, including friction. When studying friction on an inclined plane, you typically set up an experiment where an object moves or is held stationary on an inclined surface. The inclined plane apparatus was gotten from the mechanical engineering laboratory, Faculty of Engineering, University of Benin. It was used for the friction tests for all produced brake pad sample.

Figure 3.9 Inclined Plane Apparatus

3.3 Design of Experiment

In the design of experiment, mixture is defined as a product that is formed by mixing two or more individual distinct ingredients, known as the mixture components. In some cases, the properties of the mixture are only dependent on the components and their proportion, and not on the amount of mixture. There are four common designs used for mixtures: Simplex Lattice, Simplex Centroid, Simplex Axial and Extreme Vertex.

The Extreme Vertex design was used in this experiment. The Extreme Vertex design is used when there are constraints on one or more components of the mixture (such as a minimum or a maximum concentration of a component) or when there is a linear constraint on several components. In this type of design, the constraint defines the area of the factor space that can be used, usually with the boundary points used as the default run settings.

A mixture experimental design with four variables serving as mixture components was used in this study to plan the experiments to produce the composite specimens in which different test was carried out on. This design was chosen because it has been acknowledged by numerous researchers as the best experimental design for production formulation in the field of engineering. The components of the mixture for the formulation of the composite for the study specimens are coconut shell, cow horn, graphite, and epoxy resin.

The Minitab software version 17 was used to design the experiment and to analyze the experimental data obtained. In generating the experimental design matrix, the Minitab software utilizes the concept of randomization and the essence of this is to minimize the effect of unexplained variability in the chosen responses. In this case the response chosen is compression and unit load test. Our experimental runs were determined using the Minitab software by clicking on the stats tab, selecting Design of Experiment, selecting mixture, and then selecting create mixture design.

The Extreme Vertex design was selected with 4 selected as the number of components. In our design, the degree of lattice was selected as 1 and the number of replicates for the whole design was selected as 1. In components, our lower and upper value for each component (epoxy binder, Coconut shell, graphite, and Cow horn) was inputted. This was done for the software to give us a balanced mixture with the components varying in quantity but not exceeding the upper value or going below the lower value for each run. Under the options tab, randomize runs was deselected.

This gave us a total of 9 experimental runs.

3.3.1 Initial design

The design of the experiment was analyzed using mini tab statistical design and computational software to obtain the initial composition matrix of the components and the number of experiments to be carried out.

3.3.2 Results for: Extreme Vertices Design

Components: 4

Design points: 9

Process variables: 0

Design degree: 1

Mixture total: 10.00000

Number of Boundaries for Each Dimension

Point Type	1 2 3 0
Dimension	0 1 2 3
Number	4 6 4 1

Table 3.2 Number of Boundaries Table

Number of Design Points for Each Type

Point Type	1	2	3	4	0	-1
Distinct	4	0	0	0	1	4
Replicates	1	0	0	0	1	1
Total number	4	0	0	0	1	4

Table 3.3 Number of Design Table

Bounds of Mixture Components

	Amount		Proportion		Pseudo component	
Comp	Lower	Upper	Lower	Upper	Lower	Upper
A	3.5000	4.5000	0.35000	0.45000	0.00000	1.00000
B	2.5000	3.5000	0.25000	0.35000	0.00000	1.00000
C	2.0000	3.0000	0.20000	0.30000	0.00000	1.00000
D	1.0000	2.0000	0.10000	0.20000	0.00000	1.00000

Table 3.4 Bounds of mixture component

* **NOTE** * Bounds were adjusted to accommodate specified constraints.

Design Table

Run	Type	A	B	C	D
1	1	3.5000	2.5000	2.0000	2.0000
2	1	4.5000	2.5000	2.0000	1.0000
3	1	3.5000	3.5000	2.0000	1.0000
4	1	3.5000	2.5000	3.0000	1.0000
5	0	3.7500	2.7500	2.2500	1.2500
6	-1	3.6250	2.6250	2.1250	1.6250
7	-1	4.1250	2.6250	2.1250	1.1250
8	-1	3.6250	3.1250	2.1250	1.1250
9	-1	3.6250	2.6250	2.6250	1.1250

Table 3.5 Design Table 1

StdOrder	RunOrder	PtType	Blocks	Coconut shell	Cow horn	Graphite	Epoxy	Totals	Lower	Upper
1	1	1	1	3.500	2.500	2.000	2.000	10	3.5	4.5
2	2	1	1	4.500	2.500	2.000	1.000		2.5	3.5
3	3	1	1	3.500	3.500	2.000	1.000		2.0	3.0
4	4	1	1	3.500	2.500	3.000	1.000		1.0	2.0
5	5	0	1	3.750	2.750	2.250	1.250			
6	6	-1	1	3.625	2.625	2.125	1.625			
7	7	-1	1	4.125	2.625	2.125	1.125			
8	8	-1	1	3.625	3.125	2.125	1.125			
9	9	-1	1	3.625	2.625	2.625	1.125			

Table 3.6 Design Table 2

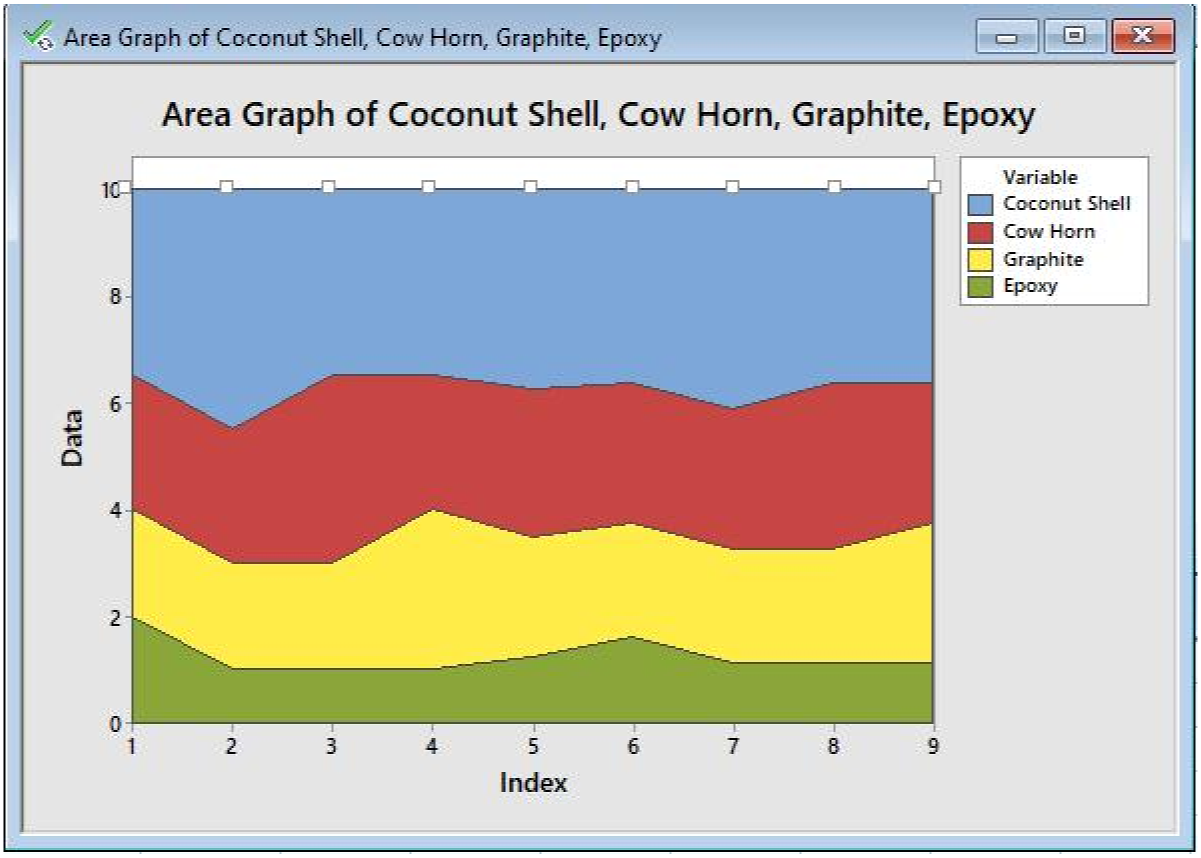

Figure 3.1 Area graph of mixture

3.4 Experimental Procedures

3.4.1 Weighing and measurement

The next step involved precise measurements using a digital weighing machine. The quantities of coconut shell powder, cow horn, graphite powder, epoxy resin, and hardener were determined based on a predefined formulation, which was developed with mini tab 17 leading the project to produce 27 samples.

3.4.2 Mixing

The coconut shell powder, cow horn and graphite powder were mixed in cylindrical plastic plate and stirred thoroughly to ensure homogeneity. Epoxy resin was gradually added to the mixture, and consistent stirring was maintained to achieve an even distribution of the resin. The appropriate amount of hardener was added following the manufacturer's guidelines together with the Minitab value for the chosen epoxy resin.

3.4.3 Molding and Shaping

A mild steel mold, weighing 40Kg, was selected for shaping the brake pad. It was meticulously cleaned and prepared for use. The formulated mixture was placed into the mold and compacted to eliminate any potential air gaps. A center punch was employed to create necessary holes and indentations in the brake pad, considering its functional requirements.

3.4.4 Curing and Quality Assurance

The newly molded brake pad was allowed to cure in a controlled environment. Curing time was up to 24hrs of natural sunlight. It was then stored at room temperature at the production foundry workshop.

Quality control measures were implemented post-curing, focusing on uniformity, dimensional accuracy, and the detection of any defects.

3.4.5 Testing and Evaluation

The brake pad underwent comprehensive testing procedures to ascertain its compliance with safety and performance standards. Tests included water absorption test, and friction test.

3.5 Water absorption Test

The purpose of this test is to determine whether the organic brake pad, made from coconut shell as the base material, can absorb water when exposed to prolonged driving in rain or water. The water absorption of the samples was tested by soaking them in both water and oil for 24 hours.

The initial weight of each sample was recorded as "$w0$" before soaking in the fluids. After 24 hours, the samples were removed from the water and oil, thoroughly cleaned to remove any residue, and then reweighed. The final weight was recorded as "$w1$". The difference between the initial and final weights for each sample was then used to calculate the absorption rate.

3.6 Coefficient of Friction

Each brake pad sample, with varying sieve sizes, was placed on an inclined plane with a known angle and a 90° wedge. The height of the wedge was adjusted to increase the angle of inclination until the specimen was on the verge of sliding down the plane. The coefficient of friction was then determined using the following equation:

Coefficient of Friction (μ) = tan Θ, where Θ is the angle of inclination.

CHAPTER FOUR

ANALYSIS AND RESULT

4.1 Introduction

This chapter shows the analysis and results of experimental method of obtaining optimality from the mechanical tests carried out on the organic brake pad produced with coconut shell as the base material.

Design of experiment on Minitab software was used to analyze the samples with the optimum property for automobile applications.

4.2 Water Absorption Test

The percentage water absorption is calculated using the formula.

$$\%W_{AB} = \frac{W_{FINAL} - W_{INITIAL}}{W_{FINAL}} \times 100$$

Where:

WINITIAL is the mass of sample before soaking in water. WFINAL is the mass of sample after soaking for 24hrs.

The result obtained from the test is showed in the table 4.1 below.

Sample	Initial Weight (g)	Final Weight (g) M2	Difference	% Water Absorption
1	90.5	125.96	35.46	0.028
2	109.5	151.81	43.21	0.027
3	98	123.64	25.64	0.027
4	112	123.70	11.7	0.0094
5	85	128.31	43.31	0.033
6	107	118.10	11.1	0.0094
7	108	120.70	12.7	0.010
8	105.5	136.49	30.9	0.022
9	922.5	111.57	19.07	0.017

Table 4.1 Water Absorption Test Result

4.3 Friction Test

ssBelow, is used to determine the coefficient of friction (μ). Coefficient of Friction (μ) = tan Ө

Where Ө is the angle of inclination.

Sample	Test result (Ө)	Coefficient of Friction (μ)
1	22	0.40

2	26	0.48
3	24	0.44
4	27	0.50
5	29	0.55
6	32	0.62
7	23	0.42
8	28	0.53
9	33	0.64

Table 4.2 Coefficient of Friction result

4.4 DESIGN OF ANALYSIS AFTER TESTING; WATER ABSORBTION RESULTS, COEFFEICIENT OF FRICTION RESULT

4.4.1 Regression for Mixtures: WATER ABSORPTION versus COCUNUT SHELL, COW HORN.

Estimated Regression Coefficients for Water Absorption (component proportions)

Term	Coef	SE Coef	T	P	VIF
COCUNUT SHELL	1.28	6.469	*	*	175632
COW HORN	-0.86	8.229	*	*	153780
GRAPHITE	-3.58	9.182	*	*	129014
EPOXY	5.25	11.419	*	*	64370
COCONUT SHELL*BONE ASH	-2.16	31.182	-0.07	0.956	308085
COCONUT SHELL*GRAPHITE	3.92	31.182	0.13	0.920	206880
COCONUT SHELL*EPOXY	-14.86	29.348	-0.51	0.702	58174
COW HORN*GRAPHITE	8.26	29.348	0.28	0.825	98462

Table 4.3 Regression Coefficients for WATER S = 0.174311

PRESS = 0.274209

R-Sq = 54.50%

R-Sq(pred) = 0.00%

R-Sq(adj) = 0.00%

Analysis of Variance for Water Absorption (component proportions)

Source	**DF**	**Seq SS**	**Adj SS**	**Adj MS**	**F**	**P**
Regression	7	0.000364	0.000364	0.000052	0.17	0.954
Linear	3	0.000177	0.000169	0.000056	0.19	0.897
Quadratic	4	0.000187	0.000187	0.000047	0.15	0.937
COCONUT*COW HORN	1	0.000013	0.000001	0.000001	0.00	0.956
COCONUT*GRAPHITE	1	0.000001	0.000005	0.000005	0.02	0.920
COCONUT*EPOXY	1	0.000148	0.000078	0.000078	0.26	0.702
COW HORN*GRAPHITE	1	0.000024	0.000024	0.000024	0.08	0.825
Residual Error	1	0.000304	0.000304	0.000304		
Total	8	0.000668				

Table 4.4 Analysis of Variance for Water Absorption

Estimated Regression Coefficients for Water Absorption (component amounts)

Term	**Coef**
COCUNUT SHELL	0.128023
COW HORN	-0.0858261
GRAPHITE	-0.357551
EPOXY	0.524800
COCONUT SHELL*COW HORN	-0.0216000
COCONUT SHELL*GRAPHITE	0.0392000
COCONUT SHELL*EPOXY	-0.148551
COW HORN*GRAPHITE	0.0826491

Table 4.5 Estimated Regression Coefficients for Water Absorption (component amounts)

The linear regression formula from MINITAB is given by;

$$WAB = 0.0597745X1 + 0.188718X2 - 0.138810X3 - 0.277867X4 - 0.0720000X1X2 + 0.0160000X1X3 + 0.0770566X1X4 + 0.0290566X2X3$$

X1= COCUNT SHELL X2= BONE ASH

X3= GRAPHITE X4= EPOXY

Unusual Observations for Water Absorption

OBS	STD ORDER	WATER ABSORPTION	FIT	SE FIT	RESIDUAL	ST RESID
1	1	0.028	0.027	0.017	0.001	1.00 X
2	2	0.027	0.026	0.017	0.001	1.00 X
3	3	0.027	0.026	0.017	0.001	1.00 X
4	4	0.009	0.008	0.017	0.001	1.00 X

Table 4.6 Unusual Observations for Water Absorption

X denotes an observation whose X value gives it large leverage.

Regression for Mixtures: Friction versus COCONUT SHELL, COW HORN

Estimated Regression Coefficients for Coefficient of Friction (component proportions)

Term	Coef	SE Coef	T	P	VIF
COCUNUT SHELL	59.2	10.71	*	*	175632
COW HORN	18.2	13.62	*	*	153780
GRAPHITE	-42.2	15.19	*	*	129014
EPOXY	-92.6	18.90	*	*	64370
COCONUT SHELL*COW HORN	-256.0	51.60	-4.96	0.127	308085
COCONUT SHELL*GRAPHITE	-128.0	51.60	-2.48	0.244	206880

COCONUT SHELL*EPOXY	245.4	48.57	5.05	0.124	58174
COW HORN*GRAPHITE	325.4	48.57	6.70	0.094	98462

Table 4.7 Estimated Regression Coefficients for Coefficient of Friction (component proportions)

S = 0.0288457

R – Sq = 98.54% PRESS = 0.750925 R – Sq = 0.00%

R – Sq = 88.34%

Analysis of Variance for Coefficient of Friction (component proportions)

SOURCE	**DF**	**SEQ SS**	**ADJ SS**	**ADJ MS**	**F**	**P**
REGRESSION	7	0.056257		0.008037	9.66	0.243
LINEAR	3	0.008575		0.012150	14.60	0.190
QUADRATIC	4	0.047682		0.011920	14.33	0.195
COCONUT * COW HORN	1	0.000850		0.020480	24.61	0.127
COCONUT * GRAPHITE	1	0.004791		0.005120	6.15	0.244
COCONUT * EPOXY	1	0.004680		0.021250	25.54	0.124
COW HORN * GRAPHITE	1	0.037361		0.037361	44.90	0.094

RESIDUAL ERROR	1	0.000832	0.000	0.000832		
TOTAL	8	0.057089				

Table 4.8 Analysis of Variance for Coefficient of Friction (component proportions)

Estimated Regression Coefficients for Coefficient of Friction (component amounts)

Term	**Coef**
COCUNUT SHELL	5.91805
COW HORN	1.82371
GRAPHITE	-4.22346
EPOXY	-9.25780
COCONUT SHELL*COW HORN	-2.56000
COCONUT SHELL*GRAPHITE	-1.28000
COCONUT SHELL*EPOXY	2.45434
COW HORN*GRAPHITE	3.25434

Table 4.9 Estimated Regression Coefficients for Coefficient of Friction (component amounts)

Unusual Observations for Coefficients of Friction

Obs	StdOrder	Coefficient of Friction	Fit	SE Fit	Residual	St Resid
1	1	0.400	0.402	0.029	-0.002	-1.00 X
2	2	0.480	0.482	0.029	-0.002	-1.00 X
3	3	0.440	0.442	0.029	-0.002	-1.00 X
4	4	0.500	0.502	0.029	-0.002	-1.00 X

Table 4.10 Unusual Observations for Coefficient of Friction

X denotes an observation whose X value gives it large leverage.

4.5 MIXTURE SURFACE AND CONTOUR PLOT OF WATER ABSORPTION AND FRICTION COEFFICIENT

Mixture Surface and Contour Plot is graphical representation that helps visualize the relationship between multiple factors or components in a mixture, and how they affect the response variable, in this case, hardness. They assist in optimization, trade-off analysis, and making informed decisions to meet hardness specifications.

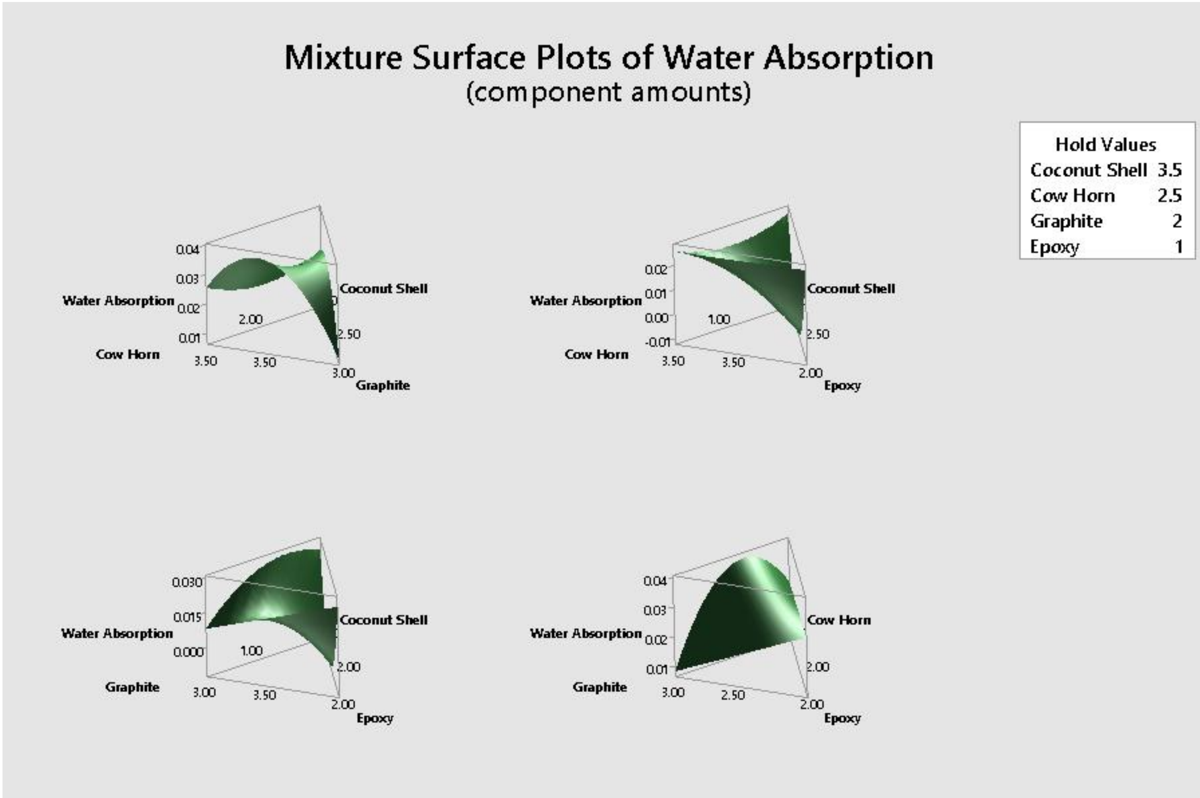

Figure 4.3 Mixture Surface Plots of Water Absorption

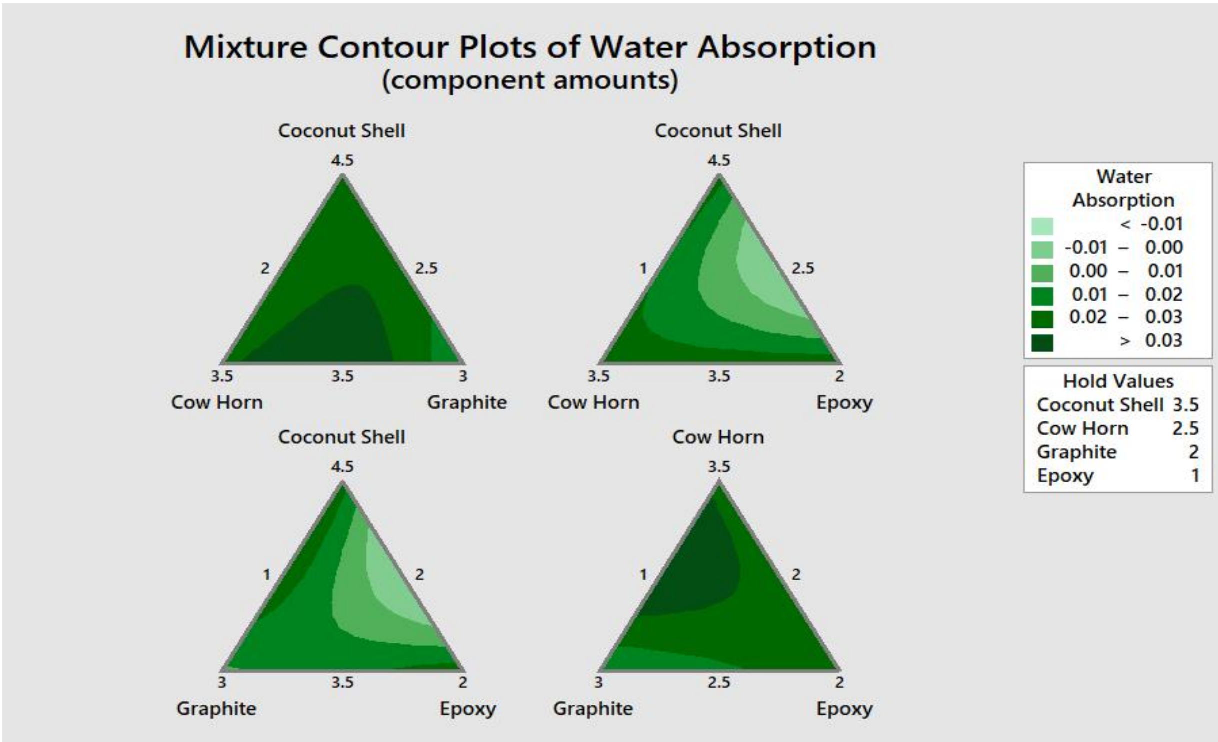

Figure 4.4 Mixture Contour Plots of Water Absorption

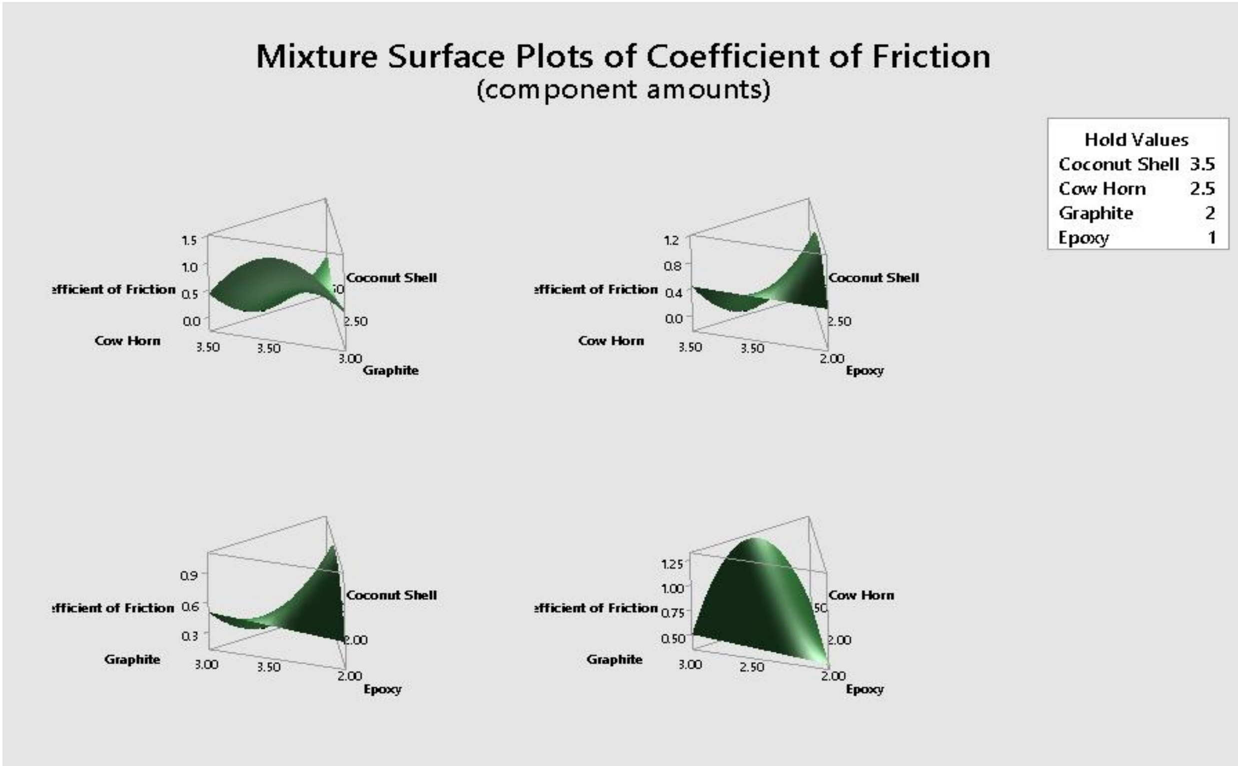

Figure 4.5 Mixture Surface Plots of Coefficient of Friction (component amounts)

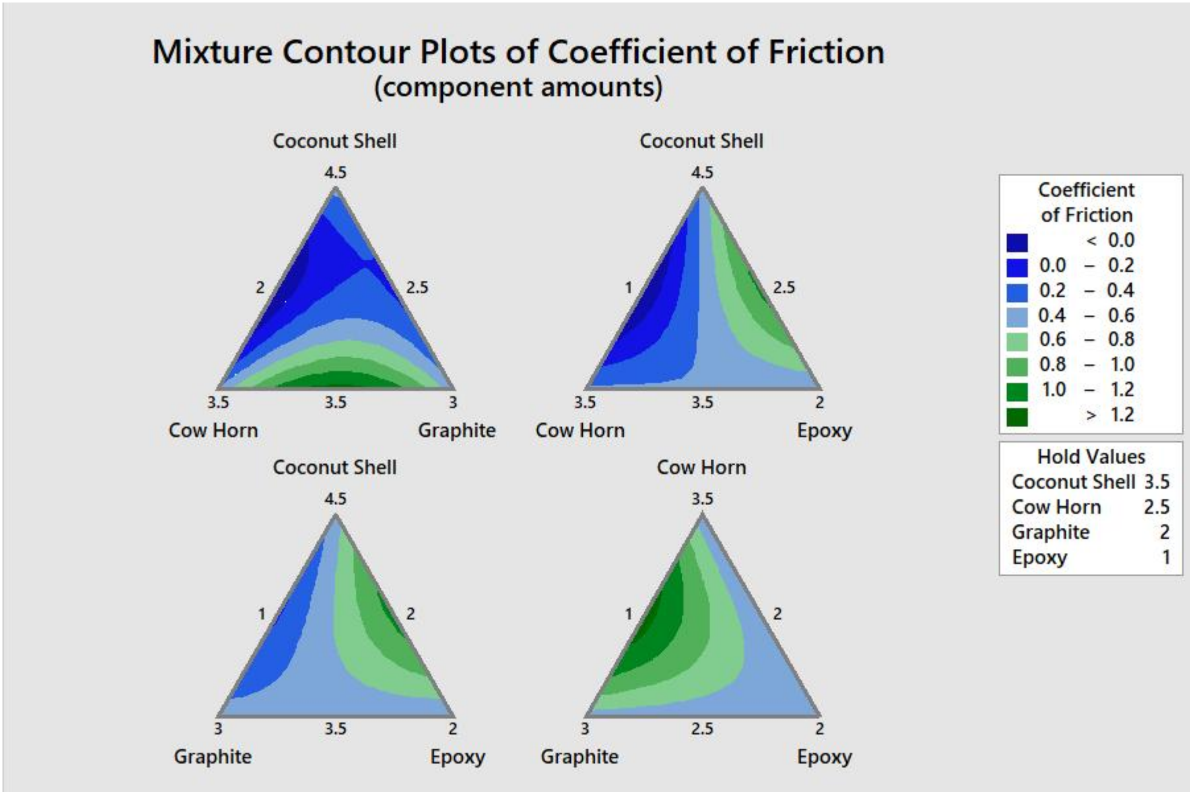

Figure 4.6 Mixture Contour Plots of Coefficient of Friction (component amounts)

4.6 Optimization Plot

This provides the most optimum design parameters that would be taken back to the lab and produced for testing.

4.6.1 Response Optimization

Paramters	Goal	Lowerr	Target	Upper	Weight	Import
Water Absorption	Target	0.017	0.02	0.028	1	1
Coefficient of Friction	Target	0.400	0.50	0.640	1	1

Table 4.6.1 Response optimization

Global Solution

Components

Coconut Shell = 3.53543 Cow Horn = 2.53524 Graphite = 2.20202

Epoxy = 1.72731

Predicted Responses

Water Absorption = 0.019988 , desirability = 0.996121 Coefficient of Friction = 0.500482 , desirability = 0.996554

4.6.2 OPTIMIZATION PLOT GRAPH

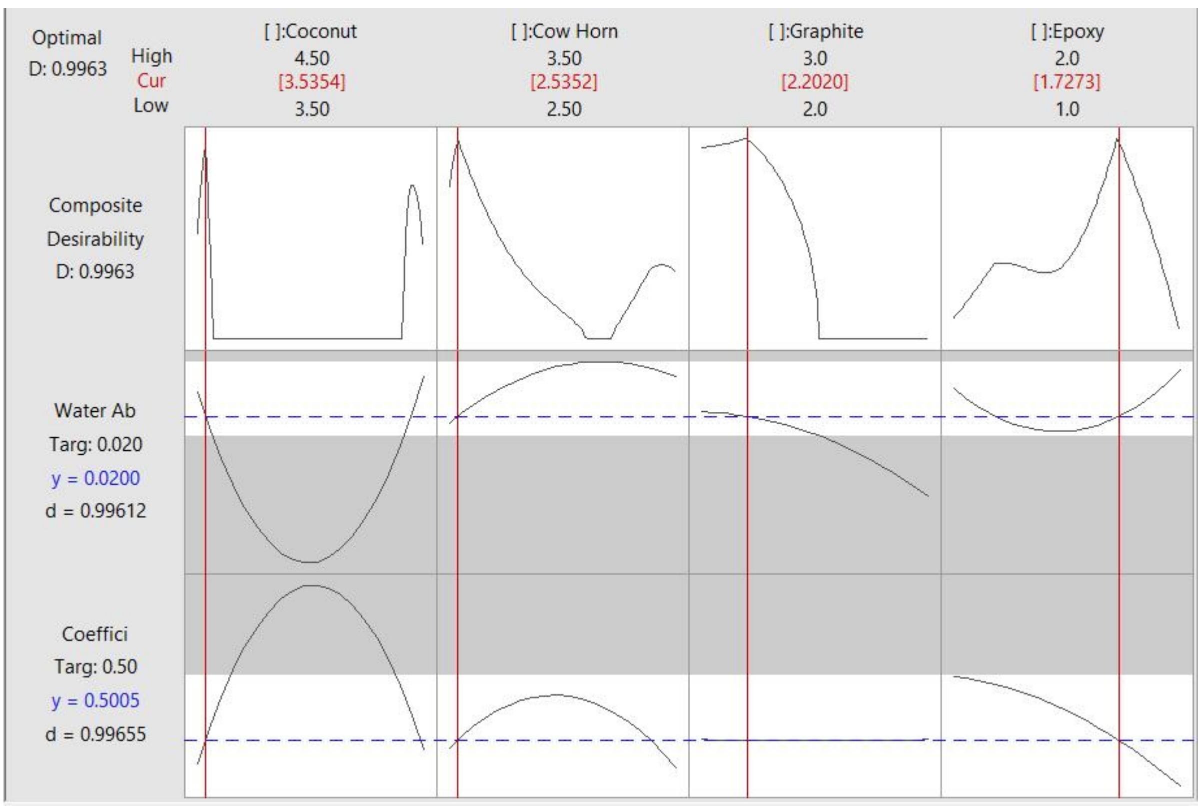

Figure 4.7 Optimization Plot

Here, the composite desirability (0.9963) is close to 1, which indicates the settings seem to achieve favorable results for all responses.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The experimental investigation and optimization of mechanical properties of organic brake pads made with coconut shell as base material. When combined properly with other additives the organic brake pad formulated from coconut shell as base material was found to possess good inter-facial bonding, improved mechanical strength, and a better water absorption rate. The fiber particle size determines interface bonding with the epoxy resin during compaction and improves the surface bonding. This presented an innovative and eco-friendly approach to brake pad development through a systematic process of material selection, formulation and optimization, the project aimed to create brake pads with desirable friction and wear characteristics while minimizing environmental impact. In the broader context of sustainable transportation and materials innovation, this project holds the promise of contributing to a greener and more environmentally conscious automotive industry.

5.2 Drawbacks

Graphite powder, a vital constituent in brake pad production which aids lubrication, was gotten in minimal quantity hence the reduction in number of samples. Minimal quantity of graphite powder was supplied for the course of this work due to the company's policy of not giving moderate quantities to individuals, group of person's rather manufacturing industries only.

Despite being given little quantity; preparation of production was further delayed due to arrival of the graphite powder as the only source of availability (steel company located at Delta state) took massive time in delivery.

Lack of grinding tool; hammer miller, for conversion of the coconut shell to powdered form yielded further delay as we had to substitute with a local grinding machine and improvised iron rod hammer which was time consuming and costly.

5.3 Recommendations

This project investigation was limited to control parameters considered in this research. The effect of another parameter such as temperature and difference in epoxy concentration can be investigated and other mechanical properties such as tensile strength, flame resistance, flexural strength.

Subsequent standard works on brake pad production using coconut shell can be carried out, with the optimum result serving as a guild.

Other natural and recycled materials such as palm kernel fiber, periwinkle shells, bamboo fiber, saw dust can be combined to form several composite materials and investigated for their mechanical properties. It will help in the creation of more cheap, stronger composite materials and determine their potential use for application in the automobile industry. These recommendations will help give more insights about the potentials of combining natural and waste/recycled materials for engineering use.

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