

DEVELOPMENT OF COMPOSITE MATERIALS FOR TRICYCLE BRAKE PADS

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Abstract Coconut fiber and rice dust are locally sourced, developed, and evaluated as agro-waste materials to replace carcinogenic asbestos fibers in brake pad production. The process involves crushing, grinding, and sieving coconut fiber into a powder, mixing it with steel dust, carbon black, and epoxy resin, filling a mould, adding hardener, and pressing and curing samples at 250 °C. The produce is tested for mechanical properties, with optimal brake pad properties achieved using a 100µm sieve grade, enhancing interfacial bonding between resin and coconut shell particles. The hardness, compressive strength, ash content, specific gravity, wear rate, and water absorption values were found to be 258, 113 N/mm², 40%, 1.91, 3.23 mg/m, and 0.63%. The study found that coconut shell has qualities similar to those needed for brake pad material and asbestos replacement in brake pad production. Coconut shell, with its 100µm particle size, has the potential to replace asbestos-based brake pad manufacturing, reducing harmful components and environmental impact.

Keywords: Agro-waste, brake pad, coconut shell, particle size, rice dust

I. INTRODUCTION

A brake is a mechanical device that prevents motion by absorbing energy from a dynamic system. Brake pads are crucial for disc brake-equipped vehicles. They are made of steel backing plates with a friction substance on the brake disc surface. It halts or slows a moving wheel, axle, or vehicle using friction. Brake pads, made of steel backing plates, absorb friction and convert kinetic energy into heat energy. The stopping force produced in the disc and rotor is primarily generated between the pad and the disc [1]. A calliper activates brake pads in disc braking operations, typically made of asbestos fiber. The lining materials, classified as carbon-based, organic, metallic, or semi-metallic, regulate wear and friction. They are categorized into four groups: binders, fillers, reinforcing fibers, and frictional additives and modifiers. Binders maintain structural integrity, fillers stabilize friction, and friction modifiers

provide structural support. These are essential components in brake linings, holding ingredients together, and cost-effectiveness [2]. Friction brakes convert vehicle kinetic energy into heat, slowing it down. Materials must meet commercial vehicle specifications for corrosion resistance, light weight, long life, low noise, steady friction, low wear rate, and acceptable cost.

Brake design influences thermal flow, dependability, noise, and servicing simplicity. Brake pads require excellent mechanical and chemical qualities like hardness, abrasion resistance, and environmental friendliness. Reinforced materials like carbon, glass, steel, natural fibers, and ceramic fibers are used to enhance the toughness of a material [3]. Fibers derived from agro-waste have economic significance and cultural impact throughout the world. Such fibers also have great potential as composite materials because

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of their high strength, low cost, eco-friendly nature, availability, and sustainability. Fibers derived from agricultural waste have many properties with potential for industrial applications. The use of organic waste and residual materials in polymer composites represents an eco-friendly and significantly high value substitute [4] - [5]. Agricultural waste, as shown in Figure 1, can be found in many plants, for example, oil palm tree, corn stalks, bagasse, bamboo, coir (coconut shell), sugarcane pineapple, banana, rice husk, rice straw, and plants (stem, leaf, seed, fruit, stem, grass, reed) [6].

The use of alternative materials in brake pad composition aims to decrease the number of potentially harmful components while preserving friction qualities as well as the rate of pad wear and adverse environmental effects [7]. There are a few things to take into account while choosing composite materials for brake pads. The substance should exhibit strong thermal stability, rapid recovery from elevated temperatures or dampness, and high wear resistance and friction coefficient values [8]. There are three types of natural fibers: plant, animal, and mineral. Natural fibers are made from materials found in nature such as stems, bark, seeds, and leaves [9] - [10]. In Figure 2, epoxy resin was used as a binder and the maize husks as a filler material to create a novel composite brake pad. The new brake pad's characteristics, including its porosity, hardness, density, wear rate, and flame resistance, were ascertained. The samples from the 100- μ m sieve grade of corn husk fiber had the greatest qualities, according to the results. Corn husk with a larger sieve size has a higher wear rate and can be used as a substitute filler when making brake pads made of asbestos [11].

Applying the bagasse shown in Figure 3 as a filler and phenolic resin as a binder, an innovative asbestos-free brake pad was created. Investigated were the tribological, physical, and mechanical characteristics. The dispersion of bagasse resin in the microstructure findings was homogenous. Studies have shown that bagasse of 100 μ m sieve grade with 70% and 30% resin composition was successfully utilized as an asbestos alternative in the production of brake pads [12]. A non-asbestos brake pad using leftover banana peels and phenolic resin shown in Figure 4 was developed. The pad's mechanical, physical, wear, and morphological features increased, except for water absorption. This suggests that asbestos can be replaced in brake pad production [13]. The hardness and impact resistance of an automobile brake pad made with rice husk dust (Figure 5) was investigated, using phenol formaldehyde as a binder. The fine mesh pad showed decreased wear rates and increased friction coefficients [14]. Pineapple leaf fiber and epoxy resin were used to create asbestos-free brake pads, varying their compressive strength, hardness, flexural strength, density, and wear. The study revealed an increase in PALF concentration but a decrease in compressive toughness, rigidity, and abrasion [15].

Aluminum composites were utilized to enhance the mechanical properties of coconut husks (shown in Figure 6), which were used as filler materials for brake pads in automobiles. The data showed that brake pads made of 10% coconut husk particles and 100% mesh had the highest friction coefficient and superior heat resistance compared to conventional pads [16]. The properties of palm kernel fiber (in Figure 7) as brake pad

filler material when combined with epoxy resin as a binder was investigated. The study examined the mechanical, physical, tribological, and microstructure characteristics of brake pads, finding that palm kernel fiber was used instead of asbestos filler [17] - [18]. The performance-to-cost ratio of the brake pad material was raised by using palm slag as a filler ingredient in addition to dolomite and calcium carbonate. Along with additional friction additives, phenolic resins were employed as binders. Within the temperature range of 50 °C to 1000 °C, the thermal characteristics, compressive strength, and wear behavior demonstrated stability and excellent performance [19].

An asbestos-free brake pad was made using lemon peel powder as a filler and epoxy resin as a binder. Properties were examined, and experiments with varying amounts of aluminum oxide, iron oxide, and lemon peel powder were conducted. The powdered lemon peel demonstrated favorable characteristics as a functional substitute for asbestos filler in the manufacturing of brake pads [20].

The creation and investigation of the non-asbestos brake pad's mechanical, physical, and tribological qualities were conducted utilizing epoxy resin as the binding agent and powdered cocoa bean shell (CBS) as filler (Figure 8). The results demonstrated that CBS, an agricultural waste product, may be used in place of asbestos in friction lining and automobile brake pad manufacture [21]. An asbestos-free brake pad using coconut shell powder (Figure 9) and palm kernel shell with polyester resin as a binder was developed, but found its high density and rapid wear rate hindered its quality. Due to its eco-friendly

nature and lack of carcinogenic properties, it can be used as a substitute for asbestos brake pads in commercial goods [22] - [23]. Palm kernel shell (as seen in Figure 10) was utilized as a friction filler for commercial brake pads as a non-asbestos alternative. The proposed materials' mechanical properties and performance were evaluated in both static and dynamic scenarios, and they were found to be satisfactory compared to asbestos-made commercial brake pads. The study suggests that palm kernel shell could potentially replace the material used in friction linings [24] - [26].

A composite of agricultural waste materials, including cocoa bean shells, maize husks, and palm kernel shells, was used to create asbestos-free car brake pads using epoxy resin as a binder. The brake pad sample made from mixed agricultural waste was compared to a single filler material sample. The analysis found that mixed agricultural waste particles can serve as a suitable alternative to asbestos brake pad friction compounds [27]. Periwinkle shell particles' characteristics in Figure 11 was examined, leading to the creation of a brake pad material free of asbestos using thermoset resin and phenolic resin as binders. The study found strong interfacial bonding and a reduction in periwinkle shell particle size (from 710 μm to 125 μm), indicating that increased load and particle size led to an increased braking pad wear rate. PSP is utilized as a filler material in brake pad manufacturing, replacing asbestos due to its ability to withstand higher temperatures [28] - [30]. An asbestos-free car brake pad was a/so created using snail shell for strength, rubber seed husk for friction, and epoxy glue for binding, with the 125 μm sieved snail shell showing superior performance [31].

Researchers explore alternative brake pad materials like natural fibers and agricultural waste, focusing on asbestos fiber reduction due to cancer risks, rice dust, and coconut fiber [32]. The present study examines the impact of volume combinations on the porosity, wear rate, hardness, and friction coefficient of brake pads, comparing them to conventional samples

II. MATERIALS AND METHODS

A. Raw Materials

Locally obtained filler, abrasive, solid lubricant, binder, friction modifier, and additive ingredients are the raw materials employed.

B. Preparation of Material

The procedure of choosing ingredients, measuring, combining, compressing, and gluing



Figure 1: Agricultural waste

Figure 2: Maize husk

Figure 3: Sugar cane fiber



Figure 4: Banana peel waste

Figure 5: Rice husk

Figure 6: Coconut fiber



Figure 7: Palm kernel fiber

Figure 8: Cocoa beans

Figure 9: Coconut shell



Figure 10: Palm kernel shell

Figure 11: Periwinkle shell

resulted in the development of a fiber-based brake pad composition. All recipes used the same amount of abrasive, solid lubricant, binder, friction modifier, and lubricant. The comprehensive composition of the five chosen materials is displayed in Table 1. The elements used to produce brake liners are shown in Figure 12 as coconut shell (CS), carbon black (CB), alumina (A), steel dust (SD), and epoxy resin (ER). Locally obtained filler, abrasive, solid lubricant, binder, friction

modifier, and additive ingredients are the raw materials employed

The process involved using coconut shell powder, epoxy resin, alumina, and steel dust as a binder and reinforcement. The coconut fiber

was collected, ground, and mixed with the resin, creating a homogenous mixture. The mixture was then placed in a mould, cured at a pressure of 16.75kN/m^2 , and removed through abrasive machining.

Table 1: Composition of brake pad samples

S/N	Materials	Composition	Samples	Sample	Sample
			A (g)	B (g)	C (g)
1	Filler	Coconut shell	40	45	50
2	Abrasive	Alumina (Al_2O_3)	20	15	10
3	Reinforcement	Steel dust	15	15	15
4	Lubricant	Carbon black	5	5	5
5	Binder	Epoxy resin and	20	20	20

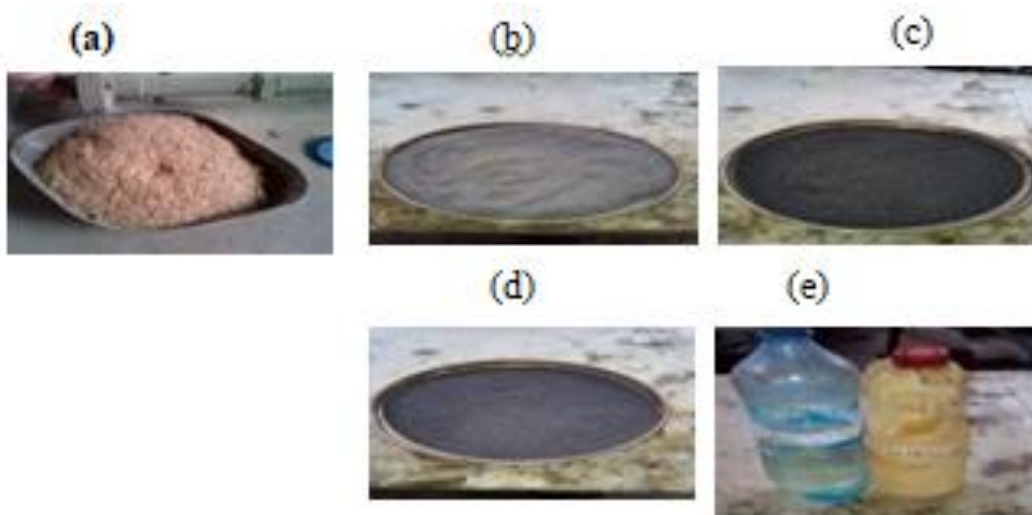


Figure 13: Materials for the production of brake lining

C. Methods

Epoxy resin was mixed with hardener to form a matrix, which was then poured onto powdered friction material. The mixture was pressed into a mould, cured at 250 °C for 95 minutes, and then tested for hardness, compressive strength, porosity, wear rate, bulk density, water absorption, and microstructure. Six test samples were made for each composition, and 54 samples were tested for various properties.

D. Microstructure analysis

After the samples were dry polished and their internal structures were examined under a microscope, they were subjected to microstructure analysis using 300, 400, and 600 grit papers.

E. Brinell hardness test, B_h

Composites' resistance to indentation was tested using Brinell hardness equipment and a tensometer, with indentation diameter measured using an optical micrometer screw gauge, and the Brinell Hardness Number obtained.

$$B_h = \frac{2P(D - \sqrt{D^2 - d^2})}{\pi D} \quad (1)$$

Where P is applied load, D is diameter of hardness steel ball, d is diameter of indentation.

F. Compressive strength test

The tensometric machine was used to conduct a compressive strength test on samples with a diameter of 29.40mm, continuously loading until failure occurred.

G. Density Test

The sample densities were determined using a digital weighing machine, and their volumes were calculated using equation (2).

$$\rho = \frac{M}{V} \quad (2)$$

where m is the mass of the test piece (g) and v is the volume of the test piece (cm³)

H. Wear rate test, W_r

The wear rate of samples was measured using a pin-on-disc machine, then removed, cleaned, dried, and weighed to determine weight loss due to wear. The difference in weight was used to calculate the wear rate. The total sliding distance (s) is calculated by dividing the total distance (S) by the weight difference (ΔW) before and after the test.

$$W_r = \frac{\Delta W}{S} \quad (3)$$

I. Water absorption test, W_a

The samples were weighed and soaked in water for 24 hours, then cleaned and weighed, and the water absorption rate was calculated using equation 4.

$$W_a = \frac{m_2 - m_1}{m_1} \times 100\% \quad (4)$$

Where M_1 is the mass of the sample (g), M_2 is the mass of the sample after absorbing water (g)

III. RESULTS AND DISCUSSION

Epoxide resin was used as a binder to create a brake pad with a coconut shell substrate. With alumina and steel dust abrasives, carbon black was used as a lubricant and strengthened. The white and black resin patches in Figure 14 indicate that the sample with the 100µm mesh grade had the best features. This represents the extremely good dispersion of sawdust particles and improved interfacial bonding between the resin and the coconut shell particles. The homogeneous dark red zone of resin and the white region of sawdust are seen in the microstructure of samples A, B, and C. This corresponds to 75µm, 100µm, and 150µm mesh grades, respectively. As sawdust particle size dropped, there was a more even

dispersion of resin with the sawdust. Due to the sawdust's bonding with the composition as a whole and the near inter-packing separation, the filter ratings fell.

Table 2 displays the Brinell hardness data according to particle size. The maximum hardness value is seen in particles with a size of 100 μ m because of their increased surface area. A greater value than commercial brake pads is shown in the hardness decreasing as the particle size rises. The greatest compressive strength of 113N/mm², slightly greater than what can be obtained from commercial brake pads, is found in the 100 μ m particle size, according to the compressive strength with particle size result. Sawdust's compressive power rises with decreasing particle size. As the size of the generated samples' particles rises, the amount of ash decreases. This is attributed to the sample having a 100 μ m sieve grade, which gives the optimum quality diffusion of reduced particle size, which causes pores to expand as particle size rises. As the size of the sawdust particles in the composition rises, the density drops. The increase in particle size is responsible for

the reduction in density. Since sawdust particles are packed closer together in the sample with the 100 μ m sieve grade, there is more stability across the whole aggregate body phase. This results in the sample having the greatest density value. As the size of the coconut shell particles rises, so does the rate of wear. This is a result of the coconut shell being packed closer together, which has strengthened the link between the coconut shell and the overall structure. The increased compressive strength and hardness values of the samples as the particle size reduces may also be responsible for this. Particle size increases cause an increase in pores, which in turn causes an increase in the rate of water absorption.

Table 3 compares the characteristics of commercial brake pads (based on asbestos) with those produced from sawdust brake lining (coconut shell brake lining).

Table 2: Samples result analysis

S/N	Parameters	Samples A	Samples B	Samples C
1.	Bulk density (g/cm ³)	1.238	1.438	1.563
2.	Compressive strength (N/mm ²)	38.147	29.741	36.187
4.	Water absorption (%)	18.75	17.425	6.478
5.	Apparent porosity (%)	75	45	20

Table 3: Results of coconut shell and asbestos based brake pads

S/N	Property	Commercial brake pad (asbestos based)	Experimental brake pad (coconut shell)
1	Hardness (HB)	101	258
2	Compressive Strength (N/mm ²)	110	113
3	Ash Content (%)	54	40
4	Specific gravity	1.89	1.91

**Figure 14: Samples of the produced brake lining**

IV. CONCLUSION

The results showed that coconut shell has properties comparable to those needed for use as brake pad material as a substitute for asbestos in the manufacture of brake pads since it gave results that are within the range for brake pad manufacture. The outcome shows that coconut shell of 100 μ m particle size has properties that can effectively replace asbestos in brake pad manufacture, since it gives better brake pad properties. The properties such as compressive strength, hardness, density, ash content, and water absorption of the produced samples decreased with increasing particle size.

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