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Production of Eco-Friendly Brake Pad Using Raw Materials Sourced Locally In Nsukka

Darlington Egeonu * Chukwumaobi Oluah Patrick Okolo
Department of Mechanical Engineering, University of Nigeria, Nsukka, Enugu State, Nigeria

Abstract

In this study, high quality asbestos free bake pad was produced from locally sourced raw materials. The disc brake friction lining with geometrical specification of Mitshibushi L-300 was produced using palm kernel shell and coconut shell powder as base material, polyester resin as binder material, graphite as lubricant, metal chips and carbides as the abrasives. A commercially bought brake pad served as control. Three different samples were produced by varying mass compositions of palm kernel shell and coconut shell. Sample A has equal mass of palm kernel shell (PKS) and coconut shell (CNS). Sample B has higher mass of PKS (83.03%) and lower mass of CNS (12.68%) while Sample C has lower mass of PKS (14.79%) and higher mass of CNS (35.92%). A constant pressure of 16.75kN/m^2 and particle size of 0.63um were used for all samples. The binder, lubricant and abrasive composition were kept constant. The test result showed that the coefficient of friction (static and dynamic) for samples A, B and C were (0.374, 0351), (0.383, 0354) and (0.362, 0.349) while the commercial pad was (0.388, 0.359). Percentage water absorption for samples A, B and C were 0.0522, 0.0399 and 0.0470 while the commercial pad was 0.0327. The hardness test results for sample A, B and C gave 3.3, 3.41 and 3.0 while the commercial pad was 2.53. The wear rate test gave 0.00366g/sec, 0.00456g/sec, 0.00334g/sec, 0.00312g/sec for samples A, B, C and commercial pad respectively. All the samples were tested under the same conditions . Sample C has a promising potential since it had a moderate water absorption, wear rate and hardness but had the least coefficient of friction.

Keywords: Brake Pad, Palm Kermel Shell, Coconut Shell, Resin,

1.0 Introduction

There has been great need to minimize the use of asbestos fibres in brake pad production. The traditional way of producing brake pad using asbestos fibres is a source of concern to manufacturers and end users because of its carcinogenic nature. Investigators have used natural fibres to replace carcinogenic asbestos fibres in brake pad production. Leman et al. 2011 reported that researchers are investigating and applying agricultural waste as raw materials for brake pad production. Palm kernel shell has equally been used as a replacement for asbestos fibres (Dagwa and Ibhadode, 2006).

From literature reviewed so far, the use of combination of coconut fibre and palm kernel shell as raw material for brake pad production has not been reported. The effect of different volume combination of this raw material on the porosity, wear rate, hardness, coefficient of friction etc will be investigated. The performance results of the produced brake pads will be compared with the commercial sample.

2.0 Literature Review

There are four classes of ingredients used in brake pad production namely binders, fillers, friction modifiers and reinforcements. Basically, brake pads generally consist of asbestos fibres embedded in polymeric matrix along with several other ingredients.

Materials for brake pad production should have good mechanical and chemical properties. These properties include hardness, resistance to abrasion, environmental friendliness.

Friction arises from surface interactions between two contacting material and is affected by volume and surface dependent properties (Rabinowioze, 1956). Iloeje *et al.* (1989) found that volume dependent properties are elastic and it modifies the hardness and thermal characteristics. Also, Iloeje (1989) reported that surface properties of importance are the chemical reactivity, surface energy, tendency to absorb molecules from the environment and compatibility of the contacting surface forces which causes friction due to adhesion, local fusion asperity and interlocking. Friction linings for automobile brakes must have a reasonably high friction coefficient typically within the range 0.40-0.47, which is stable over wide variations of temperature and pressure. They should also have low wear rates, low moisture sensitivity, low shrinkage, adequate mechanical strength,

good bonding to the back plate among other properties (Sinclair, 1964).

Since no single material can have all the properties required, linings are usually made of mixture of materials in granular form, which are compound and subject to specified pressure. The additive added include hard rubber dust, fully cured resin brass chips for reduction of wear, carbon black to increase tensile strength and bonding agents such as sulphur and zinc oxide. The bonding agents also protect the linings against abrasive wear, corrosion, oil and moisture penetration, and chemical attack.

Historically, Wood and leather were used as brake pad materials prior to the establishment of friction materials industry. However, their poor temperature resistance was only one of a number of factors which causes them to have limited application that necessitated the use of cast iron in 1870 to replace Wood and Leather. Nevertheless cast iron can undergo phase transformation leading to heat cracking of the brake drum or disk. This attribute of cast iron led to the introduction of cotton based material impregnated with bitumen solution.

However the need for operating temperature to exceed the permissible limit for cotton based materials due to high operating conditions led to the substitution of cotton with asbestos fibres. Shinya (2009) reported that medical research revealed that asbestos can lodge in the lung and induce adverse respiratory condition. This attribute of asbestos led to the introduction of other materials but none is exactly like asbestos though they offer similar performance characteristics. In 1950, resin-bonded metallic brake lining was introduced to replace asbestos; however the wear of the disc made them not to be suitable for use. In 1970, glass fibre was introduced but its brittleness led to their limited application while aramid fibre which was introduced in 1984 as brake pad material was found to have the same comparative advantage as asbestos but it is very soft. Also in 1974, Sepiolite was also proposed to replace asbestos because of the similar property it exhibit with asbestos but its limitation is that it causes inflammation of the lungs and pulmonary interstitial fibrosis which is also caused by crocidolite asbestos. Potassium titanate which was also in use is associated with a cancer called mesothelioma and in 1992, Ceramic fibre was introduced as an alternative to asbestos but its brittle nature necessitated its limited application.

Furthermore, paper type was introduced in 1998 to replace asbestos though it is associated with the problem of degrading very quickly at temperature above 150ºC. This brought about the introduction of sintered materials in 2001 which degrades at a much higher temperature but also has high production cost. The fabric type was introduced in 1999 but its high porosity gave rise to a high flow rate and permeability of fluid which was among its limitations. Since no single material could achieve all the desired attributes for an automobile brake pad, different constituents of materials were therefore introduced to overcome the challenges encountered in finding suitable materials as an automobile brake pad. The Resin binder, with the introduction of Phenolic resin which decomposes at temperatures beyond 450ºC high braking force during application of brake but decomposes into fumes likely to release its constituent which are poisonous. In an effort to overcome the phenolic resins, the following were introduced. Condensed poly-nuclear aromatic resin (COPNA) which introduced poisonous fumes like phenolic resins. Silicone-modified resin has a better heat and chemical resistance than the conventional resin. Also Cyanate ester resin introduced is stable at elevated temperatures, chemically inert but it is brittle like phenolic resin. In addition epoxy-modified resin which is still introduced has high frictional stability while thermoplastic polyimide resin introduced induces excessive brake disc wear but has low thermal polyimide conductivity compared to phenolic resin. In 1984, the fillers, with the carbonate, Molybdenum trioxide and Titanate, helped to increase the temperature of the brake pad material to 135ºC, suppressing low frequency brake noise and also providing heat stability for the material.

The use of asbestos fiber is decreasing day by day due to its carcinogenic nature (Rinek and Cowen, 1995). In order to avoid this carcinogenic asbestos, efforts are ongoing for the replacement of asbestos material. No information is available in literature on the use of coconut fiber and palm kernel shell for the formulation and production of brake pad materials. Therefore, new natural fibres brake pad materials will be formulated with the aim of using different volume combination of coconut fibre and palm kernel shell as base material in brake pad production. These natural raw materials are non-poisonous and wear resistant and can be compounded with other additives to produce high quality brake pads for automobile application.

3. Methodology

3.1 Raw Materials and Sample Formulation

The main raw materials to be used in the research were filler, abrasive, solid lubricant, binder, friction modifier and additives. The natural fibre brake pad material will be developed through the process beginning with the selection of raw materials, weighing, mixing, compacting and binding. There should be three formulations with different composition of coconut fibre and palm kernel shell content. Grouping was made based on the variation

of the coconut fibre and palm kernel shell material in the formulation. However, abrasive, solid lubricant, binder, friction modifier and lubricants should be kept same for all formulations. Table 1 shows the detail formulation of five different types of new materials.

3.2 Preparation of Material

Three different combinations (such as sample A, sample B, sample C) will be prepared with varying coconut fibre and palm kernel shell contents (see Table 1). Palm kernel shell and coconut shell powder were base material, polyester resin was binder material, graphite was lubricant, metal chips and carbides were the abrasives. A commercially bought brake pad served as control. The coconut fibre and palm kernel shell will be collected from waste coconut fruit and cracked palm kernel respectively. The impurities in the collected raw materials will be removed using ethanol. After thorough cleaning with ethanol, the coconut fibre and palm kernel shell will be crushed and ground to a fine powder (with a range of 100-200 μm), and sieved using crusher machine.

Next, for each of the following samples, palm kernel shell, coconut shell, metal chips, carbide and graphite were mixed thoroughly until a homogenous mixture was formed. Polyester resin was added to the mixture, all of them were blended together giving rise to pap-like mixture. Catalyst and accelerator in the ratio of 1:1000. The above blended mixture was transferred into already treated metal backing plate placed in the mould. It was allowed to stay for 15 minutes upon which gelling started (the surface of the moulded samples was hot showing it is an exothermic reaction). At this moment a pressure of 16.75kN/m^2 was applied and left for 6 hours upon which full curing had taken place. The excess material was removed from the sample through abrasive machining.

Table 1: Composition of Brake Pad Samples

Compositions	Sample A (grams)	Sample B (grams)	Sample C (grams)
Palm kernel shell	36	54	21
Coconut shell	36	18	51
Metal chips	22	22	22
Carbide	4	4	4
Graphite	6	6	6
Polyester	38	38	38
Total	142	142	142

4.0 RESULTS AND DISCUSSIONS

4.1 MASS, VOLUME AND THICKNESS

The volume of the samples was determined by fluid displacement method. The samples were immersed in 1000mL cylinder filled with distilled water at room temperature. The volume of water, before the immersion and after the immersion were taken, and their difference is the volume of the sample piece. The mass of the samples was determined by weighing them using meter E200 Electronic balance which has accuracy of ±0.01. The thickness of the samples A, B, C and Commercial Pad were determined using a micrometer. Readings were taking at three different locations (both ends and middle) and their average was taken. The results for the computed densities of the samples are shown in table 2

Table 2: Results for Densities of the Samples

Sample	Mass (gram)	Thickness (cm)	Volume (cm^3)	Area (cm^2)	Density (g/cm^3)
A	382.89	1.79	150	83.80	2.55
B	326.11	1.49	125	83.89	2.6
C	362.04	1.55	130	83.87	2.78
Commercial Pad	336.06	1.25	100	80.0	3.36

4.2 COEFFICIENT OF FRICTION

4.2.1 STATIC COEFFICIENT

The brake pad was placed on the polished steel plate and the angle of inclination increased until the pad just began to slide down the surface. The height, x, corresponding to this slope was measured. The length of the steel plate, L was constant. The computed coefficient of friction for samples under different conditions are shown in table 3.

Table 3: Static Coefficient of Friction

	COEFFICIENT OF FRICTION (μ)		
CONDITION	DRY	WET	OIL
Sample A	0.374	0.342	0.328
Sample B	0.383	0.350	0.331
Sample C	0.362	0.331	0.312
Commercial pad	0.388	0.359	0.338

4.2.2 DYNAMIC COEFFICIENT

The brake pad was firmly tied round with a tiny nylon thread of negligible weight and placed on a polished steel plate. The remaining thread end was tied to a load hanger passed through a frictionless groove pulley. A mass of 1000g was placed on the brake pad, this with the mass of the brake pad multiply with 9.81 m/s^2 is the **normal load,** the load hanger was gradually loaded, upon each loading the brake pad was lightly tapped, the mass that gave it a steady slow velocity was noted. This mass with the mass of the load hanger (100g) multiply with 9.81 m/s^2 is the **frictional load.** The result for dynamic coefficient of friction is shown Table 4.

Table 4: Computed Dynamic Coefficient of Friction

	Dry			**Wet**			**Oil**		
Sample	**Frictional Force(N)**	**Normal Reaction(N)**	μ	**Fric. F(N)**	**Nor. R(N)**	μ	**Fric.F(N)**	**Nor. R(N)**	μ
A	4.758	13.566	0.351	4.513	13.566	0.332	4.316	13.566	0.318
B	4.610	13.009	0.354	4.415	13.009	0.339	4.169	13.009	0.320
C	4.660	13.362	0.349	4.365	13.362	0.327	4.022	13.362	0.301
Comme-rcial Pad	4.709	13.107	0.359	4.464	13.107	0.340	4.218	13.107	O.322

4.3 THE HARDNESS TEST

This experimental work was done using the mensanto tensometer . The indentation process involves piercing or deforming the surface of the brake pad with a brinell ball of 2mm in diameter.

Hardness = force applied kgf / spherical area of indentation (mm^2)

Spherical area of indentation=$4/3\pi\ r^3$, where r= radius of indentation

The hardness test result is shown in Table 5. Also the results for the deformation of the samples at various loads is shown in table 6.

Table 5: Hardness Test Results for the Samples.

Sample	Force (Kgf)	Radius (mm)	Area (mm^2)	Hardness
A	192	2.4	57.91	3.3
B	174	2.3	50.97	3.41
C	203	2.5	65.45	3.0
Commercial Pad	98	2.1	38.79	2.53

Table 6: Loads Applied and the Corresponding Deformations.

	Deformation, (mm)					
Load (Newton)	200	500	800	1200	2000	2400
Sample A	1.4	2.3	2.8	3.1	5.6	6.0
Sample B	1.2	2.1	2.6	3.0	5.2	5.6
Sample C	1.5	2.6	3.1	3.4	5.9	6.2
Commercial Pad	1.6	3.0	4.4	5.6	6.3	7.2

4.4 MOISTURE ABSORPTION

The brake pads (lining + backing plate) were weighed and immersed in a basin of water for 24 hours under room temperature. weighing was done with electronic balance ,metler E200. After immersion, the pads were brought out and cleaned of their surface moisture. They were weighed again, and their mass difference gave the mass of water absorbed and percentage absorption (over dry mass) where determined. Table 7 shows the percentage of water absorption by various sample.

Table 7: Table Showing Percentage of Water Absorption in the Samples.

SAMPLE	Dry Mass (gram)	Wet Mass(gram)	Mass of Water Absorbed (Gram)	% of Water Absorption
A	382.89	383.09	0.2	0.0522
B	326.11	326.24	0.13	0.0399
C	362.04	362.21	0.17	0.0470
Commercial Pad	336.06	336.17	0.11	0.0327

4.5 WEAR CHARACTERISTICS

A standard centre lathe, a used automobile wheel disc of outer diameter 300 mm and inner diameter 186 mm; a plain compression spring of dimensions: 42 mm long, outer diameter 30mm, inner diameter 27mm and a fabricated brake pad holder were used in devising a friction testing machine in the absence of a specially built

alternative. The contacting face of the wheel disc had fine emery paper, aluminum silicon grit No. p-400C, made in England, bonded to it with top bond. The disc was firmly gripped in the chuck of the lathe which was run at 180rpm. The brake pad was placed in the brake pad holder, against the compression spring, and pressed unto the emery paper by fully compressing the spring. The brake pad holder was firmly clamped with the tool post. The linings/disc pressure was approximately 56.08 kN/m^2 based on spring parameters and lining contact area. The disc was run at the set speed for 15 minutes. Measurements of brake pad mass before and after the test run gave the wear sustained.

It is important to acknowledge the limitations of this test which include: possible misalignment of the compression spring, initial variations in lining thickness with location, consequent uneven pressure over lining surface and differences in disc face linear speed at different radii. Tables 8, 9, 10, 11 show the mass and wear, Rate of Wear, Wear Volume and wear rate

Table 8: Mass and Wear of Samples

Sample	Mass before(gram)	Mass after(gram)	Wear (gram)
A	382.89	379.60	3.29
B	326.11	322.01	4.1
C	362.04	359.03	3.01
Commercial Pad	336.06	333.25	2.81

Table 9: Rate of Wear (gram per minute)

Samples	**Wear**	**Time (min)**	**Rate of Wear (g/min)**
A	3.29	15.0	0.2193
B	4.1	15.0	0.2733
C	3.01	15.0	0.2007
Commercial Pad	2.81	15.0	0.1873

Table 10: Wear Volume (i.e. wear/density (m^3))

sample	Wear (gram)	Density(g/cm^3)	Wear Volume x$10^{-6}m^3$
A	3.29	2.25	1.4622
B	4.1	2.6	1.5769
C	3.01	2.78	1.0827
Commercial Pad	2.81	3.36	0.8363

Table 11: Wear Rate (wear volume/distance, (m^3/m)

Samples	Wear volume x10^{-6} (M^3)	Distance (m)	Wear Rate x10^{-10} m^3/m
A	1.4622	2544.7	5.7461
B	1.5769	2544.7	6.1968
C	1.0827	2544.7	4.2547
Commercial Pad	0.8363	2544.7	3.2864

4.6 DISCUSSION OF RESULTS

4.6.1 WATER ABSORPTION

Brake pad purchased from the market has the least water absorption while those produced from our samples in the laboratory has higher water absorption which may be due to the following reasons,

PKS and CNS are natural fibers and natural fibers are strongly hydrophilic materials with many hydroxyl groups (–OH) in the fibers. The hydrophilic nature of PKS and CNS causes the water uptake by these lignocellulosic materials which is due to the formation of hydrogen bonds between fillers and water molecules. With the presence of hydroxyl groups PKS and CNS tend to show low moisture resistance. It is known that lignocellulosic materials absorbs water by forming hydrogen bonding between water and hydroxyl groups of cellulose, hemicellulose and lignin in the cell wall .According to **Dhakal (2007**)., the maximum water uptake increased as the natural filler content increased. When the composites are exposed to moisture, the hydrophilic PKS and CNS swells. As a result of swelling, micro cracking of the brittle thermosetting resin occurs. The increase of cellulose content in coconut shell and palm kernel shell contribute to more water penetrating into the interface through the micro cracks induced by swelling of PKS and CNS creating swelling stress leading to composite failure. As the composite cracks and gets damaged, capillarity and transport via micro cracks become active. The capillarity mechanism involves the flow of water molecules along filler–matrix interfaces and a process of diffusion through the bulk matrix. The water molecules attack the interface, resulting in de-bonding of the filler and the matrix.

Compacting pressure, the lower the compacting pressure the more porous it is, more space for water molecules to fill. Percentage (%) moisture absorbed is inversely proportional to the compacting pressure (Iloeje, *et al* 1990).

The trend for the water absorption is sample A >sample C> sample B> COMMERCIAL PAD. This trend (sample A, the highest absorber) is in accordance since coconut shell and palm kernel shell are fibers and of the same mass, they will be absorbing water with nearly the same absorption ratio. Sample B shows that the water absorption ratio of coconut shell is greater than that of the palm kernel shell. Sample B has the least water absorption, since coconut shell has more water absorption ratio than palm kernel shell.

4.6.2 WEAR RATE

The brake pads produced from our samples wear faster than the one purchased from the market. The following reasons may be suffice;

The compacting pressure used during fabrication using our samples is far less than the Commercial fabrication pressure.

The type of binder used affect the wear rate. The best type of binder for fabrication of brake pad is phenolic resin, (**Onyeneke et al, 2014**). However, due to its scarcity in the local market, an alternative resin (Polyester resin) was used. Polyester resin decomposes at a temperature of 250-300^{o}C while phenolic resin decomposes at a temperature of about 450^{o}C.

5.0 CONCLUSION

Thus the objective of producing a brake pad lining from predominantly locally available materials has been realized. The base materials; palm kernel shell and coconut shell is non-carcinogenous (ie non-cancer causing), unlike asbestos which is the base material of most commercially available brake linings. Thus the use of coconut shell and palm kernel shell for fabrication of brake lining should improve environmental health of our cities and country side since the most predominant way of disposing them (PKS and CNS) at the moment is using them as fuel which also causes green house effect.

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