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DEVELOPMENT OF BRAKE PADS FOR AUTOMOBILES AND OTHER INDUSTRIAL APPLICATIONS USING LOCALLY SOURCED BIOMATERIALS

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ABSTRACT

Automotive brake friction materials are vital part of brake and clutch devices. Friction materials used for brake pads grew from simple formulation containing few elements to complex composites with as many as 20 or more elements. This work presents the use of organic-based (mainly agro-based) formulation as base materials for the production of automobile brake pad/lining and for other industrial applications aiming to replace the use of asbestos, which is carcinogenic when its dust is released. The research commenced with the preparation of experimental materials by addition in weight percent of coconut shell powder, barite, graphite, resin, zinc oxide, friction dust, carbon black, and brass powder as 2.2,2.6,1.2,1.5,0.2,0.8, 0.5, and 0.6 wt% respectively in that order. Test samples were produced by steel moulding method and machined to standard size for the purpose of determining quality bonding, hardness value and swell-growth. The result obtained show a standard homogenous bonded experimental brake pad/lining having a Brinell hardness value (BHN) of about 32.3 and swell growth of 0.625%.

KEYWORDS
Brinell-hardness, coconut shell, formulation, homogenous, indentation

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INTRODUCTION

The brake pad, one of the components of braking systems is designed for high friction with brake pad material embedded in the disc in the process of bedding while wearing evenly. They need a stable friction at different temperatures, loads, environments, and stages of wear. Furthermore, seizure, excessive wear rates, and macroscopic fracture must be avoided (Erikson & Staffan, 2000). Brake pads convert the kinetic energy of the car to thermal energy by friction. Two brake pads are contained in the brake calliper with their friction surfaces facing the rotor. When the brakes are hydraulically applied, the calliper clamps or squeezes the two pads together into the spinning rotor to slow/stop the vehicle. When a brake pad is heated by contact with a rotor, it transfers small amounts of friction material to the disc, turning it dull grey. The brake pad and the disc (both now with friction material), then stick to each other, providing the friction that stops the vehicle (Chan & Stachowiak, 2004).

Currently the major base material for the manufacture of brake pad/lining material is asbestos fibre (Shigley & Miscwe, 2001), they are used by industry, mainly in construction and friction materials. Although, in the 1920s, asbestos fibre was chosen as a friction material for use in all kinds of vehicles but due to its harmful effects on human health, non-asbestos organic (NAO) material has become mainstream nowadays. These observations and similar reasons stimulated interest in considering the use of coconut shell, coconut fibre and other agro-base residue as friction material in brake pad/lining. Hence the present work is focused on the use of alternative materials for non-carcinogenic brake pad/linings for automobiles and other industrial applications.

EXPERIMENTAL PROCEDURES.

Materials and Equipment

A 20kg quantity of coconut shell experimental material for this work was obtained from local market in Kaduna central area. The material was cleaned to remove impurities and other contaminants. The shells were ground to powder in a conventional mill (see plate1) and was graded using a set of BS 410 standard sieves (Endecotts Ltd., London). The fractions retained on the 100m were used in the formulation (Gurunath & Bijwe, 2009).

Experimental materials for formulation in brake pad/lining can be selected from the following materials or agro-waste (residue): coconut shell/fibre (CS/CSF); palm kernel (PK), mild steel iron filings (MSIF), a binder, (Phenol resin powder) combined with other additives as shown in plate 1.

Plate 1: Palm kernel

Plate 2: Coconut shell/fibre

Plate 3: Mild steel iron filings

Plate 4: Palm kernel fibre

The experimental material used in this research is coconut shell and any of the combination in the formulation. The coconut shell was ground to form coconut shell powder in a conventional mill. The grounded powder was graded using a set of BS 40 standard sieves placed in descending order of fines and shaken for 15 minutes which is the recommended period for complete classification (Endecotts Ltd, London). The fraction that was retained on the 100m sieve was used for the formulation (Gurunath & Bijwe, 2009).

Equipment used in this research include Brinell hardness tester, Chapy Impact testing machine, Electrical resistance furnace (Oven), Metallurgical Microscope, Mild steel mould, Hydraulic press, Beaker, Sieves, Venire calliper, etc.

Specimen Preparation

The production of the specimen brake pad consists of series of unit operations including mixing, cold and hot pressing, cooling, post-curing, and finishing. The ingredient for the formulations are, coconut shell powder (CNS), brass, graphite, barite, carbon black, friction dust, zinc oxide and resin were blended for 15 minutes in a mixer until a homogenous component was formed shown in plates 1, 2, 3, and 4.

A mould was prepared to the shape and curvature of a brake pad from a metal strip (made of a cope and drag). The coconut shell was crushed, processed in powdered form and mixed in a ratio 3:1 after which a binder (synthetic resin solution) is measured and poured into the mixture. Following an effective mixing, the paste was rolled and lined in the mould to a length of 26cm along the curvature of the mould, cope, and then the drag was used to cover and pressure application. The mould was placed in an oven at a temperature of 100˚C and left for 35 minutes for effective curing.

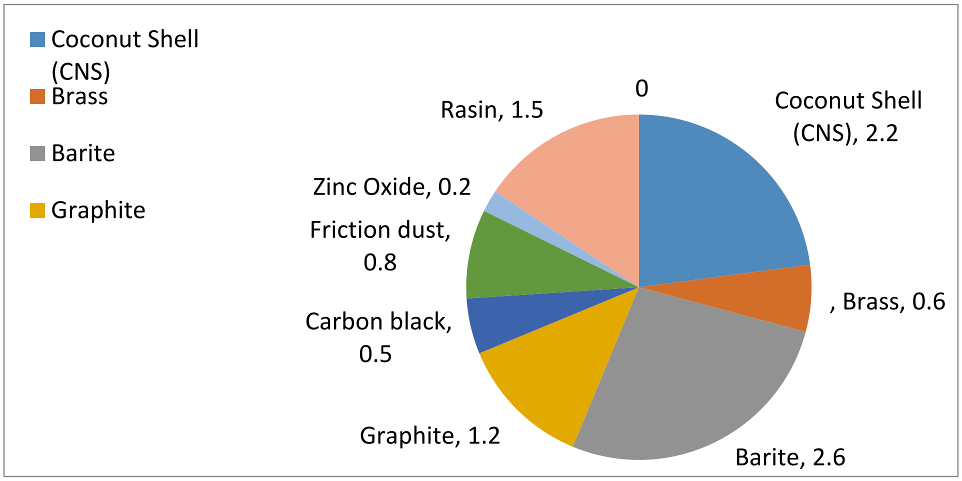

Figure 1: Consistent ingredient used in the brake pad formulation

Swell Growth Analysis

This performance standard specifies a universal method of measuring the dimensional change of friction materials to determine the effects of temperature. The test applies to both, disc and drum type linings commonly used in hydraulic and air brake systems for automotive or commercial vehicle applications. This standard describes two main test procedures. Method A, where the friction material is in contact with a heated surface to simulate the heat input to the pad that occurs during actual usage. Method B uses an oven to heat the freestanding material and is an approximate procedure requiring less instrumentation. Method A is recommended for disc brake pad assemblies, noise insulators, or flat coupons; while Method B is recommended for curved drum brake linings.

Dimensional stability of the friction composite when subjected to changes in temperature and humidity was quantified by measuring its percentage swell growth (Xu *et al*., 2006; Adewuyi

& Adegoke, 2008). The thickness of the sample before being introduced into an oven T_{bo} was measured with a venire calliper with an accuracy of $\pm$0.001mm. The temperature in the oven was stabilized at 250^0c and the sample, on a Steel tray, was kept inside the oven for one hour. The thickness of the sample after being withdrawn from the oven and allowed to cool at room temperature for 20 minutes Tc, was noted. The percentage of swell Sp, was computed as:

$$SP = \frac{(Tc - Tbo)X100\%}{T_{bo}}$$

Where,

Sp= Percentage of swell

T_{bo} = Thickness of sample before being introduced into an oven

T_c =Thickness of sample after being withdrawn from an oven

RESULTS AND DISCUSSIONS

The elemental composition of the CNS particles is shown in table 1 below. The result reveals that CNS contains semi-metals and non-metals, this suggest the need to enrich the Coconut Shell (CNS) – based lining with metallic elements to improve the thermal conductivity. The Coconut Shell (CNS) particle exhibited a bulk density of 560 $\pm$ 17.4kg/m^3 and a relative density of 1.26 $\pm$ 0.07. In comparison, the corresponding values for asbestos are 350kg/m^3 and 2.5. The higher bulk density of CNS particles implies that the particles are closely packed, which reduces the possibility of air infiltration, which may initiate cracks in the manufactured product. The lower specific gravity shows that the CNS based brake pad will be lighter than the asbestos brake pad. Consequently, CNS particles are more suitable as filler material than asbestos on the account of the overall weight of the brake pad.

The observed thermal conductivity and specific heat capacity were 6.825W/mK and 1.98K/kgK and the corresponding values of asbestos are 0.15W/mK and 1.59KJ/kgK. Because high thermal conductivity is undesirable in brake pad, this suggests the need to improve CNS particles for brake pad applications. Barite has been known for brake pad applications (Chan &

Stachowiak, 2004) and, an increase in its fraction in the formulation would inhibit conductivity of friction element on the braking fluid.

Table 1: Elemental composition of CNS particles

Elements	Conc. value	Conc. error	Unit
K	34.3586	± 0.8308	wt. %
Ca	16. 0.318	± 0.5872	wt. %
Ba	2. 5319	± 0.0100	wt. %
V	2593	± 401	ppm
Cr	6034	± 100	ppm
Ma	2. 1327	± 0. 0100	wt. %
Fa	29. 2421	± 0. 0100	wt. %
Ni	4. 2829	± 0. 0100	wt. %
Cu	4. 5568	± 0. 0100	wt. %
Zn	2. 3982	± 0. 0100	wt. %
Se	5408	± 100	wt. %
Sr	3205	± 100	wt. %
Br	6328	± 100	wt. %

Physical characteristics

Images of the preforms and finished coconut shell (CNS) based friction composite are shown below. The CNS based brake pad exhibits a bonding strength of 3375N/S compared to 5125N/S for asbestos-based, and a minimum of 2250N/S recommended by Standard Organization. The corresponding Brinell hardness number (BHN) for the three sources is 32.3, 44.2 and 27.0, respectively. The values for the CNS sample though lower than for asbestos are within the limit recommended by Standard Organization of Nigeria (SON). The CNS brake pad shows a lower Swell and growth rate of 0.62% compared with 0.86% in asbestos based, and the maximum of 2.7% as used by Xu *et al*. (2006).

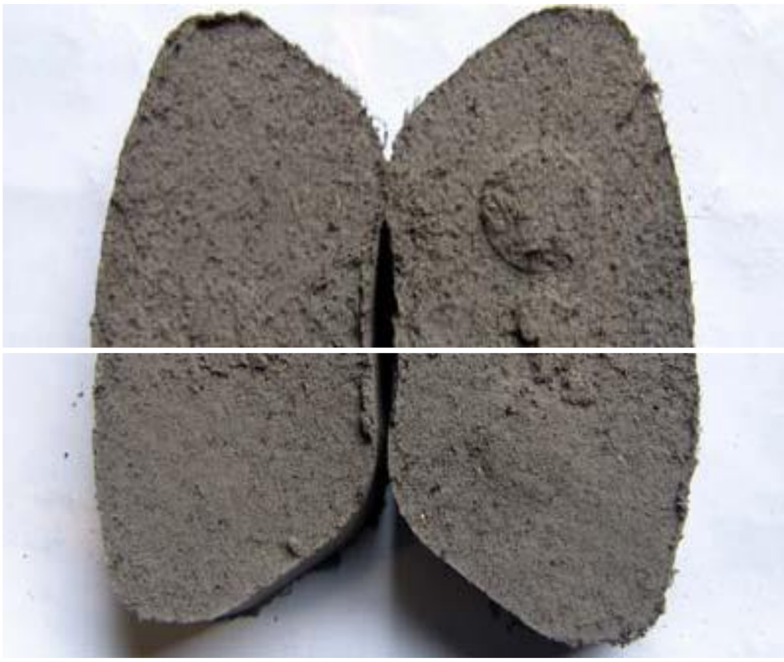

Plate 5: Perform of brake pad lining

Plate 6: Shaping and grinding of the brake pad

Plate 7: Plate of perform and finished CNS-based friction composites

Physico-Thermal Properties of Pulverized Coconut Shell

Bulk density of the pulverized coconut shell was determined using the Mass/volume relationship (Jain & Bal, 1997), a graduated empty plastic container of predetermined tare weight was filled with the sample, by pouring from a constant height, striking off the top level and weighing. The relative density was determined using a specific gravity jar, to divide the weight of the sample by the weight of water occupying the volume taken up by the sample. The jar containing a known weight of the sample was rapidly filled with water. The observed weight was then deducted from the weight of the jar when filled with water only.

The thermal conductivity of the sample was computed based on fourier law of heat transfer which is given as:

$$K = \frac{\Delta Q}{\Delta t} \times \frac{L}{A \times \Delta T} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where;

K = is the thermal conductivity;

ΔQ= the quantity of heat transmitted during the time

Δt = through a thickness

L = a direction normal to a surface of area

A = due to a temperature difference

ΔT= under steady conditions and when the heat transfer is only on the – temperature gradient.

Sample of the pulverized material was placed in a cylindrical dish (90m diameter and 12.7mm high) on a hot plate, which had been pre-heated for 3 munites, the hot plate was disconneted from the power source and a thermocouple was used to measure the temperature at the bottom of the pan and also at the surface of the material contained in the pan. Thus, the variables required in the evaluation of equation (i) were determined.

The elemental composition of the coconut shell particle was determined based on the X-Ray flourescence (XRF) analysis. Samples of the material were formed into pallets in a pelletizer with hydraulic press (Carver Inc.).The pallet were then sealed into the chamber of the X-Ray flouresence XRF (Amptek Inc.) and allowed to run for 1000s at a voltage of 25kv and a current of 50A, the resulting spectrum measured the elemental composition of the material.

The observed properties of coconut shell (CNS) were compared with those of asbestos to determined the variation in brake lining formulaion when replacing asbestos with coconut shell (CNS).

Thermal Integrity

The mass loss of the CNS and asbestos based friction composites are shown in the graph below. In both materials, the mass losses were comparable but low, up to about 300^0c. Statistical analysis using paired comparison showed no significant difference in weight loss of the two composites over the range of temperature used. Typical automotive brake lining materials are rarely subjected to temperatures higher than 399^oc (Mohanty, 2007) but when such situation arises, it is not maintained for up to 90 minutes used in the experiment. Therefore, it is believed that the CNS-based brake pad will not decompose or deform under practical application temperatures and time duration. Comparison of effect of temperature on weight of absestos and CNS-based friction composite are shown below.

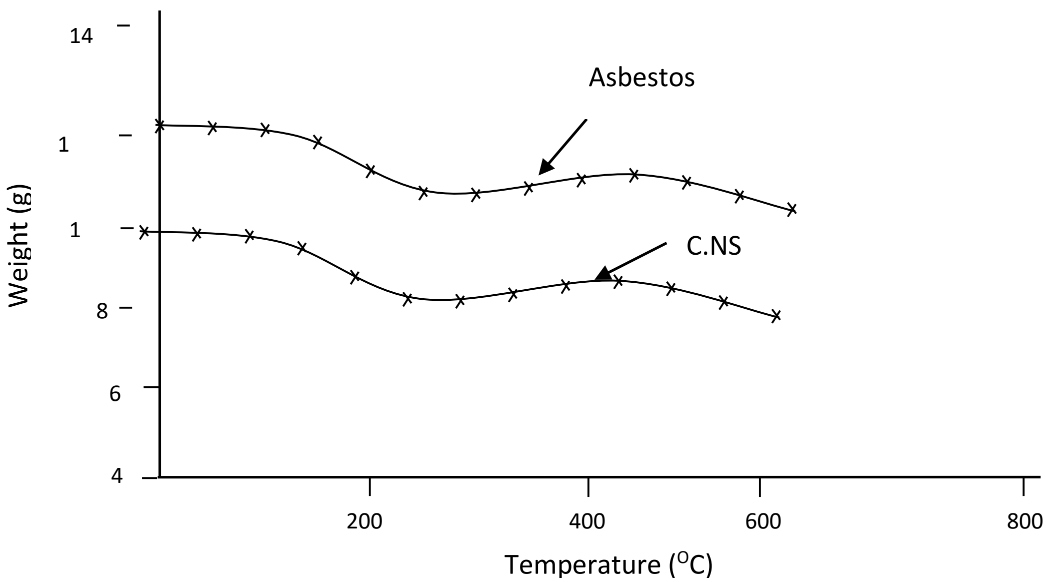

Figure 2: A graph showing comparison of effect temperature on weight of asbestos of CNS base friction composite

Wear Characteristics

Average value of wear detected in the CNS and the asbestos based friction composite were noted. Wear rate for CNS is lower than that of asbestos but both show similar trend. Regression analysis shows that the wear describes a third order polynomial relationship with run-in time. Wear rate for the CNS brake pad is 9.17E-5g/min, while for the asbestos, it is 1.11E-5g/min. the Lower wear rate of the CNS material may be due to its high abrasive properties compared to asbestos. This property is desirable in heavy truck brake lining where large braking force are involved (Blau & Jolly, 2008), furthermore, the CNS could be modified for use in other classes of automobile.

Characteristics of Friction Surface

The microstructure of the CNS and asbestos-based brake lining before and after wear test is shown in (plates 8, 9, and 10). It is clear that before wear test takes place; it is easy to identify the various ingredients in the friction element. From plate 8, CNS particles is surrounded by copper dust and other unidentifiable element. Plate 9 and 10, presents asbestos fibres surrounded by many other ingredients too. Once wear takes place, the impact of friction on friction composites has a double character: alternative for phases on friction surfaces and damaging for friction surfaces; voids are generated after wear test on both surface of plate 9 and 10. Soft copper particles are plastically deformed and smeared, while this is not the case in CNS-based friction composites (see plate 8).

Grooves parallel disk rotation appears in both base materials. The interaction between the cast iron disk and the composite material leads to the creation of iron traces on the friction surfaces. This shows that the rotor has higher Vickers hardness than the friction composite; hence the use of CNS like the asbestos does not degrade the surface of the brake disc.

Plate 8: CNC-based unworn surface

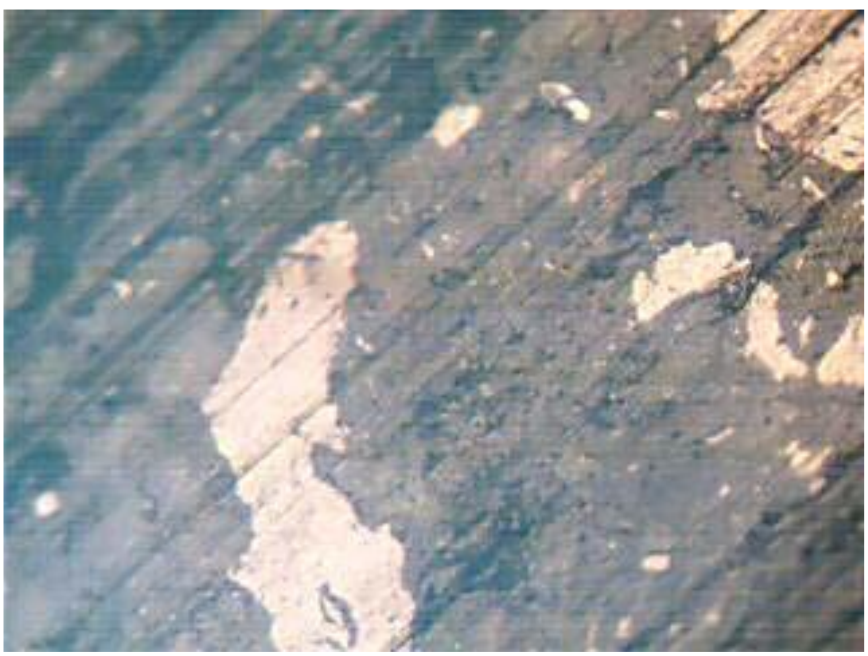

Plate 9: CNS-based worn out surface

CONCLUSION

Based on the result of the experimental work carried out in the use of alternative materials for braking system of automobiles and other industrial applications, the following conclusions are drawn:

1. Coconut shell (CNS), mild steel iron filings (MSIF), a binder, (Phenol resin powder) combined with other additives were effectively used in the formulation for the manufacture of brake pad/lining of the braking system of automobiles.
2. From the experimental results obtained in this research, tests such as: bonding test, mechanical tests, i.e., tensile test, wear test, Brinell hardness test, impact test, swell growth analysis test, and thermal analysis shows that coconut shell has a positive effect on the component produced.
3. The result also shows that both the tensile and compressive strength increases with increase in the amount of coconut shell powder and also an increase in impact strength.
4. The methods and processes involved in the manufacture of brake pad using coconut shell and other ingredients in the formulation have been followed to produce a standard brake pad comparable to the commercial ones in the market.
5. The health hazard situation involved in the use of asbestos in brake pad formulation is extremely minimized.
6. The growth of cottage industry is a catalyst for industrialization as it forms the bases for accelerated industrial transformation.

Recommendations

The result of various tests carried out shows that the overall performance of the coconut shell (CNS) in brake pad formulation is comparable with asbestos-based linings and is recommended for use in automobile brake pad/lining, since it is within the limits recommended by the Standard Organization of Nigeria (SON). Further tests of this developed CNS based brake pads is being undertaken. Therefore, more research work in this area is recommended to produce coconut shell based automotive component for new generation vehicles.

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