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DESIGN AND PRODUCTION OF ASBESTOS FREE BRAKE PAD USING CASHEW NUTSHELL

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ABSTRACT

A brake is a mechanical device used in controlling the speed of a moving vehicle using a frictional material and dissipates the absorbed kinetic energy as heat to the surroundings. A new brake pad composition has been developed with the Cashew Nutshell (CNSL), Silicon Carbide (SC), Steel Dust (SD), Carbon Black (CB), Epoxy Resin and Hardener (ERH). Five different samples of varying constituents were made with two different sieve sizes for each sample was investigated. The result showed that sample D of the 100 µm with composition 55g of (CNSL), 15g of (SC), 10g of (SD), 5g of (CB) and 15g of Epoxy resin and hardener had the best properties. The Brinell hardness value, Coefficient of Friction, Porosity, Ash content, Density and Wear rate were 75.65, 0.3528 1.925, 45.6, 1.521 kg/m³ for 100 µm and 1.17 respectively. These values are acceptable, though the 75µm samples fared better in many of the test results but lacked in the aspect of density when compared with the other sieve grades. This shows that Cashew Nutshell can be used as filler in the production of eco-friendly brake pads.

Keywords: *Brakes, Organic, Cashew Nutshell, Non-Asbestos, Tribological properties*

INTRODUCTION

Brakes are essential parts of all means of transportation. Their function is to slow or stop a vehicle by friction, converting kinetic energy to heat energy which is then dissipated (Adekunle *et al.*,2020). An asbestos free friction lining material from palm kernel shell have been developed. Both the mechanical and physical properties as well as the static and dynamic performance of produced brake pad compared well with commercial asbestos-based lining materials. However, more pad wear was observed on the PKS pad at high vehicular speeds beyond 80 km/hour which suggest that PKS is not suitable in the formulation of brake pads meant for high-speed cars (Dagwa and Ibhadode 2005, Ibhadode 2006, Ibhadode and Dagwa 2008, Deepika *et al.* 2013). Ruzaidi *et al*. (2008) produced an asbestos free brake pad composites using different fillers (palm slag, calcium carbonate and dolomite) with phenolic as binder, metal fiber as reinforcement, graphite as lubricant and alumina as abrasive. The result showed that the wear rate of palm slag composite was comparable with the conventional asbestos-based brake pad. The result was also supported by SEM micrograph. Palm slag and calcium carbonate ($CaCO_3$) brake pad composite shown better wear properties than dolomite and comparable with the conventional asbestos-based brake pads (Ruzaidi (2013).

Idris (2011) produced a new brake pad using banana peels waste to replace asbestos and phenolic resin as a binder. The result of this research indicated that banana peels particles can be effectively used as a replacement for asbestos in brake pad manufacture. Natarajan *et al.* (2012) studied the effect of ingredients on mechanical and tribological characteristics of different brake liner materials. A brake lining containing fly ash range (10%-60%), and (2) without fly ash-based friction materials were investigated. The results also showed that the friction coefficient of fly-ash was better in the range of 0.35 to 0.48 when compared with barites-based brake linings and asbestos based brake linings.

Onyeneke *et al.* (2014) developed new composite brake pad using Periwinkle and Coconut Shell., The disc brake friction lining with the geometrical specifications of Audi 90 model was produced using Periwinkle and coconut shell powder as base materials, araldite and epoxy resin as binder materials and carbon as fibre reinforcement. Aluminum, copper, zinc and cashew nut shell were used as abrasives and rubber dusts from shoe as filler. It was revealed that the co-efficient of friction of the pad material ranged from 0.4-0.65, scratch hardness of 80-85, bonding strength of 25-27Kg/cm^2 and wear rate of 0.025 mm/min to 0.06 mm/min as compared to the conventional brake pad material that has hardness of 80-85, bonding strength of 25-27 kg/cm^2 and wear rate of 0.03-0.08 mm/min. Nuhu and Adeyemi (2015) developed a brake pad using maize husks to replace the asbestos material of the brake pad, they reported that there was a reduction in the wear rate and the brake pad is environmentally stable. Swamidoss and Prasanth. (2015) worked on the fabrication and characterization of brake pad using pine apple leaf fiber (PALF). They fabricated brake pad by using pineapple leaf fiber as a reinforcement/filler. The result obtained in the work is compared with asbestos brake pad. Adeyemi *et al.*(2016) worked on development and assessment of composite brake pad using pulverized cocoa beans shells filler, the development of asbestos-free friction material from an agro-waste (cocoa beans shells - CBS) as filler element. The results show that reducing the filler content, an increase in the wear rate, tensile strength, compressive strength were observed, while hardness, density, water absorption, oil absorption and thermal conductivity varied differently. Coefficient of friction increased with increase in the filler wt%.

Bala *et al.* (2016) worked on the development of automobile brake lining using pulverized cow hooves. The results obtained showed that proper bonding was achieved as the percentage by weight of epoxy resin increased and percentage by weight of pulverized cow hooves decreased. The hardness, compressive strength, coefficient of friction, water and oil absorption, relative density and wear rate of the brake linings were determined and compared with existing brake lining properties. The result indicates that pulverized cow hooves can be used as brake lining material for automobiles. Asotah and Adeleke (2017), worked on the development of brake pad using corn husks. The result obtained showed that the brake pad produced with the corn husk having the finer 100 μm screen gave better compressive strength, higher hardness, lower porosity and lower rate of wear, consequent on the finer distribution of the corn husks particles in the matrix. Lawal *et al.* (2017), Ruzaidia, *et al*., (2011); Idris, *et al*., (2013); worked and developed brake pad from sawdust as a base material. The properties examined are microstructure analysis, hardness, compressive strength, density, ash content, wear rate and water absorption. The results obtained showed that the finer the sieve size the better the properties.

This work is part of an ongoing comprehensive study of the utilization of Cashew Nutshell (CNS), with potential application in the brake pad composite fabrication. In this study the tribological properties of Cashew Nutshell brake pad was investigated.

MATERIALS AND METHOD

Materials and equipment

The material and equipment used for this research were; Ball milling machine, Sieves (75 μm and 100 μm). Digital Weighing scale, Jaw Crusher, Electric

Heater (220/240 Volts), Hydraulic press (maximum of 100 KN/mm^2 capacity), Mixing pan and Spatula, Frank Welltest Brinell Hardness tester (Federal Institute of Industrial Research, Oshodi), Radicon MD10.00UM with automated powder diffractometer (Federal Institute of Industrial Research, Oshodi) and Pin on disk machine (University of Lagos, Akoka). For the composite developed, other constituents include; Carbon black as lubricant, Silicon carbide as abrasive, Epoxy Resin and hardener as binder and Steel slag as the reinforcing material.

Plate 1: Dried Cashew Nutshell

Plate 2: Milled Cashew Nutshell

Plate 3: sieving of Milled Cashew Nutshell

Plate 4: Silicon Carbide

Plate 5: Carbon Black

Plate 6: Can containing Epoxy Resin and Hardner

Plate 7: Steel Slag

The base raw material Cashew Nutshell was collected from the Cashew Nut Processing unit of the Directorate of University farm, Federal University of Agriculture, Abeokuta, it was cleaned to remove impurities and properly sun-dried. It was thereafter crushed to make milling faster and then ground into powder using the ball milling machine. The resulting powder was then sieved into grades of 75 µm and 100 µm which are the sieve grades to be investigated. Other experimental constituents which were purchased at Ojota, Lagos were crushed using the Jaw crusher, classified and contained in well labeled containers for easy identification. They were then added in appropriate quantity per sample as stated in the formulation tables.

Method

The formulation were determined by varying the amount of composition of Cashew Nutshell in each sample, for this, a value ranging from 40% to 60% (with a step of 5%) was chosen. The value of 60 was not exceeded because the raw material is organic and too much of that in the composition will reduce the thermal conductivity. 15% of epoxy resin was used for the formulations.

Table 1: Composition of samples A-E for all the two sieve grades (75 µm and 100 µm).

S/N	Material	Sample A (%)	Sample B (%)	Sample C (%)	Sample D (%)	Sample E (%)
1	Cashew Nutshell (CNSL)	40.00	45.00	50.00	40.00	60.00
2	Epoxy Resin and hardener	15.00	15.00	15.00	15.00	15.00
3	Steel dust (slag)	25.00	20.00	15.00	10.00	5.00
4	Carbon Black	5.00	5.00	5.00	5.00	5.00
5	Silicon Carbide	15.00	15.00	15.00	15.00	15.00

Samples production: The formulation quantities expressed in percentage weight was measured into mixing vessel and thoroughly mixed for about 15 minutes to ensure homogeneity. The desired amount of epoxy resin was then poured into a separate container with the required quantity of hardener added (in the ratio 2:1) to form the matrix and thoroughly stirred for about 5 minutes to obtain uniform mixture.

Figure 1 shows the samples produced.

Thereafter, the matrix mixture was poured onto the powdered friction material mixture and stirred further to obtain a paste-like homogenous mixture. This mixture was then transferred into a designed mould previously oiled for easy removal of the sample. The mould containing the friction materials was then cold pressed with the hydraulic press after which it was left for 24hours to dry and harden. After removing from the mould, the sample was then cured in an oven for 8 hours at 120ºC.

Experimental procedures

Three test samples were made for each composition and for each sieve size and the sieve size investigated were 75 µm and 100 µm. These samples were then tested for hardness, Compressive strength, co-efficient of friction, wear rate, water absorption rate, density, porosity and thermal conductivity and Ash content was determined. All tests were conducted at room temperature.

RESULT AND DISCUSSION

Figure 2 shows the results of Brinell hardness test carried out. Sample size of 100 μm had the highest hardness value of 30.82, 46.40, 29.80, 75.65, and 46.48 BHN for samples A, B, C, D, and E respectively. This can be attributed to increase in surface area due to reduced particle size which allowed for increased binding ability with the epoxy resin. This result is similar to what was observed by Bashar *et al*., (2021) and Bala *et al.,* (2016) stating that the hardness values decrease as the particles size increases.

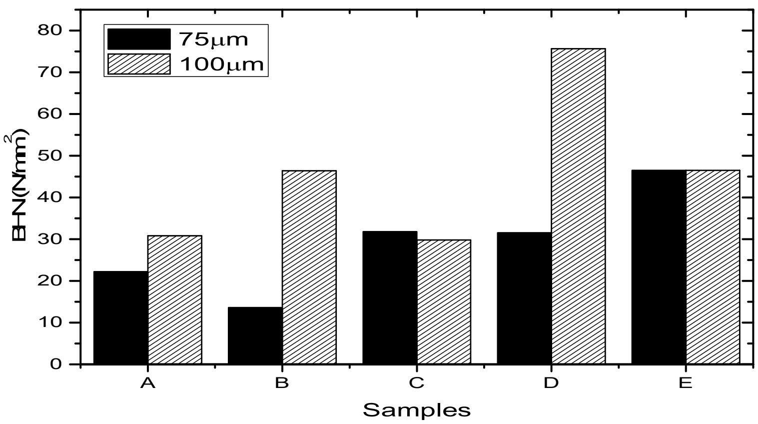

Figure 2: Variation of hardness properties of test samples

Co-efficient of friction

Figures 3 shows the result of the co-efficient of friction of the produced samples with the sieve grade sizes, 75 μm sieve grade samples have the higher co-efficient of friction of 0.3326, 0.3426, 0.2154, 0.3528, 0.3432. From figures 3, it can be observed that the co-efficient of friction of each sample decreases gradually as the sieve size increases. This can be attributed to the fact that the surface area and pore packaging capability of the filler in the resin are decreasing with increasing particle size. The co-efficient of friction for the lower sieve grade size was compared to that of asbestos brake pad (0.35), also Oyeneke *et al*., (2014) reported in the work they carried out during the production of brake pad using periwinkle and coconut shell that the co-efficient of friction should not exceed 0.4 and from the result obtained it was verified that 75 μm fared better as shown in table 2 and found to be coherent with the conventional brake pad.

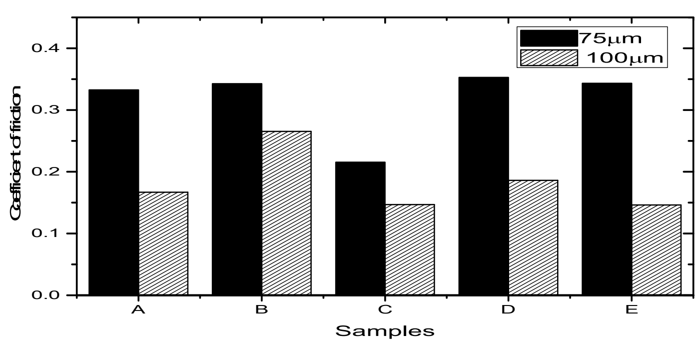

Figure 3: Relationship between Co-efficient of friction of test samples

Density

Figure 4 shows the bar chart illustration of the plot density against sieve grade of the samples and the density values for the samples A, B, C, D and E for 75 µm are 1.320 kg/m^3, 1.255 kg/m^3, 1.308 kg/m^3, 1.317 kg/m^3, 1.461 kg/m^3 and for 100 µm sieve grade 1.211 kg/m^3, 1.451 kg/m^3, 1.452 kg/m^3, 1.321 kg/m^3 and 1.401 kg/m^3. For 75 µm for sieve grade it was noticed that as the particle size of cashew Nutshell increases, the density values decreases except for some isolated cases as seen in figure 4 this is due to the fact that for smaller particles, the compressibility was higher because they were more porous i.e. the decrease in density is as result of increase in particle size which allowed for increased packing. The 75 µm sieve grade for sample E had the highest value of (1.461) which was as a result of closer packing of Cashew Nutshell particles creating more homogeneity in the entire phase of the composite body. The result agrees with what was observed in (Agbodion *et al.,* 2010).

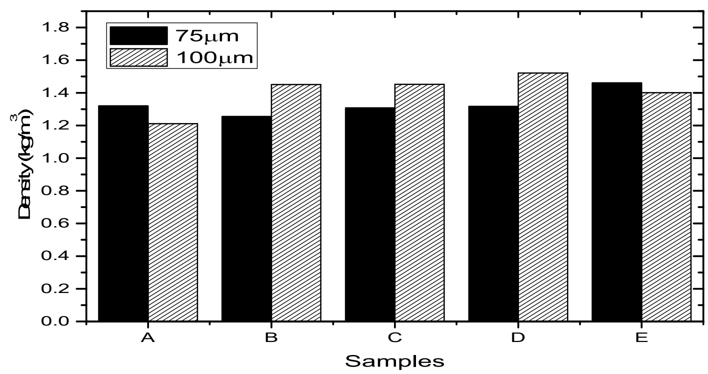

Figure 4: Variation of density (g/cm^3) with test samples

Ash content

Figure 5 shows the ash content values for the various samples, for sample A – E for 75 µm sieve grade are 45.64, 52.18, 45.68, 58.01, and 57.45, for 100 µm sieve grade the values are 56.91, 59.18, 59.18, 45.64, 59.01, and 59.45 respectively. It was noted that the ash content best value was recorded for 75 µm sieve grade, this was as a result of the increase in the particle sizes which brings about the increase in the pore size of the sample, when compared with the existing works it fared better than conventional brake pad which is 54% and hence for the safety of vehicles, sieve grade of 75 µm should be considered during the production.

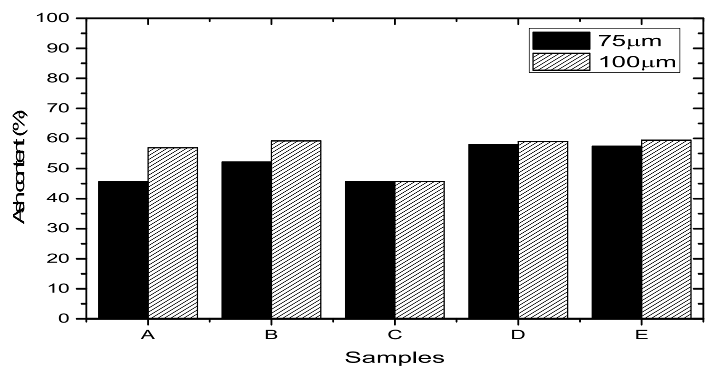

Figure 5: Variation of Ash content (%) with test samples

Porosity

Figure 6 shows the porosity test result for the samples, the porosity of the produced samples A,B,C,D and E for 75 µm are 3.061, 4.060, 2.693, 3.452 and 1.925, for the 100 µm sieve grade samples are 6.498, 5.695, 3.768, 4999 and 3.261 respectively. The porosity of the produced samples increased as the sieve grade increased. This can be traced to the increase in the number and size of pores in the samples as the sieve size increases. It can be observed from figure 6 that sample 75 µm gave the best properties as a result of a very good dispersion of the Cashew Nut shell. These results are consistent with the earlier observations by (Idris *et al*., 2015; Deepika *et al*.,(2013) and Yawas *et al*., (2016)).

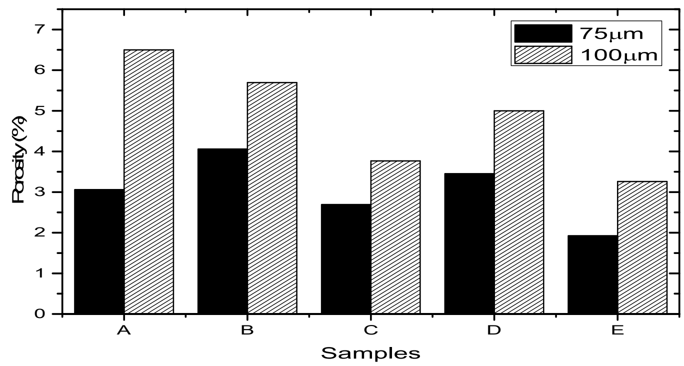

Figure 6: Variation of Porosity (%) with test samples

Wear rate

Figure 7 shows the result for the wear rate test carried out on the samples A – E produced using the 75 µm and 100 µm, the wear rate values for the 75 µm sieve grade are 1.17, 3.44, 2.33, 5.76 and 3.43, 100 µm sieve grade values are 2.30, 3.25, 3.46, 3.76 and 7.44 respectively, it was observed that 75 µm sieve grade had the least wear rate values and the least wear rate value was recorded for sample A of the 75 µm, this allow for higher or closer packaging which brings about stronger binding of the Cashew Nutshell particles within the composition. According to Elakhame *el al.* 2014, the reason for the best value obtained for the wear rate was as a result of the hardness value result. Moreover, in order to produce a durable and acceptable brake pad that will not fade away quickly, it is advisable to use 75 µm with least wear rate property. Also, Ibhadode and Dagwa, (2008); Adekunle, *et al.,* (2020); recommended that particle of size lower than the 125µm could be used to develop brake pads for vehicles with higher vehicular speed.

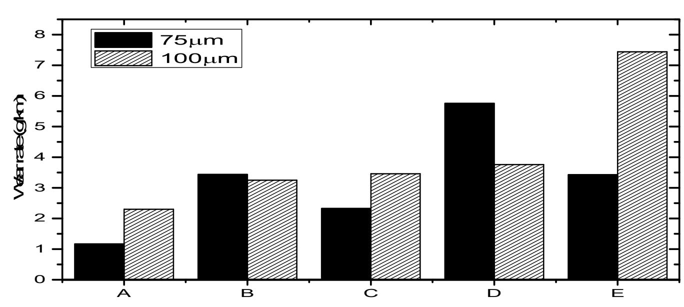

Figure 7: Variation of Wear rate (g/km) with test samples

Table 2: The summary of result findings compared with the existing ones

	Asbestos	Egg shell	Palm Kernel shell	Periwinkle	PKS + Coconut shell + Maize Husks	Bagasse	Cashew Nutshell
Swell in water	0.9	3.21	5.03	0.39	0.91	3.48	2.425
Hardness (BHN)	101	99.1	92	116.7	127.8	100.5	75.65
Wear rate (g/km) x 10^{-2}	3.8	4.0	4.4		2.146	4.2	3.21
Density (g/cm^2)	1320				0.251 – 0.372		1332
Co-efficient of friction	0.35						0.35
Ash content (%)	54		34			34	51.79

CONCLUSION

It can be concluded that sample E (60% cashew nutshell (CNSL), 15% epoxy resin and hardener, 5% steel dust (slag), 5% carbon black and 15% silicon carbide) of 75 µm sieve grade gave the best properties in some of the test results as the co-efficient of friction, thermal conductivity and densities of the produced samples decreased in value as sieve grades increased while the porosity and wear rate increased as sieve grade increased. Hardness of the samples produced does not correlate well with the conventional brake pad and that is the only issue recorded with the properties of the developed cashew nutshell brake pad. Based on the above test results of these brake pads composite, Cashew Nutshell can be used as filler / as an organic replacement for asbestos because the derived properties are within the range of that of the standard commercial brake pads.

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