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DEVELOPMENT OF ASBESTOS-FREE BRAKE PAD USING COCONUT SHELL POWDER AND COCONUT SHELL ASH AS FILLER MATERIALS WITH GUM ARABIC AS THE BINDER

Shuaibu Y.A[1],
Ameh S.E[1],
Abubakar J.A[1],
Musa A.J [2], and
Abubakar.G.M[1]
[1]Department of Mechanical Engineering Technology, Federal Polytechnic, Damaturu, Yobe, Nigeria
[2]Department of Renewable Energy Engineering Technology, Federal Polytechnic, Damaturu, Yobe, Nigeria.
E-mail: sundayameh@fedpodam.edu.ng; +2348061106314

Abstract
This paper presents the development of asbestos-free automobile Brake Pad using the combination of Coconut Shell Powder and Coconut Shell Ash as Filler materials along with other ingredients Such as Mild Steel and Graphite Powder as the friction addition and abrasive materials respectively, with gum Arabic as the binder for the production of Brake pad .This study was done with a view to utilize the characteristics and huge potentials of Coconut Shells which are largely deposited as waste to replace asbestos which has been confirmed to possess carcinogenic substance which are harmful to human health.. Nine sets of Brake Pads were developed using three sieve sizes of 154µm, 180µm and 450µm Coconut Shell particles and 18% resin using compressive moulding. The physical and mechanical properties evaluated and compared with the values of the commercial (asbestos based) Brake Pad are Hardness, Density, Water and Oil absorption. The result obtained showed that Hardness of the samples produced increased as the sieve particle sizes decreases from 450µm to 154µm, while the density, water and oil absorption decreases as the content of the Coconut Shell Powder and Coconut Shell Ash were increased in the formulation. The promising values obtained for hardness, density, water and oil absorption are 186.2BHN, 1.332g/cm3, 1.353%, 0.700%. Although the sample developed using the 154µm sieve Coconut Shell particles exhibited the highest hardness potential, but it can be seen from the results that all the sample developed using Coconut Shell particles compared brilliantly with that of commercial Brake Pad, hence it can be used as a good replacement for asbestos based Brake Pad.

Keywords: Coconut Shell Ash, Coconut Shell Powder, Gum Arabic, Hardness, Density and Water/Oil absorption

1. INTRODUCTION

A brake is a mechanical device that inhibits movement by absorbing energy from a moving system (Sadiq et al.,2019) Brake pads are steel backing plates with friction material bound to the surface with rivet or high temperature adhesives (Adegbola et al., 2017). Brake pads composites contains binders, structural materials, fillers and frictional additives. (Abutu et al., 2017). Frictional materials containing metal powders are called semi-metallic friction material, while those with asbestos are called asbestos friction materials, while those that do not contain asbestos are called asbestos-free friction materials (Afolabi et al., 2015). The purpose of friction brakes

is to decelerate a vehicle by transforming the kinetic energy of the vehicle to heat, via friction, and dissipating that heat to the surroundings.

As a part of a commercial truck or automobile, Brake materials have additional requirements, like resistance to corrosion, light weight, long life, low noise, stable friction, low wear rate, and acceptable cost versus performance. There are two common types of friction brakes drum/shoe brakes and disk/pad brakes. Brake pads consist of four major materials: binders, fillers, friction materials, and reinforcements (Tajudeen et al., 2021). Owing to the significant roles which Brake plays in automobiles, lots of studies have been conducted to develop carcinogenic free Brake Pads using locally sourced materials, such as Cashew nut Shells, Egg Shells, Palm Kernel Shells Periwinkle, Sawdust, Cow Hooves, Cow Horn, Bananas peels, and Groundnut Shell, together with other additives. However, one of the materials that have shown tremendous potential for friction material production is Coconut Shell. Coconut shell is an exoskeleton of an invertebrate composed of 27.7% pentose, cellulose 26.6%,29.9% lignin, 8% water, 4.2% extraction solvent, 3.5% uronate anhydrous and ash 0.6,and some bioactive compounds such as methylxanthines and phenolic (Bharatha et al.,2019).

The use of Coconut shell Ash as substitute for asbestos has been studied, and a replacement of up to 5% was found suitable for an excellent tribological property of Brake Pad (Vivek et al., 2020). However, these materials are expensive and are not readily available in the developing world. Consequently, numerous researches have been directed towards utilizing human friendly materials as replacement for asbestos portions in engineering components. (Yawas et al., 2016). Ossai et al., (2021), carried a study using locally available waste Coconut Shells (CS) as possible replacement for asbestos-based Brake Pads. The Coconut-based Brake Pads produced were tested for their physic- mechanical properties and compared with values obtained from commercial Brake Pad used as control sample (Adekunle et al., 2019). The study showed that further reduction of the grain size below 90μm and matrix impregnation with metals of good thermal conductivity could provide significant improvements to properties of the Coconut based Brake Pad. To produce high quality composite Brake Pads, a significant amount of binder is required. Most Brake Pads are made using urea Formaldehyde resins or other manufactured binders such as Melamine urea formaldehyde (MUF),isocyanides and phenol-formaldehyde which are toxic to human bodies(Kim et al.,2011). Gum Arabic which is eco-friendly has been considered a good substitute for urea Formaldehyde resin since it possess some unique properties that makes it an excellent binder. Edokpia et al., (2014) produced used Cashew nut along other ingredient with gum Arabic to produce asbestos free composites for automobile Brake Pads. The result of their work showed that composites possesses some promising values for hardness, compressive strength, wear rate, thermal resistance, specific gravity and microstructure. It is against this backdrop that this study is undertaken to develop a green alternative materials of Coconut Shell Powder and Coconut Shell Ash with Gum Arabic as binder for Brake pads production. The availability, cost of material, and properties are the primary considerations in choosing the materials for developing the Brake Pad.

2.0 Materials and Methods

2.1 **Materials**

In this study, the materials used include, Coconut Shell Powder, Coconut Shell Ash, Mild steel dust, Graphite Powder, and gum Arabic. The materials used are shown in plate 1

2.2. **Equipment**

The major Equipment used in this study include the Hammer mill, Mallet, the FTIR spectrophotometer, a HBRV-1875 Rockwell Vickers Hardness tester, Electric cutter, Drill press with model No:ZJ5116, Camry digital weighing machine, Vibratory sieve of different aperture sizes, local stove, stirrer, welding machine, oven, electric hot plate, electric grinder, local cooking stove. The equipment used are shown in plate 2

3. **Development process**

The Coconut shells which were obtained from Damaturu central market located at Abasha ward in Damaturu, local government area of Yobe State, Nigeria, were broken into pieces using sledge hammer in the mechanical engineering department of Federal Polytechnic Damaturu, Yobe State and was later pounded in a local mortal to reduce the particle size. Thereafter the broken pieces were grounded to powder with the aid of a Hammer mill, and sieved using an Automatic vibratory Sieving machine with different Mesh sizes to obtain a fine powdery product. The Ashing was done by burning Coconut Shells in an open local domestic stove in an operation which lasted for 3 hours. The coconut shell powder obtained and the resultant ash obtained from the burnt coconut shell were subsequently taken to multi user laboratory at the Ahmadu Bello University Zaria Kaduna State to determine the chemical and elemental characteristics of the product with the aid of an Infrared Transform Spectrophotometer. This is done to determine some desired some properties and the suitability of these products for the manufacturing of automobile parts during the course of the study. This asbestos- free brake pads were developed using series of unit operations which includes; Measuring and Weighing of the ingredients, mixing, stirring, cold and hot mixing, cooling, post-curing and finishing (Katsina et al.,2019).The study utilizes the combination of the aforementioned ingredients in some specified proportions. The mixture was mixed and stirred vigorously for 15 minutes and subsequently transferred into a prepared mold kept on a hot plate at temperature of 150^{o}c and 100,000N/cm^2 for two minutes and subsequently subjected to cold pressing and hot pressing and allowed to cool at room temperature. The samples were removed from the mould and cleaned thoroughly and afterwards heat treated using at a varying temperature of 120^0 for 8 hours in a hot oven with model No: BDC 12805, at the Mechanical Department, Federal Polytechnic Damaturu, Yobe State as adopted from Ilori et al., (2021). In this study, three different samples of Mesh sizes, 154μm, 180μm and 450μm of Coconut Shell Powder, Coconut Shell Ash and other ingredients were used to produce Nine (9) samples from respective sieve sizes and labeled respectively for the experimental analysis.

Table 1 Chemical Composition of Coconut Shell Powder

SN	Compound	Full Name	Concentration
1	Wax(g)	-	5
2	C	Carbon	11. 00%
3	K_2O	Potassium oxide	1.36%
4	SiO_2	Silicon dioxide	0.89%
5	CL	Chlorine	0.89%
6	Fe_2O_3	Iron(II) oxide	0.45%
7	MgO	Magnesium oxide	0.42%
9	Na_2O	Sodium oxide	0.31%

10	CaO	Calcium oxide	0.26%
11	M_OO_3	Molybdenum(VI) oxide	0.19%
12	S	Sulphur	0<LLD
13	Al	Aluminum	0<LLD
14	P	Phosphorous	0<LLD

(Multi -User Lab,Chem Dept. ABU ,Zaria)

Table 2 Chemical Composition of Coconut Shell Ash

SN	OXIDE CONTENT	PERCENTAGE
1	SiO_2	33.61
2	Al_2O_3	24.31
3	Fe_2O_3	16.12
4	CaO	4.861
5	MgO	1.790
6	MnO	0.891
7	Na_2O	0.901
8	P_2O_5	0.311
9	K_2O	0.741
10	SO_3	0.861

(Multi -User Lab, Chem Dept. ABU, Zaria)

Table 3 Formulation table for the brake pad

S/N	Ingredients	A	B	C
1	Coconut Shell Powder	35	40	42
2	Coconut Shell Ash	15	22	23
3	Mild Steel dust	20	10	10
4	Graphite Powder	15	13	10
5	Gum Arabic	15	15	15

Physical and Mechanical Analysis Test

Hardness Test

The hardness test was performed with the aid of HBRV-1875 Brinell Vickers Rockwell Testing Machine for hardness and shearing to determine the Brinell hardness of samples. The spherical indenter is 2.5 mm in diameter. Samples were cut to a specific size and were fixed into the tensiometer. Acompression load of 980 kg for 25 seconds was applied. The indented diameter was measured with aid of calipers and the following equation was used to calculate the Brinell hardness

BHN [=P/ [πD/2] × [D-✓D2-d2

Density Test

The density test was conducted on the developed samples using the Archimedes principle since they are of irregular shapes by measuring their masses in air and when immersed in water. The following mathematical expression was used to determine the densities.

Density=W/V

Where w denotes weight of sample in air and V denotes Volume of water displaced.

The unit of density is g/cm^2.

Water Absorption Test

The water absorption tests were carried out to determine the sample's vulnerability and porosity when submerged in water for a specified period of time. In order to determine thae water absorption properties of the Brake pad, the samples were first weighed and readings taken and recorded as W_0. The samples were then immersed in water for 6 days. The Specimens were removed from water, thoroughly cleaned to remove any remaining water from the surfaces, and reweighed to determine the new weights recorded as W_f. The following relation was used used to calculate the percentage absorptions.

% Absorption=% Absorption= W_0- W_1/ W_1 x 100

Where W_0 is the weight before immersion and W_1 is the weight after immersion in water. Oil Absorption Test

Similarly, the Oil absorption tests were carried out to determine the sample's vulnerability and porosity when submerged in oil for a specified period of time. During this test, the samples were first weighed and readings taken and recorded as W_0.rhe samples were immersed in SAE40 automotive engine oil for 144 hours (6days). The samples were removed from the oil, thoroughly cleaned to remove any remaining oil from the surfaces, and reweighed to determine the new weights which were taken and recorded as W_1. The equation below was then used to determine the percentage absorptions.

% Absorption=% Absorption= W_0- W_1/ W_1 x 100

Where W_0 is the weight before immersion and W_1 is the weight after immersion

Result

Table 3 presents the result of the physical and mechanical properties of the developed pad in comparison with the controlled sample as reported by Adebayo et al., .2022

TABLE 3.

SN	A(154μm)	B(180μm)	C (450μm)	Control values
Hardness	186.2	178.41	173.90	154.3
Density	1.380	1.344	1.332	1.533
Water absorption	1.368	1.360	1.353	3.113
Oil absorption	0.972	0.763	0.700	3.103

TABLE 4. Comparison between Developed Sample and Commercial (Controlled values)

Property	Developed sample values	Controlled sample values
Hardness	186.2	154.3
Density	1.332	1.533
Water	1.353	3.113
Oil	0.700	3.103

Discussion

From the Comparison of the results of the physical and mechanical properties presented in table 4, between the produced sample and the controlled sample as the following analysis has been put forward

Hardness Assessment using HBRV-1875Brinell Rockwell Vicker hardness machine

The results obtained as presented indicates that the hardness increases with a decrease in the particle size of the filler materials. The sample produced using sieve size 154µm exhibited the highest hardness value and this could be attributed to the reduction in surface area of the particle size which results to an increase in bonding ability with the binder (gum Arabic). The results when compared with the results achieved when other materials were used in other similar researches showed it can be used for the production of brake pad. The hardness potential of this developed samples could be attributed to the presence of fe_2O_3, Cao, $SiO_{2,,}$ k, Zn, which is present in the Coconut Shell Powder and Coconut Shell Ash as shown in table 1 and 2 respectively. The optimum value of hardness obtained from the developed pad is 186.2 BHN while the control sample value is 154.2 BHN with the least hardness value been 173.90 BHN. This results conform to the reports of Achebe et al., 2018 where an increase in palm kernel particles was confirmed to be used as a better substitute for asbestos increased hardness

Density Assessment

The result of the experiment in comparison with the controlled values as presented in table 4 shows that there was a decrease in density with increase in the content of the Coconut Shell Powder and Coconut Shell Ash in the formulation .This decrease in density could be attributed to the low density ratio of both the Coconut Shell Powder and the Coconut Shell Ash. However, the results obtained are within the acceptable limits for Brake Pad application. The lower density shows that the Coconut Shell particles based Brake Pad would exhibit a lighter weight than the commercial asbestos based Brake Pad. This observation conforms to the result obtained and reported by Elakhame **et al**., 2017

Absorption Assessment

The results of the absorption test presented in table 4 and 5,revealed that the water and oil absorption ability of the samples decreased from sample 1-3 indicating that the higher the content of the Coconut Shell Powder in the formulation, the less the absorption .

Conclusion

After a critical analysis of the results obtained from the study, the following conclusions have been put forward;

- A good interfacial bonding was observed as the particles sizes of the filler materials were decreased from 450μm to 154.μm
- Hardness, density was observed to increase with a decrease in the particle size from 450 μm -154μm, while water and oil absorption potential was observed to decrease with decrease in particle size. This was attributed to the increase in the content of Coconut Shell Powder and Coconut Shell Ash and the effective compression achieved leading to the absence of space and the impermeability nature of the Coconut Shell Powder and Coconut Shell Ash.
- The samples produced with all the Sieve sizes compares favorably with that of the commercial pad. The results showed that Coconut Shell based products has the required properties suitable for use as Brake Pad material to replace asbestos in the manufacture of Brake Pads since it gave results which are within the range for Brake Pad manufacture and it is readily available, cheap and harmless. However, the compositions with 154μm is recommended for use since its particles size has properties that can effectively replace asbestos in Brake Pad manufacture, since it exhibited a greater hardness potential alongside other great Brake Pad properties.

References

1. Abutu J., Lawal S.A, Ndaliman, M.B., and Araga R.A ,(2013). Effect of process parameters on the ultimate Tensile strength of coconut shell Reinforced friction lining, Proceedings of the 30th AGM& International for Mechanical engineer, Kaduna
2. Achebe, C.H. Chukwuneke, J. and Anene, F.A. "A retrofit for asbestos-based brake pad employing palm kernel fiber as the base filler material", J. Mater. Des. Appl., pp.1–8. (2018)
3. Adegbola J.O., Adedayo S.M., and Obigbeagbon, U.O (2017). Development of Cow bone Resin composites as a frictional material for automobile braking system. Journal of Production engineering.20 (1), 69-74
4. Adekunkle N.O, Oladejo K.A, Kuye S.I and Aikulola A.D, (2019). Development of Asbestos-free Brake pad using Bamboo leaves. Nigerian Journal environmental sciences and Technology (NIJEST) Volume 3, No 2, pp. 342-35
5. Adebayo. A, Mojeed O, Peter O,Adekunkle A, Peter I, Tajudeen P and Hassan .I(2022) Development and Analysis of friction material for eco-friendly brake pad using seashell composite, Scientist Iranica,Doi:10:24200/sci.2022,59835.6454
6. Afolabi M, Abubakar O.K, Lawal S.A and Raji. A (2015).Experimental investigation of Palm kernel shell and Cow Bone Reinforced Polymer composite for brake pad production, International journal of chemistry and materials Research, 3(2), page,27-40.
7. Ali L.Y, Ahmed M.M, Habiba D.M and Fatima M. S (2016). Determination of Physicochemical properties of gum Arabic as a suitable Binder in Emulsion House Paint, International journal of Environment,vol.5,Issue 1,Dec-feb 2015/2016, ISSN 2091-2854
8. Bhratha S, Prabu B, Gunasegaran .V, (2019), Journal of Nano science and Nanotechnology 19(7):4123-4128, Doi:101166/jnn.2019.16299.
9. Bala K.C, Okoli M and Abolarin M.S (2016). Development of Automobile Brake lining using pulverized Cow Hooves, Leonard's Journal of Engineering sciences,15(28)pp,95-108.

10. Darlington, E., Chukwumaobi, O., and Patrick. (2015). Production of Eco -friendly Brake pad using raw materials sourced locally in Nsukka, Journal of energy and Technologies policy,5(11)46-534
11. Edokpia R. O, Aigbodion V.S, Obiorah O. B, Atuanya C.U (2014). Evaluation of the properties of Eco friendly Brake Pad using Egg shell particles-Gum Arabic science direct,Elservier,B.v,Doi:10.1016/J.rinp.06.003
12. Elakhame, O.O, Olotu, T.O Abiodun, I.E Akinsanya, P.O Kaffo O.E and Oladele Z.U (2017). Production of asbestos-free Brake Pad using Periwinkle Shell as Filler material Production International Journal of Scientific and Engineering Research, volume 8, issue 6.
13. Ilori O, & Abiodun O (2022), Effect of mechanical and physical properties on Brake Pads produced from Bagasse, Banana peels and Periwinkle Shell, Lautech Journal of Engineering and Technology, volume 16, No 1
14. Jaafar N.S (2019). Clinical effect of Arabic Gum (acacia): Mini review. Iraqi.J. Pharm. sci., 28, 9-16.
15. Katsina C.B,Lawal S.S,Nuhu A, Abdurrahman A .S(2019), Review if the Composition, processing, materials and properties of Brake Pad production, Journal of physics conference series.
16. Kim K.H, Shamen A.J & Jong T.L (2011). Exposure to formaldehyde and its potential human health hazards, Journal of Environmental science and Health, part Volume 29, issue 4
17. Ossia C. V.Akuro B. A., Ekpruke E. O. (2021) Effect of particulate grain size on the Physico- mechanical properties of green automobile Brake Pads from Coconut shells. Journal of Advanced manufacturing science and Technology, 44(4):135-144
18. Sadiq S.l, Katsina. C and Abdul Kareem T.A (2020). Development and production of Brake pad from sawdust composite, academic direct.org
19. Sadiq S.l, Nuhu A.A and Katsina C .B, Abdurrahman A.S (2019). Production and Testing of Brake pads composite made from Cashew nut shells and plant Gum binder, Journal of NimechE,Vol.9 No 2,pp.54-63, printed in Nigeria.
20. Tajudeen P, Abdul Karim B.R, Hassan K.I, Peter .O, Babatunde M.A, Muhammed N& Ishaq F.O. (2021).Production of Automobile Brake Pad from Palm Kernel Shell, Coconut Shell, Sea Shell and Cow Bone, Adeleke University Journal of Engineering and Technology (AUJET),volume 4,No 2, 92-101(2021)
21. Vivek S, Jayakumari S, Stephen B.S, Suresh G, Javeed M.D,& Arulmurugan S (2020). Tribological and mechanical properties of bio-based reinforcement in a friction composite material, Material (Rio de Janeiro) 25 (03), 2020, https//doi.org 1590/5151
22. William S P, and Phillips. G.O (2000).Gum Arabic. In .G.O Phillips and P.A Editors, Handbook of hydrocolloids, Vol.9, 6, pp.155-168, New York press.
23. Yawas D.S, Aku S.Y and Amaren S.G (2016). Morphology and Properties of Periwinkle Shell asbestos- free Brake Pads. Journal of King Saud University of Engineering Sciences, 28,103-109.

APPENDIX

Plate 1:

Coconut shell

Coconut shell powder

Coconut shell ash

Graphite-powder

Mild steel dust

Gum Arabic

Plates 2: Equipment used

Hammer Mill

Vibratory Sieve

Local Cooking Stove

Camry digital Weighing machine.

Mallet