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DEVELOPMENT OF AUTOMOBILE DISC BRAKE PAD USING DOUM PALM (*HYPAENE THEBAICA*) NUT SHELL

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ABSTRACT
This article is aimed at producing a frictional material to replace asbestos in the manufacture of automobile brake pads. Due to the health hazard of asbestos fiber, alternative materials were used for making the non-carcinogenic brake pad. In the study, doum palm nutshell and Arabic gum were used as base materials and matrix (binder) respectively. A set of brake pads were produced by varying the doum palm nut shell particle sizes from 150µm, 300µm, 425µm, 600µm to 850µm with the binding materials of different weight composition ratios of the base material to the binder which includes; 90:10, 85:15, 80:20, 75:25, 70:30 according to the ASTM standard.The properties examined with their respective results were moisture content(25.05%), true density(811.10kg/m^3), bulk density (370.51kg/m^3), porosity(46.45%)hardness (115HRB),compressive strength(88.1N/mm^2), density(2.4gm/m^3),and flame resistance(15%), waterto oil absorptions(0.38: 0.35). The results showed the finer the particle size the better the properties and were compared with that of commercial brake pad (asbestos based),optimum formulation laboratory brake pad and Palm Kernel Shell based (PKS).Itwas found that the sample containing 150µm of particle size gave the best mechanical properties in all. The result obtained at 150µm of doum palm nut shell particles for commercial purpose. Hence, this research suggested that doum palm nut shell particles can be effectively used as a replacement of asbestos for brake pad.
KEY WORDS: Brake disc, Doum palm, Brake pad, Matrix (binder), Asbestos, Palm Karnel shell

1.0 INTRODUCTION

A brake pad is a vital component forbraking system. It is a frictional material which when pressed against the brake disc dissipates heat energy generated during the application of the brake. The brake pad is more efficient compared with the brake lining used in the brake drum system (Gerlici*et al.*, 2018).

The purpose of friction brakes is to decelerate a vehicle transforming the kinetic energy of the vehicle to heat via friction and dissipating the heat to the surrounding. As part of a commercial truck or automobile, brake material have additional requirements like resistance to corrosion, light weight, durability, low noise, stable friction, low wear rate, acceptable cost versus performance (monoharam*et.*, *al* 2019). For over 80 years now asbestos has dominated the industry as the best frictional materials. Its content in vehicle brakes varies from about 30%-70%. The positive characteristics of asbestos are its thermal stability, good frictional properties, thermal insulation, good wearing ability, it is strong yet flexible. Due to these aforementioned characteristics asbestos has been prominently in use as frictional material (Blau, 2001).

In spite of its good properties, asbestos is being withdrawn from all the applications where there is a possibility of alternate material due to the health hazards associated with the processing and handling of asbestos fiber particles. The use of asbestos fiber was avoided due to its carcinogenic nature. Therefore, a new friction material and brake pad was developed, (Murthur*et al.*, 2004).

Several researches have been carried out in the area of developing asbestos-free brake pads. The use of coconut shell, bagasse, palm kernel shell (PKS) was investigated by Dagwa and Ibhadode(2006).

Researches all over the world are focusing on ways of utilizing either industrial or agricultural wastes as a source of raw materials in the industry. These wastes utilization will not only be economically, but will also result to foreign exchange earnings and environmental pollution control. For example, bagasse is the residue fiber remaining when sugar cane is pressed to extract the sugar. Some bagasse is burned to supply heat to the sugar refining operation. Until recently, the remaining 90% (empty fruit bunches, fibers, fronds, trunks) was discarded as waste, and either burned in the open air or left to settle in waste ponds. This made the Sugar-cane processing industry's waste contributes significantly to CO_2Aigbodion (2010). Hence, the aim of this work was developing a new asbestos free brake pad using doum palm nut shell as the base material.

Doum palm nut shell is readily available especially in the northern part of the country and it is not toxic (Orwa*et al.*,2009).Doum palm fruits (*hyphaenethebaica*) is popularly known as goribainHausaFigure 1.1. It grows naturally and is predominantly found in Chad, Zaire, Senegal and northern Nigeria including Borno state. It is listed as one of the useful plants of the world.A typical doum palm plant is as shown in figure1.1. Doum palm fruits are commonly found in Borno state, especially in Damasak, Monguno, Marte, Kukawa areas and are consumed by both adults and young individuals. It is also found within Maiduguri metropolis in abundant. The husk from the fruit can be pounded to form powder or cut off in slices, the powder is often dried then added to food as a flavouring agent (Fletcher, 1997).

Figure 1.1: Doum palm plant

The quantity of doum palm fruits consumed every day is very high in the northern part of the country (Nigeria) particularly in Borno state.Consequently, most of the doum palm nut shell are discarded as waste products which contribute to environmental pollution, hence there is a need to recycle such waste (doum palm nut shell) into useful product (brake disc pad). The doum palm nut fruits are as shown in figure 1.2 while the doum palm nut shell is shown in plate 1.1.

Figure 1.2: Doum Palm Fruits

The brake pad presently in use is generally made from asbestos fiber for its heat resistance to heat. In spite of its good properties, it's being withdrawn from all applications because of its carcinogenic nature against health risk, it is necessary to use alternative materials for making non carcinogenic brake pad (Dagwa and Ibhadode, 2005). It has now been replaced by a mix of alternative fibers such as mineral fibers, cellulose, aramid, chopped glass, steel and copper fibbers.

The quantity of doum palm fruit consumed every day is very high especially in the northern parts of the country (Nigeria) and as a result, most of the doum palm nut shells are discarded as waste products which contribute to environmental pollution.

2.0 EXPERIMENTAL PROCEDURE

2.1 Materials

The materials used during the course of this work are; gumarabic, doum palm nut shell, engine oil (SEA 20/50) and water.

2.2 Method of Production

The doum palm nut shell sieve sizes of; 150µm, 300µm, 425µm, 600µm and 850µm were mixed with arabic gum at varying percentage compositions of 90:10, 85:15, 80:20, 75:25, 70:30. Trial combinations of these percentage compositions is shown in table 2.1, where both the weights of doum palm nut shell and arabic gum were measured and the respective percentage compositions used. A sample from each of the sieved sizes according to the percentage compositions of 90:10, 85:15, 80:20, 75:25, 70:30 doum palm nut shell and Arabic gum were then produced using these compositions. Each composition was blended and mixed thoroughly using a stirrer before transferring it to a mold having an inserted back plate. Using predetermined weights, the materials were weighed for every sample formulation that is, samples 1, 2, 3, 4, and 5 which include 150µm, 300µm, 425µm, 600µm and 850µm, according to ASTMstandard.

Table 2.1: A Trial Experiment Using 150µm, 300µm, 425µm, 600µm and 850µm, of Doum Palm Nut Shell Granules

Trial S/No	(%)of; Arabic gum	Weight of Arabic gum(g)	Doum palm nut shell(granule)	Weight of doum Palm nut shell	Total weight of sample	Total weight of sample(g)
1	10	3.5	90	51.5	100	55
2	15	5.25	85	49.75	100	55
3	20	7.00	80	48.00	100	55
4	25	8.75	75	46.25	100	55
5	30	10.50	70	44.50	100	55

2.3 CHARACTERIZATION

The following physical and mechanical tests;Density, water and oil absorption, hardness, flame resistance, wear and friction and compressivetests were carried out in order to determine the properties of the brake pad produced.

3.0 RESULTS AND DISCUSSION

Density of the Samples

Figure 3.1 shows the density measurement results. From the Figure,, the density of the sample increased as the sieve size decreased from 850µm to 150µm. The higher density of doum palm nut shell at 150µm implies that the particles are closed packed which reduces the possibility of air infiltration which may initiate crack in the manufactured product (Mathur*et al*., 2004). The increase in density as the particle size decreased from 850µm-150µm can also be attributed to the increase in bonding achieved, that is increased packing of the particles resulting in reduction in porosity. The higher density which resulted to closer packing or particles creates more homogeneity in the entire phase of the brake pad composite body. The levels of density obtained are within the recommended values for brake pad applications Kim *et al.*, (2003).The formulated brake pad of doum palm nut shell is of lower density in comparison with the corresponding values of asbestos which is 2.8 kg/m^3. The lower density shows that the doum palm nut shell brake pad would be lighter that the asbestos brake pads. Consequently, doum palm nut shell particles are more suitable as filler material than asbestoson the account of the overall weight of the brake pad. The result is in line with the earlier work of Aigbodion*et al.*, (2010).

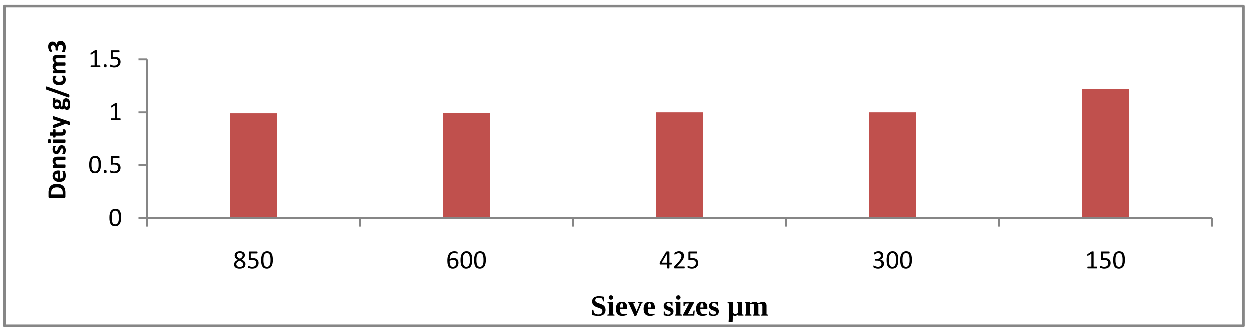


Figure 3.1: variation of density with different sieve size

Water Absorption Test

The results of the water absorption test by the formulated brake pad were as shown in Figure 3.2. The results shows a decrease in water absorption as the particle size decreases. This may be attributed due to the decrease in pores because of the close interphase packing achieved (Osarenmwinda*et al.,* 2001). For the doum palm nut shell based brake pad increase in the interphase bonding between the binder and the doum palm nut shell particles led to decrease in the porosity level.

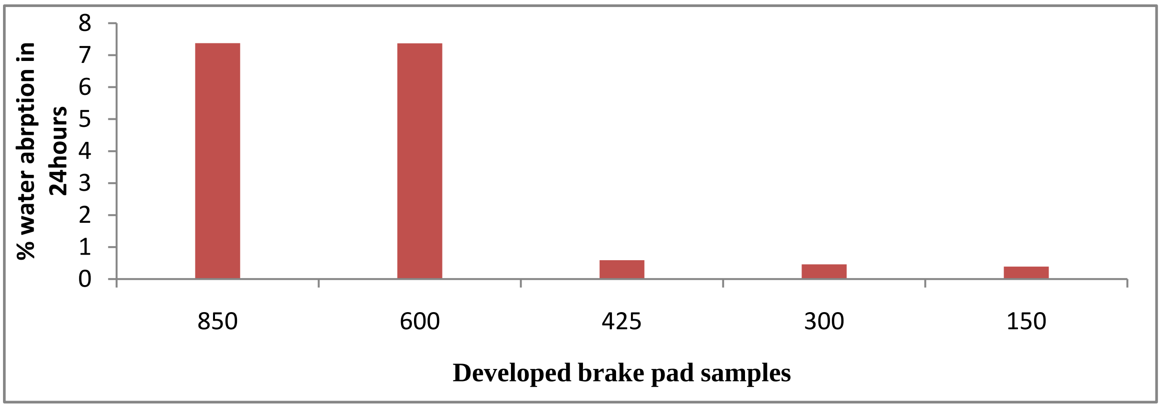


Figure 3.2: Water absorption of the developed brake pad

Oil Absorption Test

The results of the oil absorption by the formulated brake pad are as shown in Figure 3.3 and Table A3 in appendix A. The results show a decrease in oil absorption as the particle size decreases. The swelling that occurs during the oil absorption is the sum of two components which include swelling by hygroscopic particles and the release of compression stresses imparted to the brake pad composite during the compaction of material, Aigbodion, (2010). The release of compression stresses, known as spring back is not recovered when the brake pad composite is in a dry state. Higher sieve size resulted in more water absorption because more pores are observed (Yesnik, 1996). This result was influenced by porosity and voids formed in the brake pad samples. Theoretically, lower oil absorption by the brake pad will result in higher friction coefficient and wear rate due to higher contact area between the mating surfaces. These result obtained for the formulated brake pad composite at 150µmdoum palm nut shell particles are within the recommended standard. These results agree with earlier observations of the work done by and Mathur*et al.* (2004).

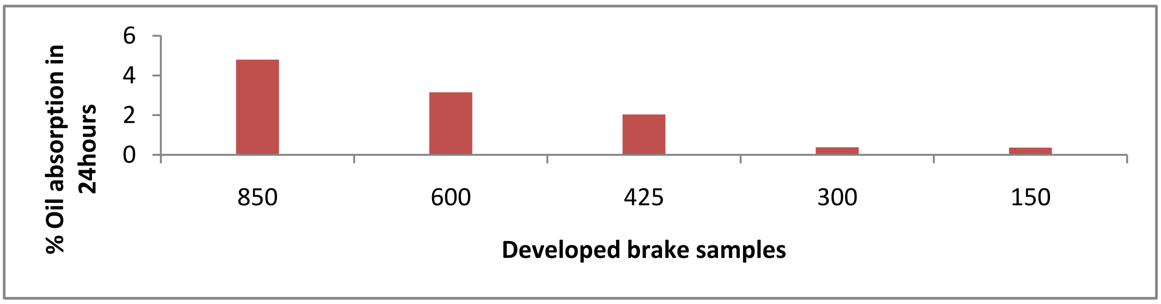


Figure 3.3: Oil absorption of the developed brake pad

Hardness Values

The hardness values of the formulated brake pad were obtained using a Brinell hardness tester. The results obtained were as shown in the bar chart in Figure 4.4. From the bar chart in Figure 4.3, it is clear that the hardness increased with decrease in particles size. The sample 150µm sieve size has the highest hardness value of 115 HBN. The high hardness for the 150µm sieve grade was a result of reduced particle size that is increased in surface area which resulted to increase in bonding ability with the binder (Arabic gum). The hardness value for the material was compared with other materials from other researches as shown in the Table 4.2 which indicated an acceptable result with the findings of other researchers. It was found that the hardness values of doum palm nut shell particles based brake pad is slightly higher than that of asbestos at 150µm size but within acceptable limit (Aigbodion*et al.*, 2010). Therefore, it can be recommended for used as a brake pad material.

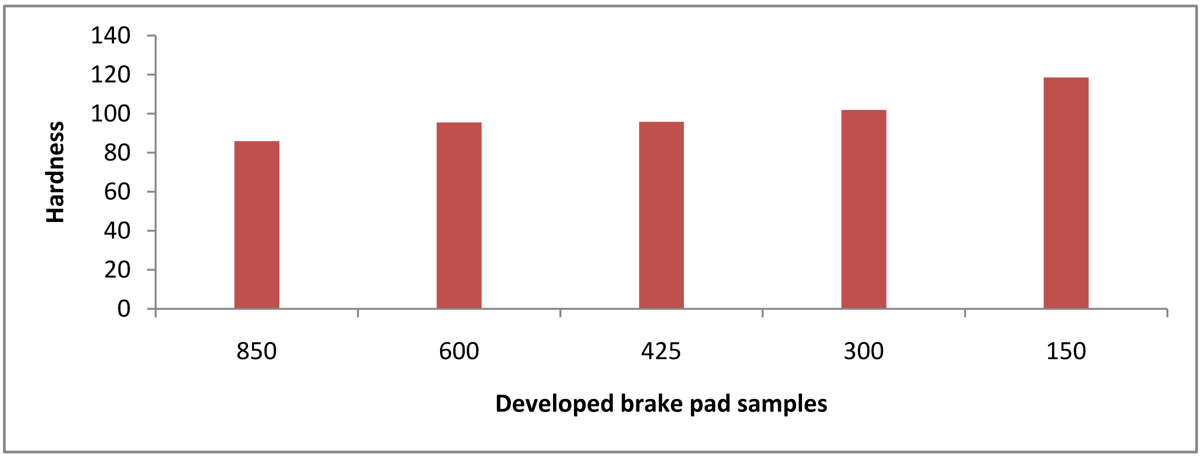
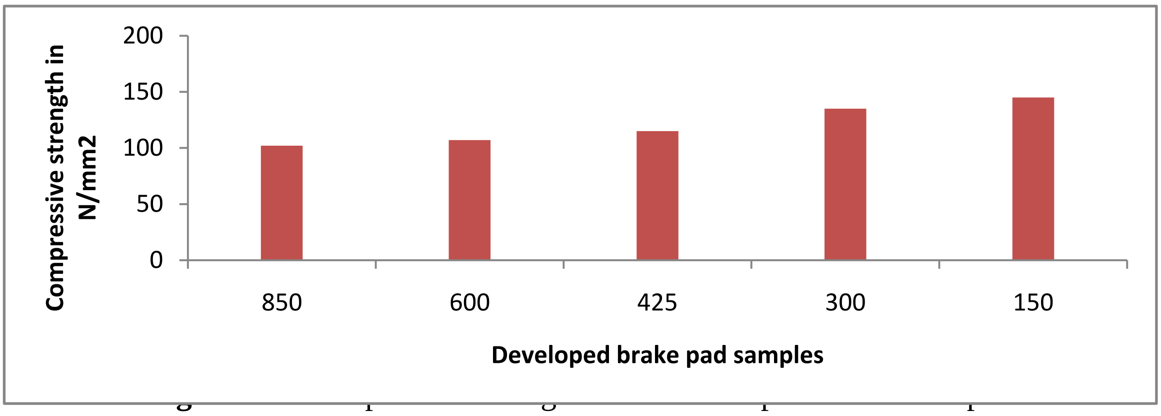


Figure 3.4: Hardness values of doum palm nutshell

Compressive Strength

The result of the compressive strength of the developed brake pad is as shown in the bar chart in Figure 4.5. It is also clear as seen in Figure 4.5 that the compressive strength of the developed brake pad increased as the particle size decreased. This may be due to the hardening of the binder particles. Brake pad formulation with 150µmdoum palm nut shell particles showed the highest compressive strength compared to other sieve size used, this is because the smaller the pores the more compact is the mixture. The150µmdoum palm nut shell showed a significant increase of compressive strength (Rajiva*et al.*, 2016). The values obtained were within acceptable limit as compared with those already existing, so it is recommended for use as a base material for brake pad production.

The decrease in compressive strength as the particle size increased is due to the interference of particles in the deformity of the binder. This interference is created through the physical interaction and the immobilization of the binder by the presence of mechanical restraints thereby reducing the strength, Mohanty (2007).



Wear Characteristics of the Developed Brake Pad

The wear characteristics of the formulated doum palm nut shell was determined where a pin-on-disc test apparatus were used to investigate the dry sliding wear characteristics of the samples as per ASTM standards for wear test (Aigbodion*et al*., 2010). It can be seen in Figure 4.6 (a-d) that as the sliding speed, load and temperature increase, the wear of developed brake pad also increased. The wear of the 850µm particle size is more than those of the other samples at all sliding speed, loads and temperatures because it particles are not well packed. As the sliding speed and temperature increase the wear rate of the samples increases, as the sliding speed and temperature increases the wear rate of the samples increases.

However, the wear rate decreases with decreasing the particle size since the smaller the particle size the higher the packing. A decrease in particle size reduces the wear rate when the load applied is low, the wear loss is quite small, and increase with increase in applied load. It is quite natural for the wear rate to increase with applied load. A similar trend was also observed independently for the different wear distances as a function of load and speed (Aigbodion*et al*., 2010). Consequently, the effect of particle size on the brake pad composite wear resistance is better at low load. With higher loads contact temperatures became high and plastic deformation occurs with the consequence of high wear.

Figures 3.5 (a, b, c and d) show the variation of wear rate with sliding speed, applied load and temperature of the developed brake pad.

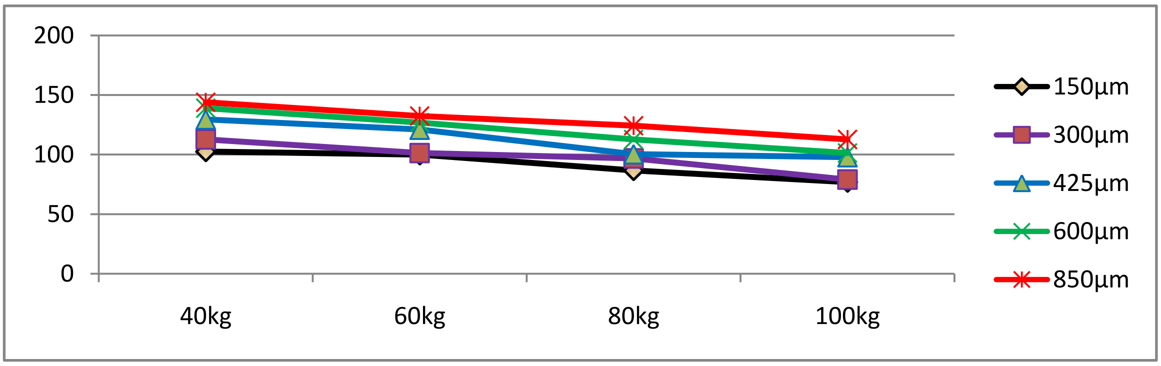


Figure 3.5(a): Variation of wear (mg) of the developed brake pad with varying load at constant speed 2.4m/s, time 45 minutes at 150°C

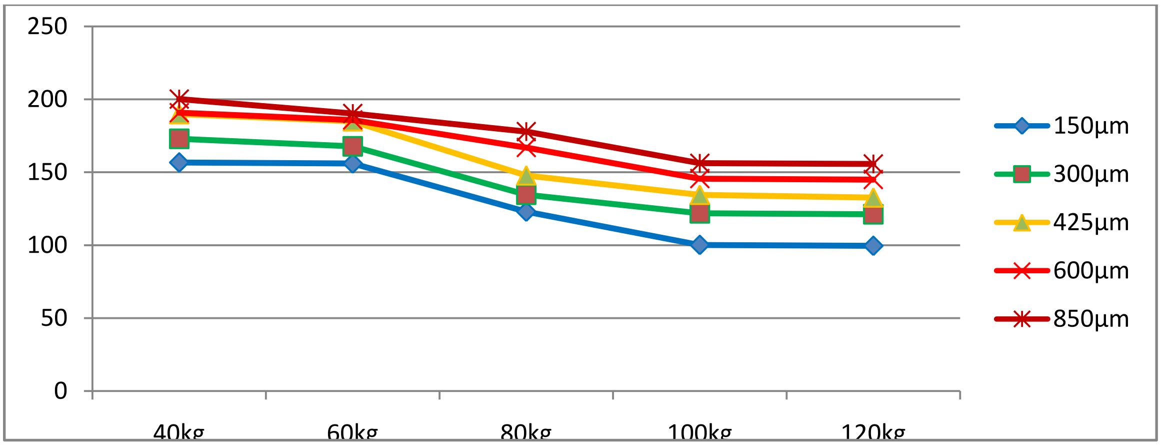


Figure 3.5(b): Variation of wear (mg) of the developed brake pad with varying load at constant speed 2.4m/s, time 45minutes at 250°C

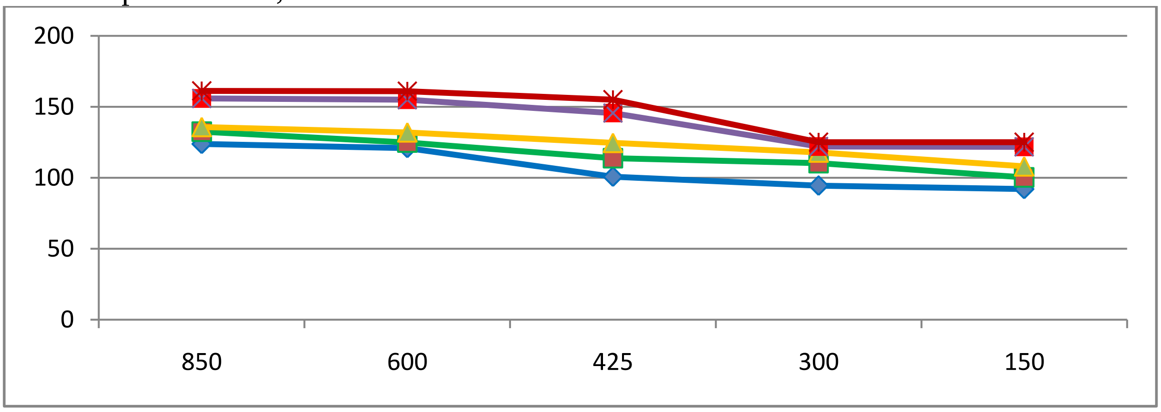


Figure 3.5 (c): Variation of wear (mg) of the developed brake pad with varying load at constant speed 2.4m/s, time 45 minutes at 250°C

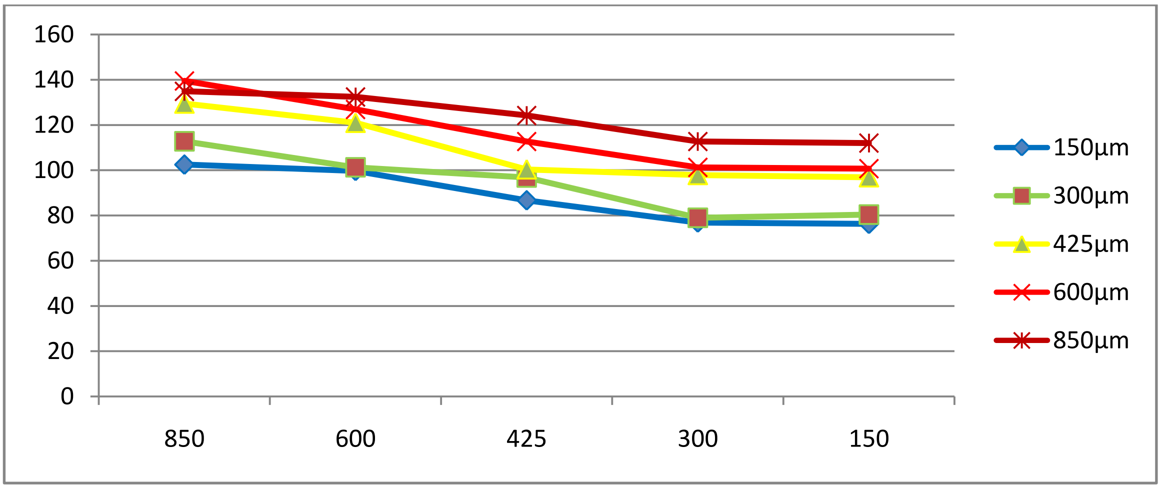


Figure 3.5 (d): Variation of wear (mg) of the developed brake pad at varying speed at constant load 120kg, time 45minutes at 150°C

Coefficient of the Developed Brake Pad

The result of coefficient of friction of the developed brake disc pad is as shown in the figuresand figure 3.6 (a-d) show variation of co-efficient of friction with applied loads, sliding speed and temperatures of the developed brake pad and the commercial brake pad. The coefficient of friction for both the developed and commercial brake pads decreases as the applied loads, sliding speed and temperature increased and for the developed brake pad, it also decrease as the doum palm nut shell particle size decreases.

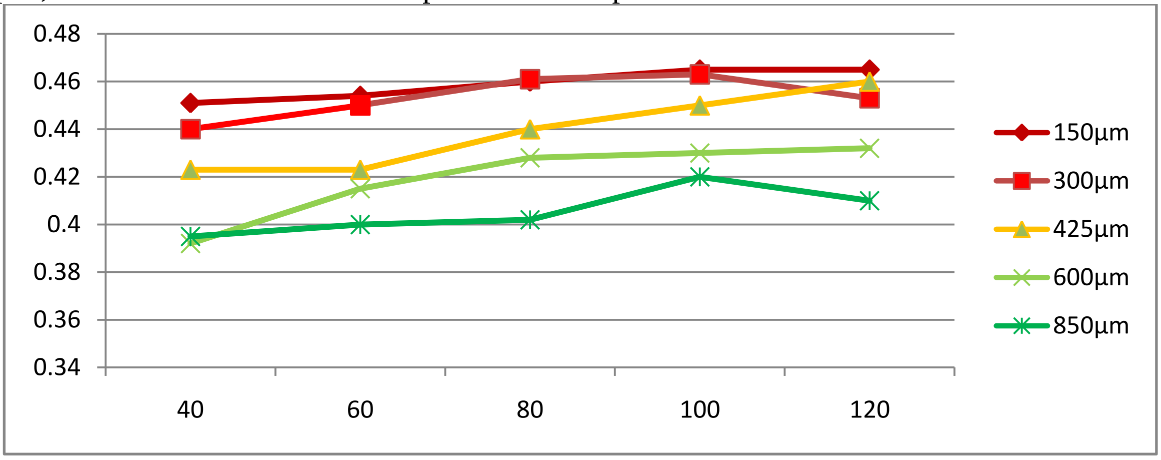


Figure 3.6 (a): Variation of coefficient of friction of the developed brake pad with varying load at constant speed, time at 150^{o}C.

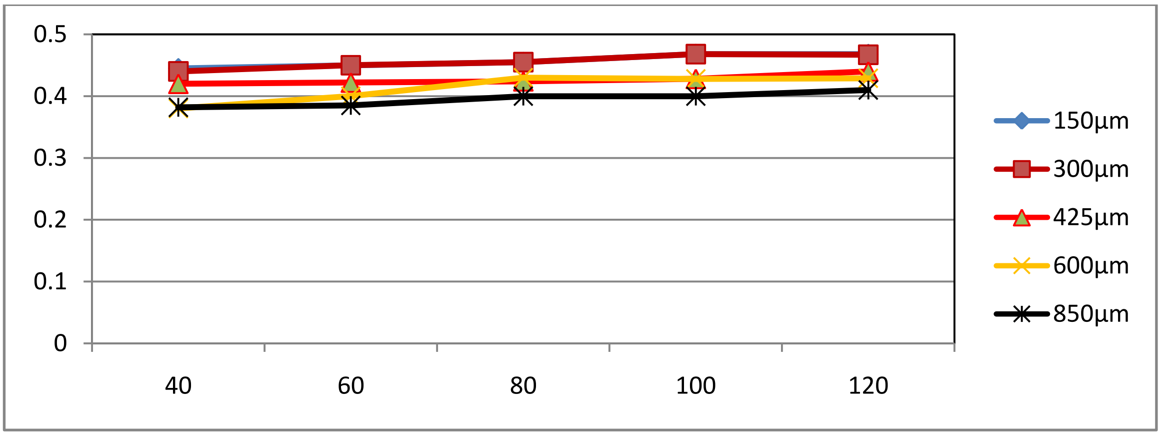


Figure 3.6 (b): Variation of coefficient of friction of the developed brake pad at varying load at constant speed, time at 250^{o}C

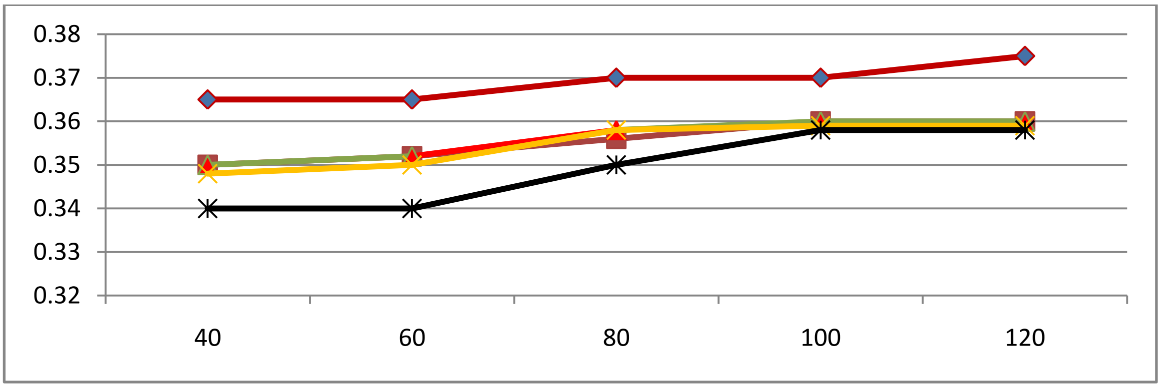


Figure 3.6 (c): Variation of coefficient of friction of developed brake pad at varying speed and at constant load, time at 150^{o}C

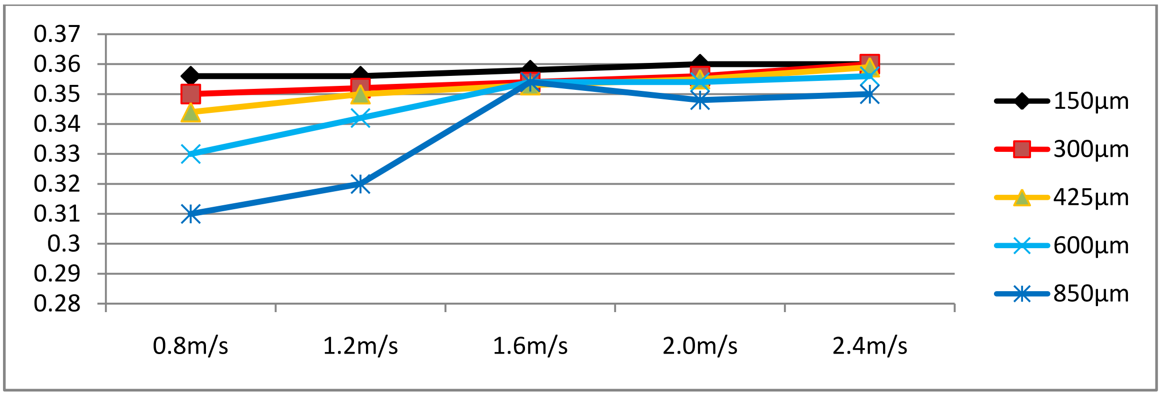


Figure 3.6 (d). Variation of coefficient of friction at varying speed at constant load, time at 250 ^{o}C

The decrease in wear rate of the doum palm nut shell based pads compared to that of the commercial brake pad that is asbestos based. Brake pad composite may also be composite may also be attributed to higher load bearing capacity of hard materials and better interfacial bond between the particle and the binder reducing the possibility of particle pull out which may result in higher wear. The improvement in wear resistance accompanying the presence of decreasing particle size of the doum palm nut shell in the binder is due to an increase in average hardness values and compressive strength. The wear rates obtained for this doum palm nut shell brake pads of at 150-300µm size fall within the automotive standard ranges for the production of automotive brake pad, Warren and Daniel (2008).

The friction coefficient (µ) also decreases when the applied loads, sliding speed and temperatures increased. The amplitude of the friction fluctuation was seen at all the stages. Due to sliding surface irregularities, temperature, speed and applied. Load cause stick-slip oscillation as observed in friction profiles. This decreased could be explained by the appearance of significant plastic deformation of pin surface, Mohanty (2007). Again the effect of particle sizes shows a marked effect as higher friction was recorded for brake pad composites as the particle size decreased. This marginally higher friction coefficient can be attributed to the higher number of particles present in the brake pad composite.

From the result, the frictional coefficient of the doum palm nut shell based brake pad do not only fall within the industrial standard range of 0.3-0.45 for automotive brake pad systems, Nicholson (1995) but are better than the values obtained from the commercial brake pad.

Comparison Result (Summary of result findings compared with existing ones)

The result of this work indicates that sample containing 150µm particles size gave better properties than other samples tested. Hence, a decrease in particle size leads to the best properties. The result of formulation of 150µm particle size was further compared with those of the commercial brake (asbestos) and other laboratory formulated brake pad-that is, Palm Kanel Shell Based (PKS) as shown in the Table3.1, which were tested under similar conditions, Nicholson (1995) and Aigbodion*et al.*, (2010).

Table 3.1: Summary of Result Findings Compared with existing Ones

Properties	Asbestos Based	Palm kanel shell based	FormulatedDoum palm nutshell based (150µm)
Specific gravityg/cm^3)	1.89	1.65	1.25
Friction Coefficient	0.3-0.4	0.440	0.41
Thickness swellin water (%)	0.9	5.03	0.38
Thickness swell in SEA oil (%)	0.30	0.44	0.35
Hardness Values(HRB)	101	92.0	115
Compressive Strength (N/mm^2)	110	103.5	88.1
Thermal Resistance	Charred ash 9%	Charred ash 46%	Charred ash 15%

The results in the table 3.1 showed that the formulation using doum palm nut shell pads produced higher frictional coefficient, wear, hardness and compressive strength than those of the commercial brake pads. The percentage of swelling in water and oil showed no significant difference. The results are in close agreement; hence asbestos free brake pad can be produced from these formulations.

Mould

A mould made of steel sheet metal to be used in the moulding process was fabricated. This was made in a shape identical to that of a brake pad already existing-that is, Mercedes Benz car 230E. It was made by folding a steel sheet of metal of height 3mm to the shape of that which is already existing(Mercedes Benz car 230E) and the joint was arc welded. Themould prepared isas shown in plate 3.1.

Plate 3.1: A fabricated mould

Moulding Process

The different weighed contents (compositions of doum palm nutshell and arabic gum; 90:10, 85:15, 80:20, 75:25, 70:30) were put in a bowl and thoroughly mixed by the use of stirring rod (according to the ASTM standard).

The steel backing plate was smeared with binder (Arabic gum) to ensure proper sticking of lining to the backing plate and positioned into the mould. The steel backing plate is as shown in plate 3.2.

Themixture was transferred into a compressive mould and pressed into the required shape before being ejected (Dagwa and Ibadode, 2005).

The ejected brake pad was allowed to be sundried for about 48 hours. Plate 3.2 is a test sample of the produced brake pad.

Plate 3.2: A Steel backing plate

The function of the steel backing is to transmit the force from the caliper pistons to the friction material. It also contains retention features such as holes or serrated edges to provide a better anchor point for the friction material.

Finishing Process

After the moulding processes, finishing operations were done on the brake pads. The surfaces of the constructed brake pads were leveled to acquire a uniform thickness as well as a uniform surface finish. This was done by the use of a grinding machine and file to reduce the excess materials (Ibadode*et al*., 2005). The formulated brake pads are as shown in plate 3.3.

Plate3.3: The formulated brake pad

4.0 CONCLUSION

A brake disc pad of materials free of asbestos was produced. The base material used in the production wasdoum palm nut shell (granule) and Arabic gum was used as a matrix (binder). Doum palm fruit is available in abundant quantity especially in the northern parts of the country (Nigeria) and the nut shells are discarded as waste products which contribute to environmental pollution. Hence, this study succeeded in converting this agricultural waste into useful product-disc brake pad.

The physical properties of doum palm nut shell which include moisture content, true density, bulk density and porosity were determined.

The locally available material (doum palm nut shell) were used to produce formulations for five different samples of different sieve sizes; 150µm300µm, 425µm, 600µm and 850µm which were then used to produce a brake disc pad. Sample 1 with 150μm of doum palm nut shell granule gives the best properties and compared with those of commercial brake pad.

Test for hardness, flame resistance, frictional coefficient, density, water/oil absorption, wear and compressional test were carried out on the produced sample and it was in relative agreement with the existing ones and within the standard provided by ASTM.

Evaluation of the developed brake pad was carried out successfully using Mercedes Benz car-230E. Therefore, materials used for manufacture of the brake pad could be obtained locally within Nigeria.

REFERENCES

1. Aigbodion V. S., Akadike U., Hassanku S. B., Asuke F., Agunsoye J. O. (2010) Development of Asbestos Free Brake Pad Using Bagasse. *Journal of Tribology in Industry. Vol. 32. No.1, Pp.12-17.*

2Blau, P. J. (2001). Compositions, Functions, and Testing of Friction Brake Materials and their Additives. Being a Report by Oak Ridge National Laboratory for U.S Department of Energy: **www.ornl.gov/webworks/cppr/y2001/rpt/112956.pdf**

3. Dagwa, I. M. and Ibhadode, A. O. A. (2005). Design and Manufacture of Experimental Brake

4. Dagwa, I. M., and Ibhadode, A. O. A. (2006). Determination of Optimum Manufacturing Conditions for Asbestos free Brake Pad Using Taguchi Method.*Journal of Engineering Research and Development, Vol. 5, No. 4, Pp.1-8.*

5. Fletcher R. (1997) Listing of Useful Plants of the World. Austrelia New Crops http: www.newcrops.uq.edu.au/listing/hyp haenthebaica.htm

6. JurajG., Myakola G., Kataryna K. and Olga P (2018). Assessment of Innovative Methods of Rolling Stock Brake System Efficiency Increasing. *ManufacturingTechnologyVol.18, No 1*

7. Mathur, R.B. Thiyagarajan, P. and Dhami, T.L. (2004). Controlling the hardness and TribologicalBehaviour of Non-asbestos Brake Lining Materials for Automobiles. *Journal of Carbon Science, vol. 5, No. 1, Pp. 6-11.*

8. MonoharamS., Vijay R., Linin S. andMohamed K. (2019). Experimental Investigation on theTribo-Thermal Properties of Brake Friction Materials Containing various Forms of Graphite: A Comparative Study. *Arabian Journal for Science and Engineering, Vol. 44, Issue 2, Pp. 1459-1473.*

9. Orwa C., Matua A. Kindt R., Jamnadas R., and Anthony S., (2009) Agro-Forest Tree Data Base: A Free Reference and Selection Version 4.0 (**http://www.worldagroforestry.org/sites/treedatabase.asp**)

10. Osarenwinda J. O. and Bekewei I. A. (2011) Production of Automobile Brake Pad Using Cow Bone. *Nigerian Journal of Engineering Research andDevelopmentVol. 4. No.3. Pp.15-24.*

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