

Development of Asbestos - Free Brake Pad Using Bagasse

Development of asbestos-free brake pad using bagasse was investigated with a view to replace the use of asbestos whose dust is carcinogenic. The bagasse were sieve into sieve grades of 100, 150, 250, 350 and 710 μ m. the sieve bagasse was used in production of brake pad in ratio of 70%bagasse-30%resin using compression moulding. The properties examined are microstructure analysis, hardness, compressive strength, density, flame resistance, water and oil absorption. The microstructure reveals uniform distribution of resin in the bagasse. The results obtained showed that the finer the sieve size the better the properties. The results obtained in this work were compared with that of commercial brake pad (asbestos based) and optimum formulation laboratory brake pad Palm Kernel Shell based (PKS), the results are in close agreement. Hence bagasse can be used in production of asbestos-free brake pad.

Keywords: Bagasse, Density, Microstructure, Hardness and Wear

1. INTRODUCTION

Brake pads are important parts of braking system for all types of vehicles that are equipped with disc brake. Brake pads are steel backing plates with friction material bound to the surface facing the brake disc. Different types of brake materials are used in different machines [1-2].

The brake pads generally consist of asbestos fibers embedded in polymeric matrix along with several other ingredients. The use of asbestos fiber is been avoided due to its carcinogenic nature. Therefore a new asbestos free friction material and brake pads has been developed.

It is envisioned that future developments in the field of brake friction materials will closely mimic the current trends of the automotive industry. The shift towards environmentally friendly cars has already seen the release of hybrid cars such as Toyota Prius and Honda Insight [3].

The brake pads were formally generally made from asbestos fibers. In site of its good properties, asbestos is being withdrawn from all the applications, where there is a possibility of alternate material for making non-carcinogenic brake pad [1, 4].

Although use of asbestos for brake pads has not been banned, much of the brake pad industry is moving away from asbestos brake pads because of concerns. Regarding airborne particles in the factories and disposal of wastes containing asbestos.

There are several patents for asbestos free organic friction materials. Some of these materials were starting to be used in rear drum brakes in 1984, changes in brake pad formulation were also driven by the promulgation of the corporate average fuel efficiency requirements in the late 1970's and mid 1980's. These requirements led the automobile industry to switch from rear wheel drive cars to front wheel drive cars. This switch required more front braking which resulted in higher temperatures and a preference for semi-metallic brakes [5-6].

A several research has been carried out in the area of development of asbestos-free brake pads. The use of coconut shell, palm kernel shell (PKS) etc. has been investigated [1, 5]. Researches all over the world are focusing on ways of utilizing either

V.S. Aigbodio¹⁾, U. Akadike¹⁾, S.B. Hassan¹⁾,
F. Asuke¹⁾, J.O. Agunsoye²⁾

¹⁾ Department of Metallurgical and Materials Engineering, Ahmadu Bello University, Samaru, Zaria, Nigeria.

²⁾ Department of Metallurgical and Materials Engineering, University of Lagaos
aigbodionv@yahoo.com, +2348028433576

industrial or agricultural wastes as a source of raw materials in the industry. These wastes utilization will not only be economically, but may also result to foreign exchange earnings and environmental control. 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 [7]. 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 way, the Sugar-cane processing industry's waste contributes significantly to CO₂ [7]. Hence, the aims of this work are to develop a new asbestos-free brake pad using bagasse. Bagasse is readily available and is not toxic.

2 EXPERIMENTAL PROCEDURES

2.1 Materials

The materials used during the course of this work are: Phenolic resin (phenol formaldehyde), Bagasse with compositional analysis and photo as shown in Table 1 and Figure 1.



Figure 1. Photo of Bagasse

Table 1. Compositional analysis of Bagasse [7]

Compound	%
Cellulose	45
Hem Cellulose	23
Lignin	13
Pith Fibre	10
Ash	3
Waxes	0.6

2.2 Method of production

The bagasse was sun dried for about one week after extracting the juice. The dried bagasse was ground into powder using a milling machine and then sieved into different sieve sizes of aperture 710 μ m, 350 μ m, 250 μ m, 150 μ m and 100 μ m. A different

particle size of bagasse was collected as powder and is shown in Figure 2.

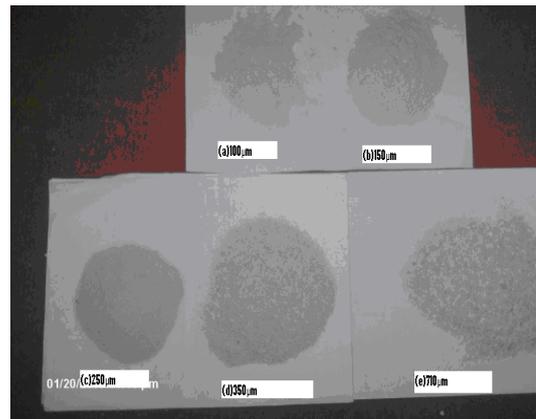


Figure 2. Photo of different Sieve Grade of the Bagasse

The samples were produced using a compression moulding machine. With compression moulding, the counter mould was used to close the mould after impregnated. Different composition and sieve grades (i.e. 710 μ m, 350 μ m, 250 μ m, 150 μ m and 100 μ m) of bagasse and phenolic powder were added together in the ratio 70%bagasse- 30% resin respectively. The combination were properly dry mixed in a mixer, almost achieving a homogenous state and transferred to a mould kept in a hot platen press at temperature of 140 $^{\circ}$ C at 100KN/cm² pressure for 2 minutes. After removing from hot press, the brake pad was cured in an oven at a temperature of 120 $^{\circ}$ C for 8 hours [8, 9]. The photos of the produced samples are shown in Figure 3.



Figure 3. The photo of the produced samples

2.3 Method of characterization

The Brinell hardness values of the samples were obtained using a digital hardness tester. The sample of diameter 22.7 was used to carry out the test as different sieve grades. The test was conducted using 10mm diameter steel ball indenter with a load of 3000kg.

The compressive strength test was done using the Honsfield Tensometer. The samples of diameter 22.7mm was subjected to compressive force, loaded continuously until failure occurred. The load at which failure occurred was then recorded. The flame resistance of the samples was carried out by placing the sample on wire gauze positioned directly on the blue flame of a Bunsen burner. The sample weight before and after burning was taken after 10 minutes and was used in obtaining the percentage of flame resistance [1, 5].

The water and oil (SEA 20/50) absorption of the samples were determined by soaking the samples water and oil for 24hours. Before the test the weight of the sample was determined, after oven drying of the sample the weight was also measured. The percentage of absorption was determined [9, 10]. The true density of the samples was determined by weighing the samples on a digital weighing machine and measuring their volume by liquid displacement method. Subsequently their specific gravities were determined by dividing the unit weight of the sample by the unit volume

The wear rate for the sample was measured using pin on disc machine by sliding it over a cast iron surface at a load of 20N, sliding speed of 5.02m/s and sliding distance of 5000m. All tests were conducted at room temperature. The initial weight of the samples was measured using a single pan electronic weighing machine with an accuracy of 0.01g. During the test, the pin was pressed against the counterpart rotating against a cast iron disc (hardness 65 HRC) of counter surface roughness of 0.3 μ m by applying the load. A friction-detecting arm connected to a strain gauge held and loaded the pin samples vertically into the rotating hardened cast iron disc. After running through a fixed sliding distance, the samples were removed, cleaned with acetone, dried, and weighed to determine the weight loss due to wear. The differences in weight measured before and after tests give the wear of the samples. The formula used to convert the weight loss into wear rate is [11, 12]:

$$\text{Wear rate} = \frac{\Delta W}{S} \quad (1)$$

Where ΔW is the weight difference of the sample before and after the test in mg, S is total sliding distance in m.

The microstructural analysis of the samples was carried out by grinding the samples using 300, 400, and 600 grit papers respectively. Dry polishing was

then carried out on these samples and the internal structures were viewed under the computerized Metallurgical microscope [7].

3. RESULTS AND DISCUSSION

Figures 4-8 has show the microstructure of the samples.



Figure 4. Microstructure of 100 μ m sieve grade sample(X100). Showing Uniform dark region of resin and white region of bagasse.



Figure 5. Microstructure of 150 μ m sieve sample(X100). Showing slight uniform dark region of resin and white region of bagasse.



Figure 6. Microstructure of 250 μ m sieve grade sample(X100). Showing dark region of resin and white region of bagasse.

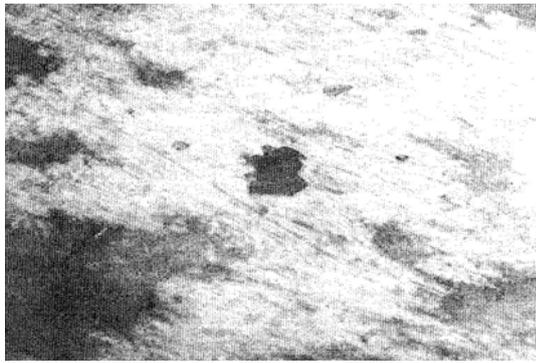


Figure 7. Microstructure of 350µm sieve grade sample(X100). Showing dark region of resin and white region of bagasse

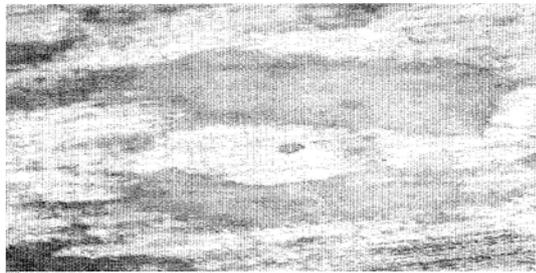


Figure 8. Microstructure of 710µm sieve grade sample(X100). Showing segregation of dark region of resin and white region of bagasse region.

From the microstructure there is more uniform distribution of the resin with the bagasse as the particles size of the bagasse decreased. This is as a result of proper bonding between the bagasse and the resin as the sieve grade decrease and also closer inter-packing distance. This can be appreciable if one compares Figure 4 with Figure 8. The results of the hardness values are shown in Figure 9. From the figure it can be seen that as the sieve grade is decreased the hardness values of the samples increases.

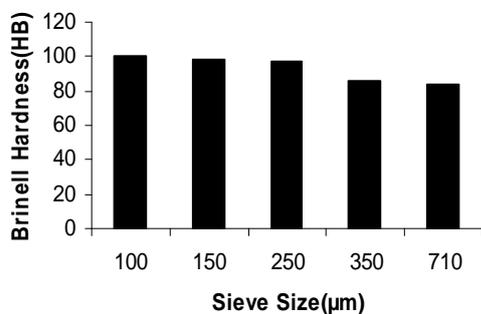


Figure 9. Variation of Hardness values with Sieve Grade

The sample with 100µm sieve grade has the highest hardness value of 100.5HBN. A sharp drop in hardness was observed in the samples with higher

sieve grades (150, 250, 350, and 710µm). The high hardness for the 100µm sieve grade was as a result of reduced particle size of bagasse i.e. increasing in surface area which resulted to increase bonding ability with the resin. The hardness value for this material was compared with other materials from other researches [1, 11-12] as shown in the Table 2 which indicated an acceptable result with the findings of other researchers. Figure 10 shown the compressive strengths of the produced samples. From the results similar trend with that of hardness values was observed that is compressive strength increases with decreased in sieve size of the samples.

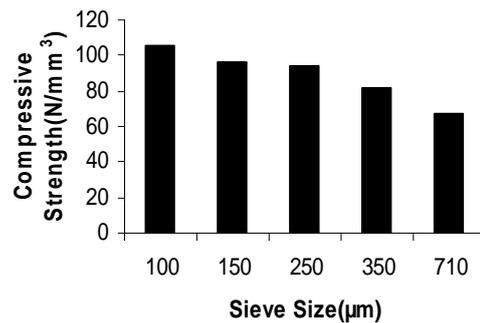


Figure 10. Variation of Compressive strength with Sieve Grade

The 100 µm sieve grade also has the highest compressive strength of 105.6N/mm². The gradual decrease in compressive strength as the sieve size increases can be attributed to the decreasing surface area and pore packaging capability of the bagasse particles in the resin. Hence, compressive strength increases as particle size of bagasse decreases. Figure 11 show the result of the density with sieve size. The density decreased as the sieve size of the bagasse particle increasing in the resin.

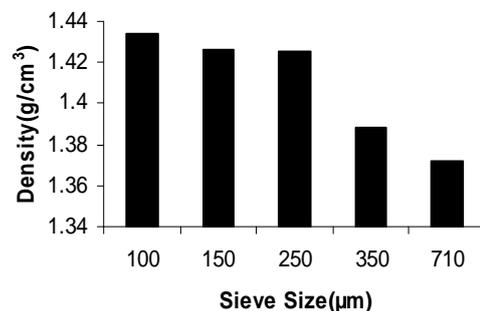


Figure 11. Variation of Density with Sieve Grade

The decreased in density can be attributed to the increases in particle size i.e. increased packing of bagasse. The 100µm has the highest density which is as a result of closer packing of bagasse particles creating more homogeneity in the entire phase of the composite body[5].

Figure 12 shown the wear rate of the produced samples. The figure shows decrease in wear rate as the sieve grade of bagasse increases. The resulted to higher/ closer packing which has affected stronger binding of bagasse with resin. This may also be due to high hardness values and compressive strength of the samples as sieve size is decreased

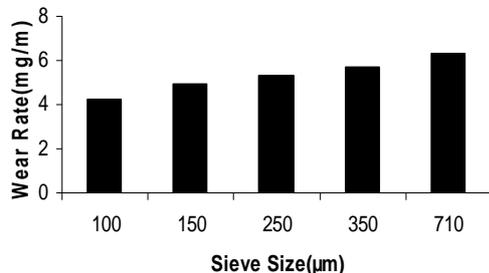


Figure 12. Variation of Wear rate with Sieve Grade

Figure 13-15 shown the water, oil soak absorption and flame resistance of the produced samples. Those properties increased as the sieve grade increases which can eventually be attributed to the increases pores as sieve size increases. These results are in par with the earlier observation of Refs. [1-5].

It can be seen from the result that sample with 100 µm gave the best properties as a result of a very good dispersion of bagasse particles as shown by the white region and dark region resin(see Figure 4) which led to a better interfacial bonding of the resin and the bagasse particles as seen in subsequent samples probably must have resulted to poor distribution of resin used, as denoted by the dark portions on the Figure 5-8 respectively.

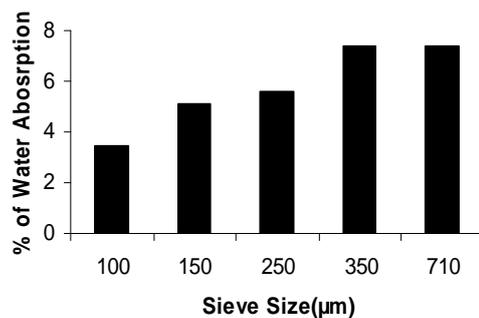


Figure 13. Variation of % Water Absorption with Sieve Grade

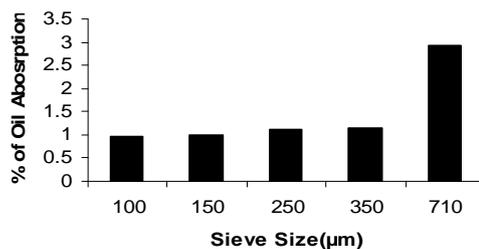


Figure 14. Variation of % Oil Absorption with Sieve Grade

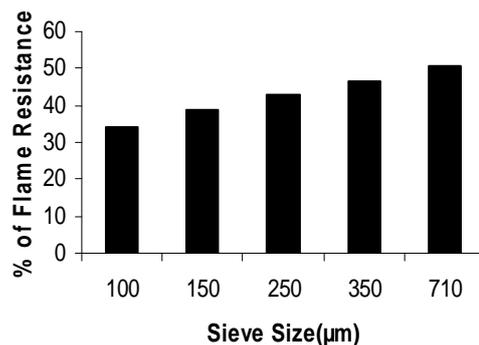


Figure 15. Variation of % Flame Resistance with Sieve Grade

Table 2. Summary of result findings compared with existing ones[1, 5].

Property	Optimum Formulation Laboratory brake pad (PKS based)	Commercial brake pad (asbestos based)	New Formulation Laboratory brake-pad (bagasse based) Recommended
Specific gravity	1.65	1.89	1.43
Average wear (mg/m)	4.40	3.80	4.20
Thickness swell in water after 24 hrs (%)	5.03	0.90	3.48
Thickness swell in oil (SEA 40) after 24 hrs (%)	0.44	0.30	1.11
Flame resistance test after 10 minutes	Charred with 46% ash	Charred with 9% ash	Charred with 34% ash
Compressive strength (MPa)	103.50	110	105.60
Hardness, Brinell (at 3000 kgf)	92	101	100.50

The result of this work indicates that sample containing 100 μ m (70% bagasse- 30% resin) gave better properties than other samples tested. Hence, the lower the sieve grades of bagasse, the better the properties. The 100 μ m sieve size results were compared with that of commercial brake pad (asbestos based) and optimum formulation laboratory brake pad (Palm Kernel Shell based (PKS) as shown in the Table 2[1, 5]. which was tested under similar conditions.

The results are in close agreement. Hence asbestos free brake pad can be produced with 100 μ m sieve size formulation. Taking into consideration, all the desired dimensions of the brake pad, a prototype of Peugeot 504 brake pad of length 77mm, width of 65mm and depth of the friction material was 12mm was produced with this 100 μ m sieve size formulation (see Figure 16). The produced prototype was carried out to show that the formulation can be used in the production of automotive brake-pad without adding any binders to this formulation(70%bagasse-30%resin)



Figure 16. Produced bagasse brake pads

4. CONCLUSIONS

From the results and discussion in this work the following conclusions can be made:

1. The samples, 100 μ m sieve grade of bagasse gave the better properties in all.
2. Compressive strength, hardness and densities of the produced samples were seen to be decreasing with increase in sieve grade while there oil soak, water soak, wear rate and percentage charred increased as sieve grade increased.
3. The result of this research indicates that bagasse can be effectively used as a replacement for asbestos in brake pad manufacture by using the 100 μ m sieve grade of bagasse with a composition – 70% and 30% of resin.

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