Development and production of brake pad from sawdust composite

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Abstract

This paper presents research work on new alternative materials for brake pad. A new asbestos free brake pad was developed using an agro waste material of sawdust along with other ingredients. This was with a view to exploiting the characteristics of sawdust which are largely deposited as waste around sawmills in replacing asbestos which has been found to be carcinogenic. A brake pad was produced using sawdust as a base material following the standard procedure employed by the manufacturers. The sawdust was sieved into sieve grades of 100µm, 355µm and 710µm. The sieved sawdust was used in production of brake pad in ratio of 55% sawdust, 15% steel dust, 5% graphite, 10% silicon carbide and 15% epoxy resin using compression moulding. 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. The results obtained in this work were compared with that of commercial brake pad (asbestos based) and showed a close correlation. Hence sawdust can be used in production of asbestos-free brake pad.

Keywords

Development; Brake pad; Sawdust; Resin; Composite; Asbestos; Hardness; Automobiles

Introduction

Brake pads are components of disc brakes used in automobiles. They are steel backing plates with friction materials bound to the surface facing the brake disc. Brake pads are used in the braking systems to control the speed of the automobile [1] by converting the kinetic energy of the automobile to thermal energy by friction and dissipating the heat produced to the surroundings.

Brake pads generally consist of asbestos in the matrix along with several other ingredients [2]. The use of asbestos is being avoided because of its carcinogenic and harmful nature. Countries like USA, UK, Colombia, Japan, China and some others have banned the use of asbestos as a friction material because of its risk of causing cancer for production workers and the end users. Consequently numerous researches have been on to discover human friendly material replacements for asbestos portions in engineering components. Asbestos constituents in brake lining pad composites impart desired high friction property that automotive pads require to function properly as motion stoppers. Brake pads are important components of braking system for all categories of vehicles equipped with brake discs.

Brake pads use as automobile brakes are of two types: drum brakes and disc brakes. The drum brake is located inside a drum so that on application of the brakes, the brake lining is forced outward and pressed against the drum, while disc brakes operate in similar way except that they are exposed to the environment [3].

The use of thermosetting resins to produce moulded brake lining instead of knitted linings were made by combining fiber with resin and polymerizing resin under elevated pressure and temperature. The fabrication and performance evaluation of a composite material for wear resistance application [4] made use of an agro-waste (palm kernel shells -PKS) as filler material with sulphur, cashew nut shell liquid, calcium carbonate, brass chips, quartz, iron ore, ceramics, and carbon black. Similarly, coconut shells based brake pad was produced with a formulation of grinded coconut shells (filler), epoxy resin (binder –matrix), iron chips (reinforcement), methyl ethyl ketone peroxide (catalyst), cobalt nephthanate (accelerator), iron and silica (abrasives), and brass (friction modifier) [5].

Brake pads from Periwinkle shells [6] have also been produced with formulation which included periwinkle shell powder, phenolic resin (phenol formaldehyde), engine oil (SEA 20/50) and water. Kaolin clay properties were examined and processed for automotive

friction lining material [7] and found to be of good heat resistance for friction lining material in automotive industry. An investigation was carried out on the use of banana peels [2] to replace asbestos in brake pad with phenolic resin (phenol formaldehyde) as binder. The resin was varied from 5 to 30 %weight in an interval of 5 %weight. Egg Shells (EG) based eco-friendly (biodegradable) brake pad was developed and evaluated [8] in which Gum Arabic (GA) was use as binder by varying the GA from 3 to 18 %weight. Most recently,pulverized cow hooves based brake lining was developed as replacement for asbestos for automobile application [9]; palm kernel fibres (PKFs) [10] was used to produce asbestos-free automobile brake pads. Similarly, the use of biosourced raw materials such as tannins and furfuryl alcohol and biosourced thermoset resin to develop resin matrix of automotive brake pads [11] has been achieved. This research therefore aimed to develop brake pad from agro waste material composite of sawdust with a view to investigate the functional properties as compared with the commercial brake pad.

Material and method

The materials used during the course of this work include sawdust, steel powder, silicon carbide, graphite and epoxy resin shown in Figure 1. A 30kg quantity of sawdust was obtained from sawmill. The sawdust was cleaned and sun-dried for about one week to remove the moisture content. The sawdust was ground into powder using a ball milling machine and then sieved into different sieve sizes of aperture 710µm, 355µm, and 100µm.

Production of the brake pad consists of a series of unit operations including mixing, cold and hot pressing, cooling, post-curing and finishing [12]. The samples were produced using compression moulding machine after the mould was impregnated with the various composition and sieve grades of 710µm, 355µm, and 100µm of sawdust, steel dust, graphite, silicon carbide and epoxy resin were added together. The various compositions are presented in Table 1. The combination were properly dry mixed in a mixer for 20 minutes to achieve a homogenous state and then transferred to a mould kept in a hot platen press at temperature of 150°C at a pressure of 100kN/cm^2 for 2 minutes. After removing from hot press, the brake pad was cured in an oven at a temperature of 120°C for 8 hours**.**

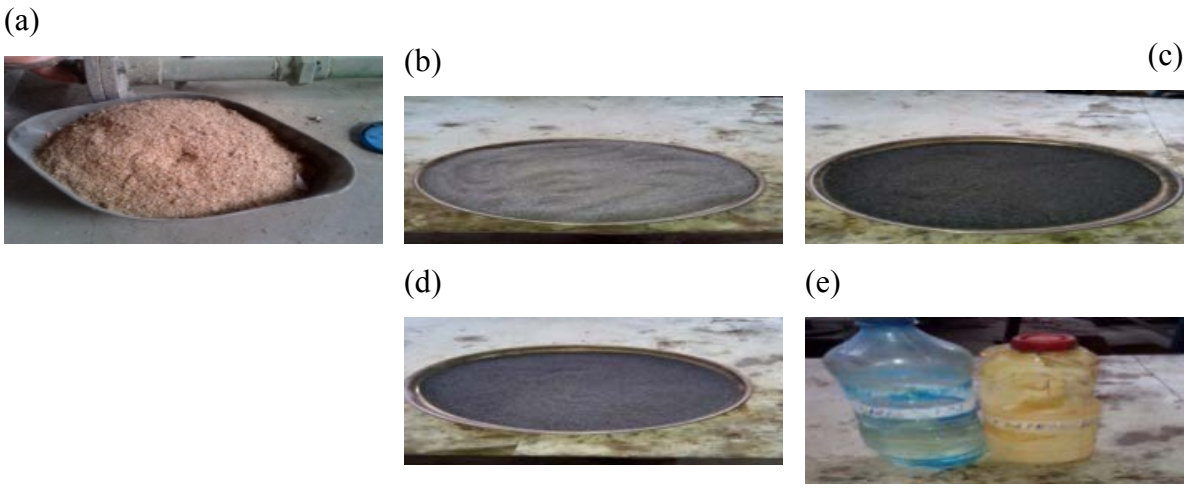

Figure 1. *Various materials for producing brake lining: (a) Sawdust, (b) Silicon carbide, (c) Graphite, (d) Steel dust, (e) Epoxy resin*

Table 1. Proportion of materials for production of brake lining

S/no.	Brake lining materials	Percntage weight (%wt)
1	Saw dust	55
2	Steel dust	15
3	Graphite	5
4	Silicon carbide	10
5	Epoxy resin	15

The product was then allowed to cool at room temperature and then subjected to various tests to determine its functional characteristics as presented.

Microstructure analysis

The microstructure 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.

Brinell hardness test

The resistance of the composites to indentation was carried out using the Brinell hardness testing equipment of BS240, a Tensometer (M500-25kN, hardened steel ball of diameter *D* to indent the test specimen. Based on ASTM specification, a steel ball of D = 10 mm diameter steel ball was used, and the load applied P was kept stable at 3000 kgf. The diameter of the indentation, d, was measured along two perpendicular directions, using an optical micrometer screw gauge. The mean value was used to obtain the Brinell Hardness

Number (BHN) using equation (1).

$$BHN = \frac{2P}{\pi D\left(D - \sqrt{D^2 - d^2}\right)} \quad (1)$$

where P = applied load, D = diameter of hardened steel ball, d = diameter of indentation.

Compressive strength test

The compressive strength test was done using the Tensometric Machine. The samples of diameter 29.40mm was subjected to compressive force, loaded continuously until failure occurred. The load at which failure occurred was then recorded.

Ash content test

About 1.20g ± 0.1g of the samples were weighed in a cooled crucible which was oven dried by heating in a furnace to 550°C for 1 hour. Then the samples were charred by heating in a hot plate after which the charred samples were placed in a furnace and heated at 550°C for 1 hour. Then cooled in a desiccator and weighed. This process of heating, cooling and reweighing were repeated until a constant weight was obtained the ash content was calculated using equation (2).

$$Ash\ content = \frac{W_2 - W_0}{W_1 - W_0} \times 100\% \quad (2)$$

where W_0 = weight of empty crucible, W_1= weight of crucible and sample, W_2= weight of crucible and residue after cooling.

Density test

The density of the samples was determined by weighing the samples on a digital weighing machine and their volumes determined by liquid displacement method. The density was determined using equation (3).

$$Density, \rho = \frac{M}{V} \quad (3)$$

where M = mass of test piece (g), V = volume of the test piece (cm^3) by liquid displacement method.

Wear rate test

The wear rate for the samples were measured using pin on disc machine by sliding it

over a cast iron surface at a load of 10N, sliding speed of 125rev/min and sliding distance of 2000m. 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 cast iron disc of Rockwell hardness 65HRC of counter surface roughness of 0.3μm 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 difference in weight measured before and after the tests give the wear of the samples and the wear rate is calculated by equation (4).

$$Wear\ rate = \frac{\Delta W}{S} \tag{4}$$

where ΔW = weight difference of the sample before and after the test (mg), S = is the total sliding distance (m).

Water absorption test

The samples were weighed on a digital weighing machine and soaked in water at room temperature for 24 hours. The samples were then removed, cleaned and weighed. The water absorption rate was calculated thus:

$$Water\ absorption = \frac{M_2 - M_1}{M_1} \times 100\% \tag{5}$$

where M_1= mass of the sample (g), M_2 = mass of the sample after absorbing water (g).

Results and discussion

Figure 2 shows the produced samples of the brake lining and Figure 3 is the microstructure of the produced samples. Table 2 shows the results of the Brinell hardness, compressive Strength, ash content, density, wear rate, water absorption.

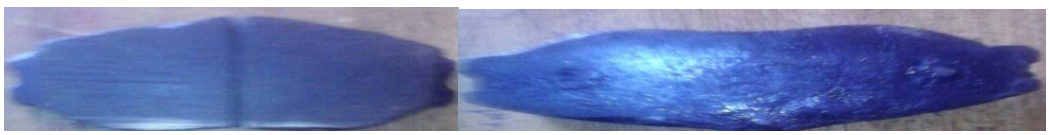

Figure 2. *Samples of produced brake lining*

Figure 3. *Microstructure of samples*

Table 2. Results of various properties of produced brake lining

Sample	Sieve size	Brinell Hardness	Compressive strength	Ash content	Density	Wear rate	Water Absorption
A	100	258	113	40	1.91	3.23	0.63
B	355	234	111	38	1.85	3.62	1.11
C	710	228	102	37	1.82	3.90	2.09

The microstructure of samples A, B, and C for 100µm, 355µm and 710µm sieve grades samples respectively at magnification (×100) shows uniform dark red region of resin and white region of sawdust. From the microstructures, there is more uniform distribution of the resin with the sawdust as the particles size of the sawdust decreased. This is as a result of proper bonding between the sawdust and the entire composition as the sieve grades decreased and also close inter-packing distance.

The results of the Brinell hardness with the particles size as shown in Table 2 indicates the 100µm particles size have the highest hardness value due to the increase in surface area as result of reduced particle sizes which results in increased bonding ability with resin. It is observed that the hardness values decrease as the particles size increases. This value is quite higher than the commercial and other experimental brake pads [5,9].

The result of the compressive strength with particles size in Table 2 also shows that the 100µm particles size also has the highest compressive strength of 113N/mm^2 a little over what is obtainable from commercial brake pads. Hence compressive strength increases as particle size of sawdust decreases.

The ash content of the produced samples particles size increases the ash content decreases. This is attributed to the increase in pores spaces as the particles size increases as result of the sample with 100µm sieve grade which gave the best property dispersion of decreased particles size.

The density decreases as the particles size of the sawdust increases in the composition.

The decreased in density can be attributed to the increase in particle size (i.e. decreased packing of sawdust). The sample with 100µm sieve grade has the highest density value which is as a result of closer packing of sawdust particles creating more homogeneity in the entire phase of the composite body.

Table 2 shows increase in wear rate as the particles size of the sawdust increases. This is as a result of closer packing of the sawdust which has affected stronger bonding of the sawdust within the composition. This may also be due to high hardness values and compressive strength of the samples as the particles size decreases as confirmed by [5].

The water absorption rate increases as the particles size increases which can be attributed to the increase pores as particles size increases. These results are consistent with the earlier observations by [2, 6 and 4]. It can be seen from the result that sample with 100µm sieve grade gave the best property as a result of a very good dispersion of sawdust particles as shown by the white region and dark region of resin as shown in Figure 3 which led to a better interfacial bonding of the resin and the sawdust particles.

A comparison of sawdust brake lining with commercial brake lining

A comparison of the results of the properties of developed sawdust brake lining and commercial brake pad (asbestos based) is shown in Table 3 [13].

Table 3. Summary of result findings compared with asbestos based brake pad

S/N	Property	Commercial brake pad (asbestos based)	Experimental brake pad (sawdust based)
1	Hardness (HB)	101	258
2	Compressive Strength (N/mm^2)	110	113
3	Ash Content (%)	54	40
4	Specific gravity	1.89	1.91
5	Wear Rate (mg/m)	3.80	3.23
6	Water Absorption (%)	0.9	0.63

Conclusion

The results showed that sawdust has properties comparable to that needed 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. The results of the research show that sawdust of 100µm particles size has properties that can effectively replace asbestos in brake

pad manufacture, since it gives better brake pad properties. The properties such as compressive strength, hardness, density, ash-content and water absorption of the produced samples decreased with increasing particles size.

References

1. Nagesh S. N., Siddarayu C., Prakash S. V., Ramesh M. R., *Characterization of brake pads by variation in composition of friction materials,* Procedia Materials Science, 2014, 5, p. 295-302.
2. Idris U. D., Aigbodion,V. S., Abubakar I. J., Nwoye C. I., *Eco-friendly asbestos free brake-pad: using banana peels,* Journal of King Saud University - Engineering Sciences, 2015, 27, p. 185-192.
3. Bono S. G., Dekyrger W. J., *Auto technology, theory and service*, New York, DELMAR Publishers, 1990.
4. Deepika K., Bhaskar R. C., Ramana R. D., *Fabrication and performance evaluation of a composite material for wear resistance application*, International Journal of Engineering Science and Innovative Technology, 2013, 2(6), p. 1-6.
5. Bashar D. A., Peter B. M., Joseph M., *Production of cold-worked brake pad*, World Journal of Engineering and Pure and Applied Science, 2012, 2(3), p. 92-97.
6. Yawas D. S., Aku S. Y., Amaren S. G., *Morphology and properties of periwinkle shell asbestos-free brake pad*, Journal of King Saudi University – Engineering Sciences., 2016, 28(1), p. 103-109.
7. Aderiye J., *Kaolin mineral material for automobile ceramic brake pad manufacturing industry*, International Journal of Technology Enhancements and Emerging Engineering Research, 2014, 2(3), p. 84-88.
8. Edokpia R. O., Aigbodion V. S., Obiorah O. B., Atuanya, C. U.,WITHDRAWN: *Evaluation of the properties of eco-friendly brake pad using egg shell particles–gum Arabic*, ScienceDirect Elsevier, 2014, DOI: 10.1016/j.rinp.2014.06.003
9. Bala K. C., Okoli M., Abolarin M. S., *Development of automobile brake lining using pulverized cow hooves,* Leonardo Journal of Science, 2016, 15(28), p. 95-108.

10. Ikpambese K. K., Gundu D. T., Tuleu L. T., *Evaluation of palm kernel fibres (PKFs) for production of asbestos-free automobile brake pads,* Journal of King Saud University-Engineering Sciences, 2016, 28(1), p. 110-118.
11. Lagel M. C., Hai L., Pizzi A., Basso M. C., Delmotte L., Abdalla S., Zahed A., Al-Marzouk F. M., *Automotive brake pads made with a bioresin matrix,* Industrial Crops and Products, 2016, 85, p. 372-381.
12. Fono-Tamo R.S., Koya O.A., *Characteristics of pulverized palm kernel shell for sustainable waste diversification*, International Journal of Science & Engineering Research, 2013, 4(4), p. 6-10.
13. Aigbodion V. S., Agunsoye J. O., *Bagasse (sugarcane waste): non-asbestos free brake pad materials, Germany, Lambert Academic Publishing, 2010.*