Evaluation of Mechanical Characteristics of Friction Lining from Agricultural Waste

[1]R.S. Fono-Tamo, [2]O.A. Koya

[1]Department of Mechanical Engineering, Bells University of Technology, Ota, Nigeria; [2]Department of Mechanical Engineering, Obafemi Awolowo University, Ile-Ife, Nigeria.
Email address: ftrromeo@gmail.com.com

ABSTRACT
Optimizing the use of agricultural waste through applying it in engineering is achieved. Friction material for automotive application is developed following standards factory procedure using palm kernel shell. Mechanical characteristics of the developed product are evaluated. The bonding of the friction material to the back plate is tested and found to be 3375 N/s; the evaluated Brinell Hardness of the composite has a mean of 32.34 while the mean Shear Strength by Punch Tool is about 40.95 MPa; and the tested coefficient of friction estimated at 0.43. All these value fall within the recommended limits for automotive friction material thus making palm kernel shell suitable for manufacturing friction linings.

Keywords: Agricultural waste, composites, friction lining, automotive, brake pads.

1. Introduction.
Agricultural waste like cocoa pods, rice husk, maize husk, palm kernel shell, coconut shell to name a few present environmental hazard as their disposal is often a concern. Recent development in friction material industry where a search for non-asbestos substitute is the order of the day has gingered researchers to explore the potential of some of these agricultural wastes to be used in friction material development. The fact that these materials can be acquired at close to no cost is an added advantage beside their abundant presence. Friction material and especially brake pads are made up of essentially four group of material which includes binders, fillers, reinforcing fibres and friction modifiers. Combined together, these groups of materials provide the developed brake pads with the necessary properties needed for it to perform effectively. Nicholson (1995) lists the wollastonite (calcium silicate),vermiculite (hydrated calcium aluminum silicate), polyester (chopped glass fiber and aramid fibers.), fiberfrax, ceramic fiber, polyacrylonitrile (PAN) as replacement materials for asbestos. None is exactly like asbestos but they offer some similar performance characteristics. The purpose of reinforcing fibres is to provide mechanical strength to the friction material. Coefficients of friction of palm kernel shell (PKS) on metal surfaces was found to be in the range of 0.37-0.52 (Koya *et al*., 2004). In contrast, friction coefficient in the range of 0.30-0.70 is normally desirable when using brake lining material (Roubicek *et al*., 2008). It has been found (Teo, 2006) that incorporation of PKS in the production of structural light weight concretes increased the mechanical strength. Thus, PKS appeared suitable for use as base material in friction composites, because they are subjected to hard and variable braking forces.

This paper considers some physical and mechanical properties of brake pads developed from palm kernel shell. Brake pads with substantial quantity of palm kernel shell was developed as well as brake pads from asbestos following standard factory procedure, their mechanical properties were also examined and compared.

2. Materials and Methods
2.1. Development of experimental brake pad
The experimental brake pad was developed following standard factory procedure as described by Fono (2009) in the work on study of palm kernel shell as friction material in automotive brake pads and lining.

2.2. Quality Assessment of Experimental Brake Pad.
2.2.1 Bonding test.
Adherence of the friction composite to the back plate was investigated by means of a PERMAFUSE testing machine (Type 05/024, ENERPAC). Prior to the shearing test, the binding of the composite was visually evaluated by experts in the company and was found satisfactory.

The Permafuse testing machine is equipped with a hydraulic system, which functions as a hydraulic press. It is also equipped with a clamping set-up, where the sample brake pad is tightly fixed. The pressing ram was connected to the hydraulic arm and doted with accessories such that, when the arm was actuated, the pressing ram came down on the brake pad. The accessory mounted on the machine pressed the iron back plate down (not the friction composite) till it sheared or separate from the friction composite. A meter reader mounted on the equipment recorded the exact load up to the very moment the shearing occurred.

2.2.2. Brinell Hardness Test

The resistance of the composites to indentation was carried out through the Brinell Hardness test using a Tensometer. It consists of pressing a hardened steel ball into a test specimen. According to ASTM specifications, a 10 mm diameter ball was used for the present investigation.

The diameter of the ball was kept stable at 10 mm and the load applied W was also kept stable at 500 kg. The specimen was mounted in the holding device and the ball fixed in its location. The hand wheel was rotated so that the ball moved toward the specimen. The desired load was applied mechanically by a gear driven screw pressing the ball into the specimen. The diameter of the indentation made in the specimen by the pressed ball was measured by the use of a micrometer microscope having a transparent engraved scale in the field of view. The indentation diameter d was measured in two places at right angles to each other, and the average of the two readings was taken. The Brinell Hardness Number (BHN) which is the pressure per unit surface area of the indentation in kg per square metre is calculated using the following Equation;

$$BHN = \frac{w}{(\pi D/2)(D-\sqrt{D^2-d^2})} \quad \text{............(1)}$$

where, BHN is the Brinell Hardness Number; w is the imposed load; D is the diameter of the spherical indenter; d is the diameter of the resulting indenter impression.

This test was conducted on 4 different samples: 3 of PKS based friction composite and 1 of asbestos based friction composite. Three spots were selected on each sample. This approach was used by Khan *et al.* (2006) on detecting the BHN of a developed friction composite comprising a mixture of Fe-Mo Intermetallic and copper oxide.

The quality of PKS-based friction composite was compared to the quality of asbestos-based friction composite and the true difference between them was determined at various confidence levels. The formulae involved in the application of this method is presented in

$$(\bar{x}-\bar{y}) - At_{\alpha/2;\nu} \le (\mu_x - \mu_y) \le (\bar{x}-\bar{y}) + At_{\alpha/2;\nu} \quad \text{.....(2)}$$

Where

$$\nu = n_x + n_y + 2 \quad \text{.......................(3)}$$

and

$$A = \left[\frac{(n_x-1)s_x^{\,2} + (n_y-1)s_y^{\,2}(n_x+n_y)}{(n_x+n_y-2)n_x n_y}\right]^{1/2} \quad \text{............(4)}$$

where; $\bar{x}$ and $\bar{y}$ are mean BHN for PKS and Asbestos sample respectively; n_x and n_y as number of PKS and asbestos specimen tested respectively; $s_x$and s_y as respective standard deviation for PKS and asbestos samples; $\mu_x$and $\mu_y$as population mean for PKS and asbestos samples respectively; $t_{\alpha;\nu}$ as specific value of variable t

2.2.3. Shear strength by punch tool.

The test was performed by clamping a test sample between two metal fixtures. A male punch was then forced through the hole in the metal fixture causing shear along the edge of the hole. A tensometer machine (MOSANTO Tensometer, Serial No 10035) was used to push the punch till shearing occurred. The specimen size was 2x2 cm square plates with various thicknesses. The results were expressed as shear strength and are given in the units of MPa. The shear strength was calculated by dividing the force required to shear the specimen by the area of the sheared edge. The area of the sheared edge is equal to the circumference of the punch multiplied by the thickness of the specimen. The corresponding equation is presented as follows;

$$SSTP = \frac{Force\,Required}{AreaOfShearedEdge} \quad \text{.................(5)}$$

The testing machine is calibrated in kgf unit thus the need to convert all the values obtained to the Newton.

2.2.4 Coefficient of friction test

The equipment used here was an incline plane apparatus (Model 12558, Norwood Instruments LTD, Honley). The apparatus is operated by raising the plane surface from the horizontal position toward the vertical position through various angles. The coefficient of friction is obtained by calculating the tangent of the angle at which the sample start sliding down the plane surface. The samples used were full size product. Each sample was placed on the flat surface made of mild steel material. The plate was raised until the sample started sliding. The process was immediately stopped and the angle at that particular point was noted. Loads of various weights were laid on each

ISSN 2278-7763

sample and the experiment repeated. The average angle at various loads for the five samples was then calculated and the coefficient of friction obtained. The formulae used for the calculation is;

$$\mu = \tan\theta \quad \text{……………………………..(6)}$$

Where; μ is the coefficient of friction.

3. Results and Discussion

3.1 Bonding Test

The result of the bonding test for the asbestos and PKS based brake pads yielded the adhesion of 5125 and 3375 N/s, respectively. It is clear that asbestos-based brake pad is more firmly attached to the back plate than the PKS based brake pad. It is possible that the curing time combined with the high thermal conductivity of PKS particle had adversely influenced the heat flow to the back plate and that the heat in some ways had weakened the adhesive on the back plate. Therefore, a weaker bond of the friction composite to the back plate resulted. Nevertheless, judging by the recommendations of the Standard Organization of Nigeria (SON), PKS-based brake pad exhibits a good adhesive bond since the value recorded still falls within the designated range, 4500±2250 N/s (NIS 323, 1997). In addition, the surfaces of the back plates (Figures 1) after shearing show very little material remaining on the back plate, that is, less than 20%, which is another criterion of SON.

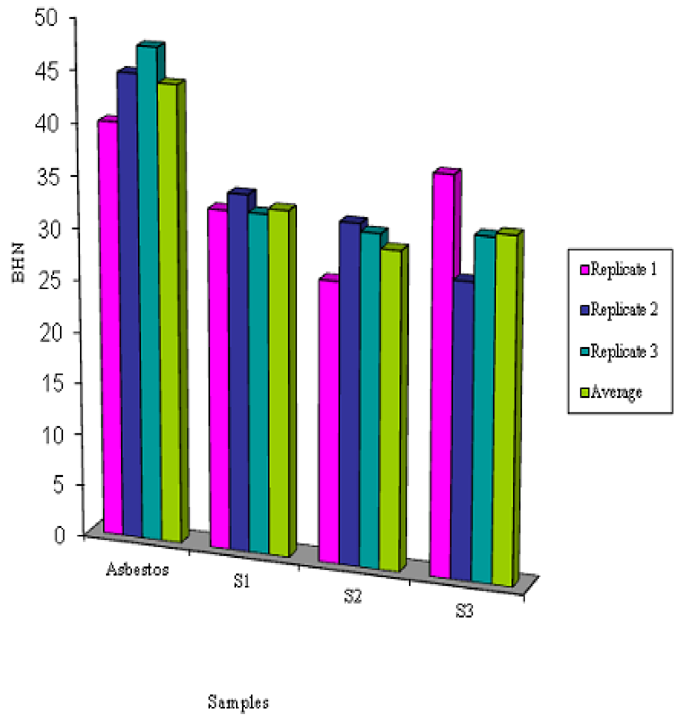
3.2 Brinell hardness test

The calculated mean BHN for PKS and asbestos based brake pad are 32.34 and 44.15 respectively and the bar chart of Figure 2 shows the data for each specific test. From statistical analysis and comparing the mean value of BHN for the asbestos and PKS based samples showed that the hardness of the PKS sample is significantly less (t= -5.54) than the asbestos based at 99% confidence test level. The actual difference between the two BHN is then determined using the indicated equation 2 above.

a) Asbestos-base Friction Composite Brake Pad Sample

b) PKS-base Friction Composite Brake Pad Sample

Figure 1. Surfaces of Back Plate after Bonding Test



2. **Figure 2. Comparison of BHN of asbestos and PKS based friction composites: S_1, S_2, S_3 are PKS based samples**

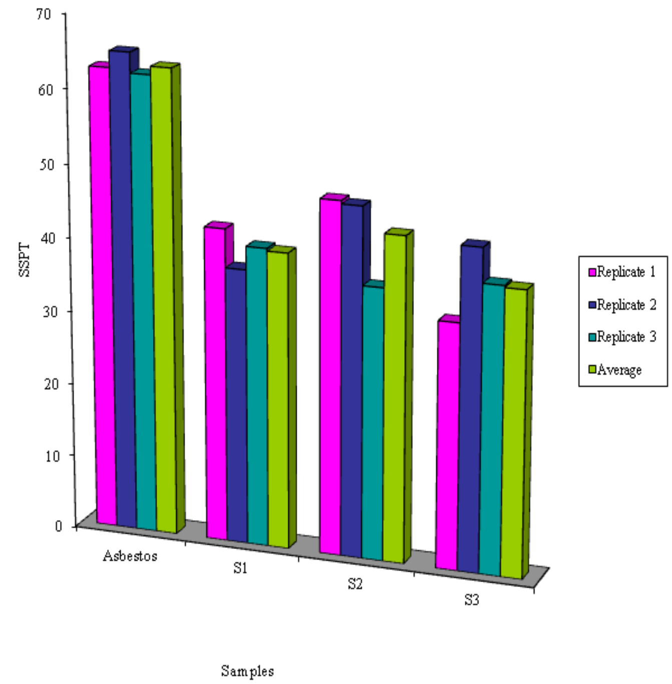


Figure 3. Comparison of SSPT of asbestos and PKS base friction composite: S_1, S_2, S_3 are PKS based samples

Therefore, asbestos friction composite exhibited a higher BHN compare to PKS based friction composite. This could be accounted for by the compressibility of asbestos fibres during manufacturing, either at the cold press or at the hot press. The indenter finds it harder to penetrate the friction element because compaction would have increased its resistance.

3.3 Shear strength by punch tool (SSPT)

The calculated mean value of SSPT for PKS and asbestos based brake pad are 40.95 and 63.35 respectively and the bar chart of Figure 3 shows the data for each specific test.. From statistical analysis and comparing the mean value of SSPT for the asbestos and PKS based samples showed that the hardness of the PKS sample is significantly less (t= -7.73) than the asbestos based at 99% confidence test level. The true difference between the two SSPT is then determined using the indicted equation 2 above.

Therefore, asbestos friction composite exhibited a higher SSTP compare to PKS based friction composite. Just as in hardness test, this could be accounted for by the compressibility of asbestos fibres during manufacturing, either at the cold press or at the hot press. The indenter here has a sharp edge but still finds it hard to penetrate the friction element because the compaction might have increased its resistance.

3.4. Coefficient of friction

From the graph in Figure 4, it is shown that the PKS-based friction composite has a better or higher coefficient of friction on mild steel in the range of 0.41 to 0.44 compare to that of asbestos-based friction composite, which is in the range of 0.37 to 0.41. These values are in good agreement with recommendations by SON, which is at least 0.3. The PKS based friction linings thus, meet the required standard for brake pad.

ISSN 2278-7763

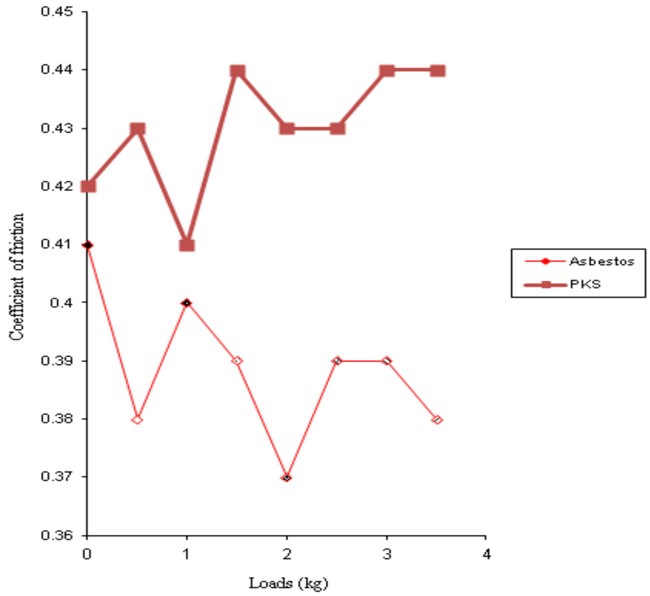


Figure 4. Comparison of coefficient of friction of asbestos and PKS based friction composite

4. Conclusion

A friction material for automotive application was developed following standards factory procedure. The based material used was palm kernel shell because of it abundance and more importantly it mechanical property. The evaluation of the mechanical properties of the developed brake pads show that;

- Though asbestos-based friction material present stronger bond, the value obtained for PKS-based still meet the required standard,
- The fibrous quality of the asbestos-based friction material contributes to its high compaction, largely improving its BHN and SSPT and thus making it better than PKS-based friction material in that respect

The characteristics evaluated still fall well within the limits recommended for friction material for automotive application.

It is however imperative to also evaluate the thermal characteristics as brake pads are usually subjected to high heat generation at the disc/pad interface.

Acknowledgements

This research was partly funded by the Raw Materials Research and Development Council and the National Automotive Council, Abuja, Nigeria. The authors acknowledge Mr Chidi Ukachukwu (Managing Director, Star Auto Industries, Lagos Nigeria) for the use the facilities in his company; Mr. A. Aremo and Mr. J. Abiodun of the Centre for Energy Research and Development (CERD), Obafemi Awolowo University, Ile-Ife, Nigeria for their assistance during the execution of experiments at CERD.

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