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Thermal stability of pulverized palm kernel shell (PKS) based friction lining material locally developed from spent waste

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Abstract : Pulverized Palm kernel shell (PKS) based non-asbestos friction material for brake linings was produced containing fibrous reinforcing constituents, friction imparting and controlling additives, elastomeric additives, fire retarding components and a thermosetting resin. The results showed that onset degradation temperature of the Palm kernel shell based friction lining material was obtained at 53.84°C with final degradation temperature of 634.87°C and percentage weight loss of 86%. For the Original Equipment Manufacturer (OEM) lining material in the market;it was observed that the onset degradation temperature of 54.28°C with final degradation temperature of 583.57°C and percentage weight loss of 42.37% was also obtained. The PKS based friction linings were found to have a high wear rate of 0.24μm compared to OEM lining material with a wear rate value of 0.16μm. The composite formed from the pulverized PKS materials as friction lining materials show good thermal stability when compared with those obtained from the OEM.

Keywords : Palm kernel shell; Friction lining material; Brake lining, Thermal degradation.

INTRODUCTION

The friction materials used in brakes are required to provide a stable coefficient of friction and a lower wear rate at various operating speeds, pressures, temperatures and environmental conditions. These frictional materials must also be compatible with the rotor material in order to reduce its extensive wear, vibration and noise during braking[10].

Friction materials can be applied in automotive, aerospace and industrial brake systems. Friction materials are chiefly composed of a matrix of polymeric blends, reinforcing material, friction and anti-wear material[7]. Phenolic resins or modified phenolic resins are well known as polymeric materials for use in friction lining material production due to its thermal stability and thermosetting properties. Asbestos fibers were previously the preferred choice as reinforcing materials for use as friction lining materials but have the limitation of being carcinogenic and as such pose a serious health concern globally[7,14]. Aleksendric and Duboka[2] studied the operational life expectancy of friction pads based on fiber combinations where the higher wear resistance exhibited by composites with aramid fibers was analyzed by artificial neural network. The compositional effects of steel fibers, steel wool, brass fibers and other metallic fibers were studied by several researchers[8,13]. Filip et al.[9] reported on the mechanistic attributes with respect to the functioning of the friction materials with regards to the role of friction layers. These research findings and discussions on the performance of composite friction materials led to further modifications in the composition and fabrication of non-asbestos organic friction lining materials especially where natural fibers needs to be incorporated. Research activities are still ongoing to find alternative reinforcing materials for the production of brake linings. Barites, mica, cashew dust, fly ash, ceramic fiber, pulverized palm kernel shell are some of the materials that have been considered for use as filler[3-6]. Other alternative materials that replaced Asbestos include mineralfibers, cellulose, aramid, chopped glass, steel, and copper fibers. Depending on material properties, disc wear rates vary. The properties that determine material wear involve trade-offs between performance and longevity.

Palm Kernel Shell (PKS) is sourced directly as by-products in palm oil production. Large quantities of PKS are produced annually and only some fractions are used for fuel and other applications such as palliative for road construction in un-tarred areas and in the production of activated carbon.

The unused PKS are dumped around the palm oil processing mills which on its own constitutes environmental and economic impediments for the palm oil mills.

PKS must be ground and pulverized into fine micro particles or particulates to be suitable for use in friction lining for automobiles. There is limited information in the literature on the grounded shell particles, although there is lots of information available for the ungrounded PKS.

Coefficient of friction of PKS on metal surfaces was found to be in the range of 0.37-0.52[11]. In contrast, friction coefficient in the range of 0.30-0.70 is normally desirable when using brake lining material[12]. It has been found[15] 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. Akporhonor et al.[1] reported that PKS did not change significantly in physical structure and weight, for appreciable time duration, when exposed to organic solvent. It is also important that the friction materials experience very little or no changes on contacting varying environmental conditions: wet or dry weather, or hydraulic fluid spilling over. These reports have spurred further research interest in considering PKS for use as friction material in brake lining.

Friction lining materials and additives are classified based on their expected functions as follows:

a) Abrasives
b) Friction producers/Modifiers
c) Fillers and reinforcements
d) Binder materials

Abrasives

Abrasives help maintain the cleanliness of mating surfaces and control the build-up of friction films. They also increase friction, particularly when initiating' a stop (i.e., they increase "bite"). Example is the Palm Kernel Shell.

Friction producers/Modifiers

These materials lubricate, raise the friction, or react with oxygen to help control interfacial films. Example: Brass-typ. 62% Cu - 38% Zn; sometimes used as chips or machine shop cutting dust, said to improve wet friction and recovery, it is a common additive.

(a) Carbon black

Cheap and widely-used; but there are many forms and sources, some of which can contain abrasive contaminants; burns in air at >7000C, friction level is affected by moisture and structure. In this work, the carbon used was obtained from the remains of burnt vehicle tires.

(b) Iron chips

Consist of Fe chips, used in semi-metallic brake pads; a number of different particle grades (sizes) are available depending on requirements for surface area, light-medium-heavy duty vehicle applications.

Fillers and reinforcements

Fillers are used to maintain the overall composition of the friction material, and some have other functions as well. They can be metals, alloys, ceramics, or organic materials.

(a) Calcium carbonate

Basically inert, but increases density and may aid in wear resistance, stable at high temperature.

(b) Calabash powder

They are inert particulate fillers used to increase volume and aid in wear resistance.

Binder materials

The binder materials used in this work are the polymeric resins.

The aim of this work is to develop an asbestos-free friction lining material for automobiles using pulverized palm kernel shell as base filler material and spent workshop metallic cutting fillings as abrasives. The new friction lining material developed will be characterized to ascertain its thermal stability as compared to commercially available ones produced by original equipment manufacturers (OEM) in the market. In this work, phenolic resin in combination with alkyd resin, hardeners, rubbers, pulverized palm kernel shell, calabash dusts, reinforcing and friction imparting and modifying fillers (cast iron fillings, bronze fillings, and aluminum fillings) were used to form an asbestos-free friction lining brake composition.

While a guide to the percentages of some of the constituting components has been obtained from the references listed in this work, the appropriate amount of fillers, resins, hardener and other constituents were selected based on trial and error iterations. The composition was tested for friction and thermal stability.

MATERIALS AND METHODS

Materials

In this work the following materials were employed in the development of the brake friction lining materials:

a) Calabash (*Crescentia cujete*)
b) Palm kernel shell (*Elaeis guineensis*)
c) Burnt vehicle tire powder (as graphite or carbon black)
d) Iron fillings
e) Brass fillings
f) Aluminum fillings
g) Phenolic resin (Phenol formaldehyde)
h) Alkyd resin
i) Cashew nut shell liquid (CNSL)
j) Accelerator (rubber solution)
k) Catalyst (DMP 30, 2,4,6-tri dimethylaminomethyl phenol)

Methods

The Asbestos-free friction lining materials were synthesized using the following methodology: A mould was fabricated to generate disc shaped friction linings. 50ml of phenol formaldehyde was blended with 40ml of alkyd resin. To the uniformly blended mixture was added 10ml of CNSL along with 4 g of burnt tires and the resultant composition mixed well. 25 g of Palm kernel shell, 6 g of brass fillings, 4 g of aluminum fillings, and 5g of iron fillings were blended into the mixture. Slowly, 4 g of calabash, and 6 g of calcium carbonate were added. On obtaining a uniform blend, 5ml of rubber solution and 3ml of trisphenol hardener were added. The above ratio of phenolic resin and alkyd resin gave a pot life of 10–20 min. The mixture was blended and transferred to a mould for compaction. After allowing the mixture to harden partially, it was compacted in a press at a pressure of about 200 psi to give the shape of the mould. The compacted sample was then subjected to a preliminary curing process at 60°C for 2 h after which it was post cured at 180°C for 3 h in an oven.

Characterization

(a) Surface characterization studies

The friction surfaces of the samples were characterized using Optical Stereomicroscopy (ZEISS). Representative samples were cut from the brake lining produced and the OEM purchased from the market for comparison.

(b) Thermal characterization of the friction lining materials

Samples of the produced friction lining materials and purchased OEM friction lining were both subjected to simultaneous thermo-gravimetric and differential thermal analysis (TG/DTA) using Simultaneous Thermal Analyzer

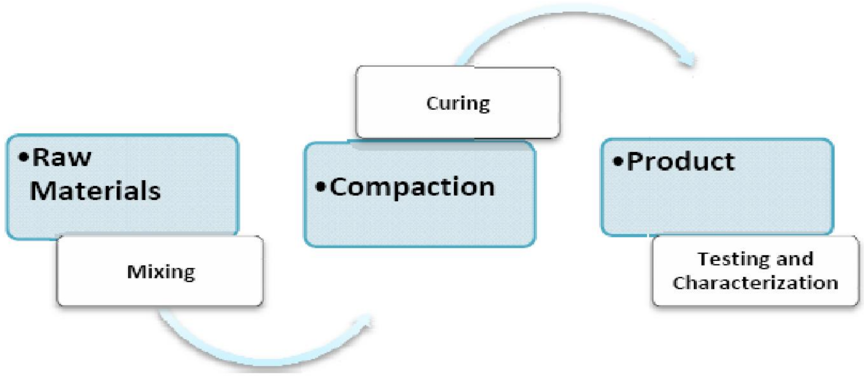

Figure 1 : Flow process for friction-lining formulation and production

TABLE 1 : Physicothermal properties of the pulverized palm kernel shell at 13% weight basis moisture content

Property	Mean value ± SD
Bulk Density (Kg/m^3)	560±17.4
Specific gravity	1.26±0.07
Thermal Conductivity (W/mK)	0.68±0.05
Specific Heat (kJ/KgK)	1.983±0.10

(STA-6000; Perkin Elmer). The TGA procedure monitored the weight of the respective samples as a function of temperature. The purpose of DTA testing was to assess the endothermic weight loss of each material sample as a function of temperature. For this study, both the test procedures were performed on a single sample during course of a single experiment, with the same experimental setup. Weight of the samples and heat flow were monitored at the same time as a function of temperature. Both the samples were tested for the temperature range of 0–1000°C. Oxygen was used as the reference gas during all the experiments at a flow rate of 20ml/min. Both the samples were oven dried prior to the test.

(c) Wear test

The wear test was performed on a test rig as per ASTM G99-95a standards. Each of the test samples was mounted on the load arm and pressed against the rotating disc. The rotating cast iron disc has a constant sliding of 2950 rpm and the duration of the test was 40minutes.

RESULTS AND DISCUSSIONS

TGA and DTA results of the friction lining materials

The TG/DTA data are presented in Figures 2 and 3 and TABLE 2. As observed in the Figures 2 and 3, the material undergo three distinct phase transitions, in terms of material loss and heat flow behavior, as the temperature is increased.

The temperatures at which material transition/loss is initiated are known as onset temperature, and in the case of Figure 2 the three onset temperatures are 53.84°C, 270.40°C and 634.87°C respectively. The cumulative material loss up to the first transition is 18.78%; cumulative material loss up to the second transition phase is about 71% while cumulative material loss up to the third transition phase is about 86%. Contrary, in Figure 3, the OEM automotive brake lining material purchased showed the following onset temperatures for the three phases: 54.28°C, 237.14°C and 538.57°C respectively and weight loses of 6%, 27% and 42.37%.

The limits of heat resistance and strength of the frictional material are governed largely by the heat resistance and strength of the resin binder. The temperature achieved in high performance braking systems is hot enough to decompose phenolic resin and similar organics by high temperature oxidation. The phenolic resin first chars, which means it is converted to carbon accompanied by weight loss and then wears down into carbon dioxide.

The overall char content is lower for the OEM friction lining material as compared to the PKS based friction lining material produced. The material transitions observed are endothermic in nature and mostly reflect the physical transformations in terms of volatile matters escaping the bulk of the PKS particles. As volatile materials present in PKS are not expected to play a major role in the overall friction process, they may be suitable for being used as brake lining filler from a Physicothermal point of view. The PKS based lining material produced

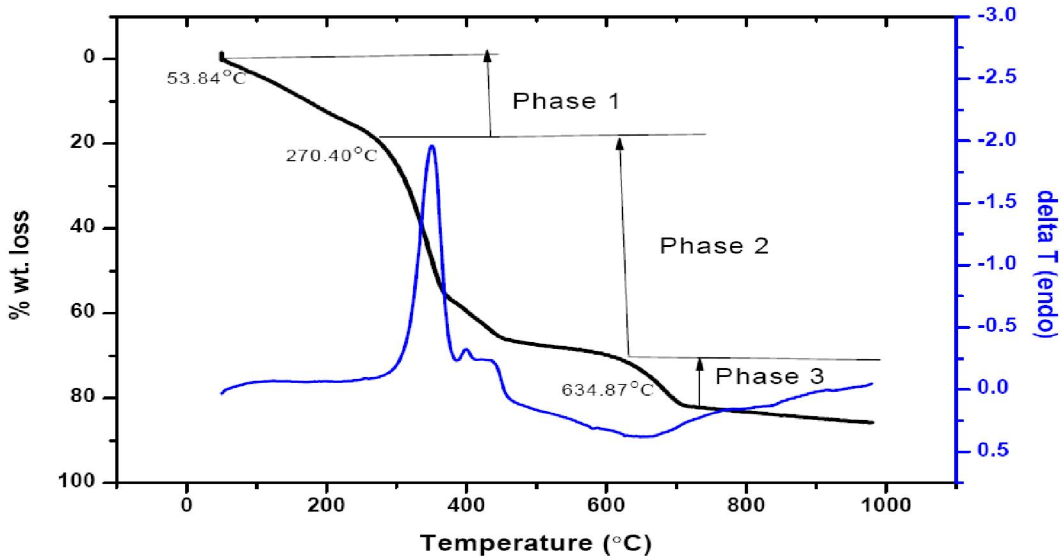

Figure 2 : TGA/DTA results of the produced PKS based friction lining material

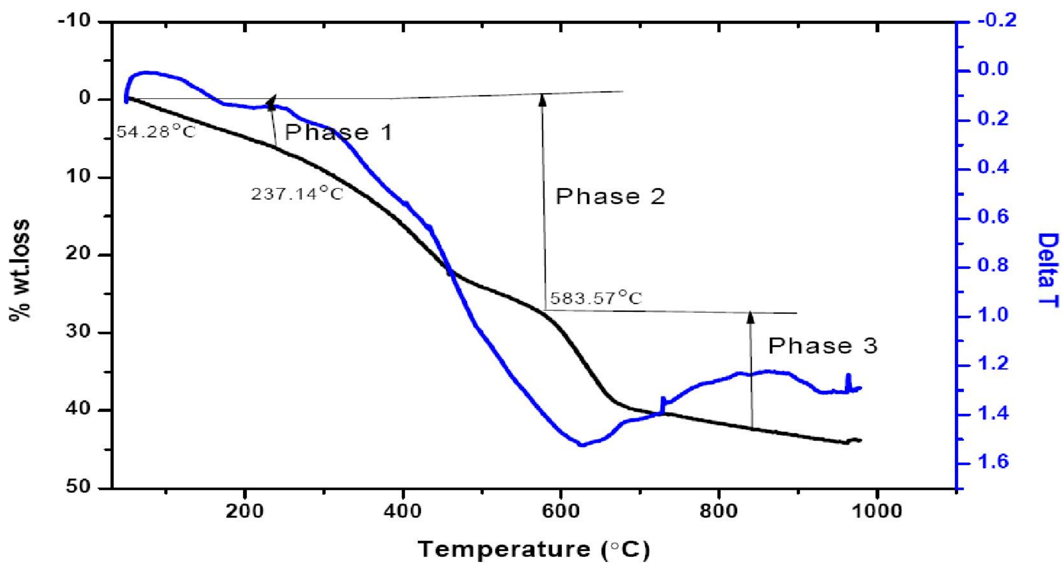

Figure 3 : TGA/DTA results of the purchased OEM friction lining material

TABLE 2 : Onset degradation temperature, final degradation temperature and percent weight loss of the friction lining materials evaluated under active atmosphere

Sample	Onset degradation temperature (°C)[a]	Final degradation temperature (°C)	Percent weight loss (%)	Residue after final degradation (%)
PKS based material	53.84	634.87	86	14
OEM material	54.28	583.57	42.37	57.63

[a]Onset degradation temperature assumed to be the temperature at 1% weight loss.

is more thermally stabled when compared to the OEM lining material.

Optical stereomicroscopy results

Figures 4 and 5 show the optical micrographs of the OEM friction lining material and the PKS based friction lining material produced. In Figure 5, the arrow indicates agglomeration of the PKS in the composite matrix.

It is clearly shown in Figure 5 that the PKS filler material was not well dispersed in the composite matrix of the PKS based friction lining. This is due to manual method employed during the mixing and compounding of the friction lining.

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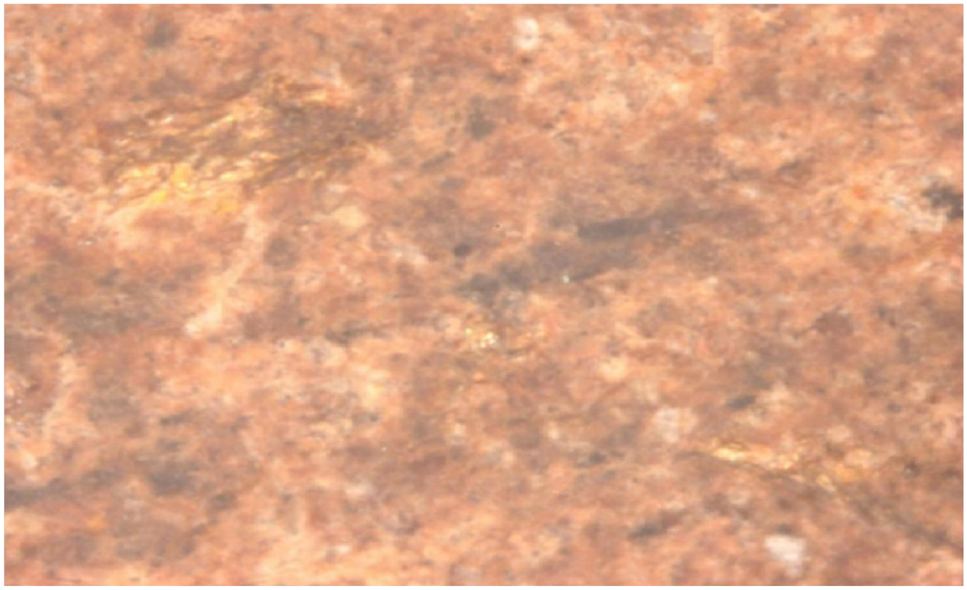

Figure 4 : Optical stereo micrograph of OEM friction lining

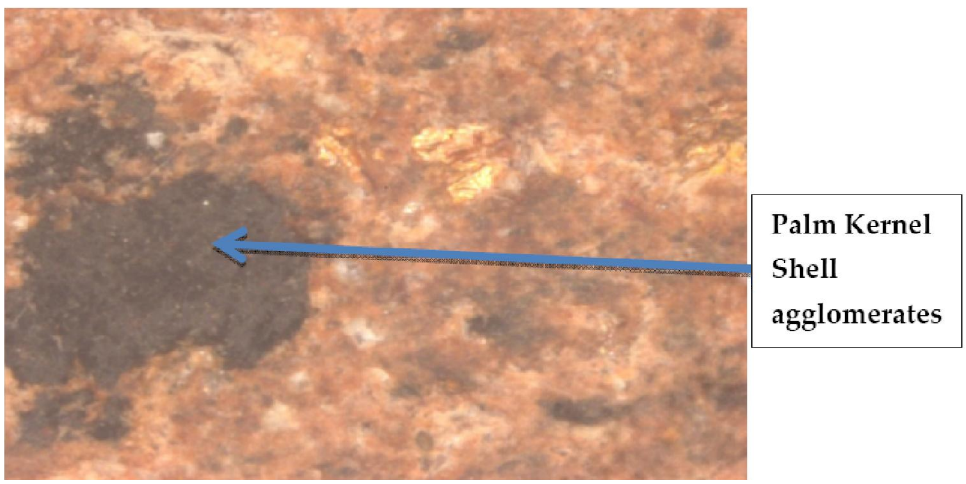

Figure 5 : Optical stereo micrograph of PKS based friction lining produced

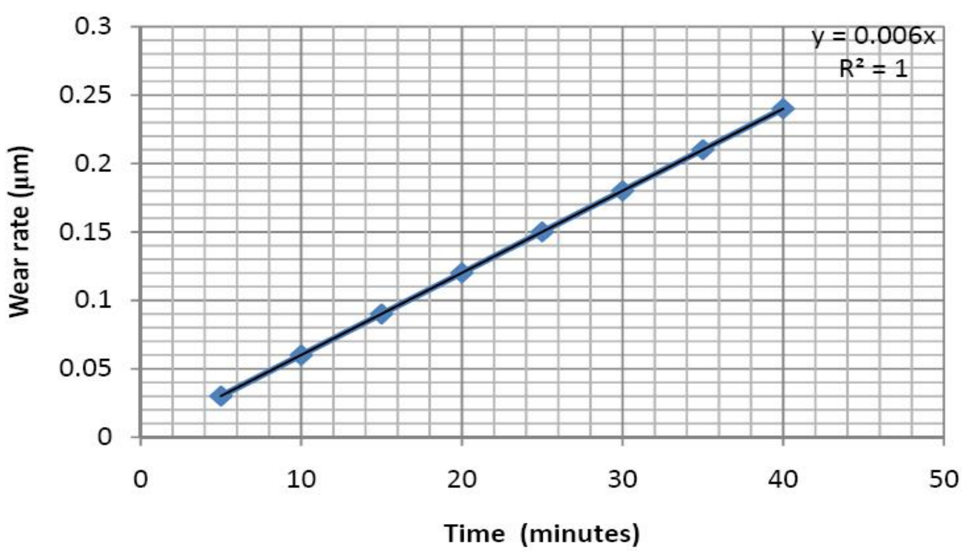

Figure 6 : Time vs. wear for PKS based brake lining

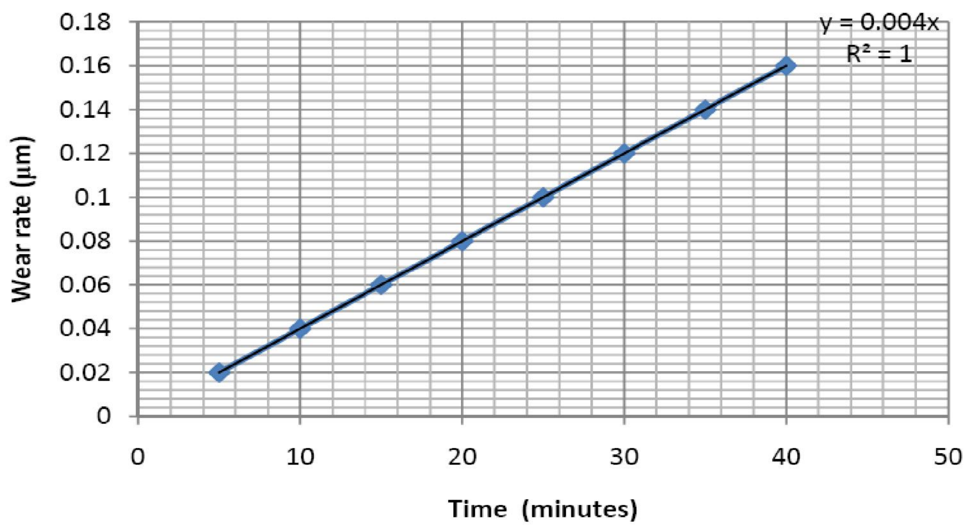

Figure 7 : Time vs. wear for the OEM brake lining

Wear test

The wear test results are graphically presented in Figures 6 and 7 below for the PKS based friction lining material developed and the OEM lining in the market. The PKS based friction lining material wears faster when compared to the wear rate of the OEM lining when tested using the same speed, load and duration.

CONCLUSION

This work has established that:

- Pulverized Palm kernel shell (PKS) particles can be well suited for use in brake linings formulations when properly combined with other additives.
- Burnt vehicle tires can effectively supply the carbon black content needed to boost the friction gripping of the lining material.
- PKS based brake linings were found to be thermally stable enough not to decompose at typical braking temperatures and durations.
- The PKS based brake linings have high char content as compared to OEM brake linings.
- The wear rate of the PKS based brake linings is high as compared to OEM brake linings.

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REFERENCES

[1] E.E.Akporhonor, P.A.Egwaikhide, F.E.Okieimen; Equilibrium sorption properties of palm kernel husk and N330 filled natural rubber vulcanizates as a function of filler volume fraction, Scientific Research and Essay, **2(5)**, 159-162 **(2007)**.

[2] D.Aleksendric´, C.Duboka; Fade performance prediction of automotive friction materials by means of artificial neural networks, Wear, **262**, 778-790 **(2007)**.

[3] I.M.Dagwa, A.O.A.Ibhadode; Some physical and Mechanical properties of palm kernel shell (PKS), Botswana Journal of Technology, **17(2)**, **(2008)**.

[4] I.M.Dagwa, A.O.A.Ibhadode; Field performance evaluation of asbestos – free brake pad, Nigerian Journal of Engineering Research and Development, **5(1)**, **(2006)**.

[5] I.M.Dagwa; Development of Automobile Disk Brake Pad from Local Materials, Ph.D Thesis, University of Benin, Benin City, Nigeria, **(2005)**.

[6] I.M.Dagwa, A.O.A.Ibhadode; Determination of optimum manufacturing conditions for asbestos-free brake pad using Taguchi method, Nigerian Journal of Engineering Research and Development, **5(4)**, 18 **(2006)**.

[7] A.Ganguly, R.George; Asbestos free friction composition for brake linings, Bull.Mater.Sci., **31(1)**, **(2008)**.

[8] S.C.Ho, J.H.Chern Lin, C.P.Ju; Effect of fiber addition on mechanical and tribological properties of a copper/phenolic based friction material, Wear, **258**, 861-869 **(2005)**.

[9] P.Filip, Z.Weiss, D.Rafaja; Friction layer formation in polymer matrix composite materials for brake applications, Journal of Wear, **252(3-4)**, 345-352 **(2001)**.

[10] P.Kosbe, C.More; Performance of a NAO friction material for disc brake, National Journal on Advances in Building Sciences and Mechanics, **1(2)**, 1-5 **(2010)**.

[11] O.A.Koya, A.Idowu, M.O.Faborode; Some properties of palm kernel and shell relevant in nut cracking and product separation, Journal of Agricultural Engineering and Technology, **12**, 33-45 **(2004)**.

[12] V.Roubicek, H.Raclavska, D.Juchelkova, P.Filip; Wear and environmental aspects of composite materials for automotive braking industry, Wear, **265**, 167-175 **(2008)**.

[13] B.K.Sataphathy, J.Bijwe; Composite friction materials based on organic fibres: Sensitivity of friction and wear to operating variables, Journal of Applied Science and Manufacturing, **37(10)**, 1557-1567 **(2006)**.

[14] R.T.Spurr; Fillers in friction materials, Wear, **22**, 367-409 **(1972)**.

[15] D.C.L.Teo, M.A.Mannan, V.J.Kurian; Structural concrete using oil palm shell (OPS) as lightweight aggregate, Universiti Malaysia Sabah, Civil Engineering Program, Sabah-MALAYSIA, **(2006)**.