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Wear Characteristics of a Locally Fabricated Automobile Brake Pad

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Abstract

The design, fabrication and testing of automobile brake pad using locally available raw materials are presented. The disc brake friction lining with the geometrical specifications of a Toyota Camry 2000 model was produced using palm kernel and coconut shells powder as base materials, Araldite™ and epoxy resin as binder materials, carbon as fiber reinforcement; aluminium, copper and zinc as abrasives and rubber dust as filter. Tests on the specimens indicate static and dynamic friction coefficient of 0.37 – 0.39 and 0.70 – 0.78, respectively as compared to static and dynamic friction coefficients of 0.40 and 0.72, of the reference commercial asbestos lining produced by Ibeto Group. The scratch hardness, bonding strength to the back plate and wear rate of the specimen ranged over 80 – 85, 25 – 27 kg/cm^3 and 0.25 – 0.27 mm/min, respectively, while similar properties for the control specimen was 85 for scratch hardness, 30 kg/cm^3 for bonding strength and a wear rate of 0.26 – 0.50 mm/min. From these results, it is deducible that the specimen has the potential to replace the conventional asbestos brake pad.

Keywords: Wear, Brake Pad, Palm Kernel, Coconut Shell, Scratch Hardness, Epoxy Resin.

1.0 Introduction

Friction results from interactions between surfaces of contacting materials. It is affected by volume and surface dependent properties of the materials. Iloeje, *et al*., (1989) reported that volume dependent property is elastic and it modifies the hardness and thermal characteristics whereas the surface properties of importance are the chemical reactivity, surface energy, tendency to absorb molecules from the environment and compatibility of the contacting surface forces which causes friction due to adhesion, local fusion asperity and interlocking. Any or all of these factors can cause fracture of the surface material, which implies the occurrence of wear. For low wear rates therefore, a friction material needs to have high shear strength. The hardness of a material, particularly its scratch hardness, is an indication of its resistance to wear. However, hardness decreases with temperature and since friction linings attain elevated temperature during operation, their production materials should have high hot hardness.

Friction linings for automobile brakes must have a reasonable high friction coefficient, typically within the range 0.40 – 0.47, and also be stable over wide variations of temperature and pressure. They should also have low wear rates, low moisture sensitivity, low shrinkage, adequate mechanical strength, good bonding to the back plate among other properties (Rothbart, 1964). Since no single material can have all properties required, linings are usually made from a mixture of materials which are compounded and subjected to specified pressure and temperature. In fact typical formulations consist of more than 10 ingredients, and more than 3000 materials are in different brands (Roubicek *et al*., 2008). These ingredients are classified into four broad groups: binders, reinforcing fibres or structural materials, fillers, and frictional additives/modifiers, based on the major function they perform apart from controlling friction and wear performance. There is normally, also, a base material that provides mechanical strength and bulk.

Lining, which is the major component in the brake pad, is categorized as metallic, semi-metallic, organic and carbon-based, depending on the composition of the constituent elements. For organic based linings, cotton and more especially asbestos (because of its additional stability over high

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temperature ranges) are used. The additives include hard rubber dust, fully cured resin, brass chips for reduction of wear, carbon black to increase tensile strength and bonding agents such as resins and rubber latex. Where resin is used as bonding material, vulcanization agents like sulphur or zinc oxide is added. Apart from the bonding properties, bonding agents also protect the linings against abrasive wear, corrosion, oil and moisture penetration and chemical attack.

Wood and leather were used as brake pad material prior to the establishment of friction materials industry. Unfortunately, their application was limited due, primarily, to their poor temperature resistance. Consequently in the late 19th century, they were replaced by cast iron. Cast iron undergoes phase transformation leading to heat checking of the brake drum or disk. This attribute of cast iron led to the introduction of cotton based material impregnated with bitumen solution in 1897 (Blau, 2001). However, the need for operating temperature, to exceed the permissible limit for cotton based material due to rising levels also led to the substitution of cotton with asbestos fibres. Asbestos had a few engineering properties that made it very suitable for inclusion in brake linings. It was the most preferred filler material up till 1989 (Mohanty and Chugh, 2007). Medical researches (Lemen, 2004; Department of Human Service, 2005) have revealed that the mechanics who work on asbestos brakes often suffer from Mesothelioma; a health problem which led to the introduction of other materials having similar performance characteristics like asbestos. In fact since the advent of braking systems in automotives, different materials have been tested as possible permanent brake materials with the intension overcoming either their potential health hazard or poor performance characteristics or both. Table 1 (Nicholson, 1995) shows the historical composition of some of the already tested automotive friction brake materials. Thus there is continuing work towards developing automotive brake material that will satisfy the medical, performance and cost requirements. This is seen from the works of Chan and Stachowiak (2004), Hee and Filip (2005), Mohanty and Chugh (2007) and Ruzaidi *et al*., (2011).

In this work therefore the design, fabrication and testing of automobile brake pad using locally available raw materials are presented. The materials used are palm kernel and coconut shell powder as base materials, Araldite™ and epoxy resin as binder, carbon as fibre reinforcement; aluminium, copper and zinc as abrasives and rubber dust as filter. The palm

Table 1: The historical composition of some already tested automotive friction brake materials.

Material Description	Application(s)	Approximate Year
Cast iron on steel	railroad car brake blocks and tires	prior to 1870's
Hair or cotton belting (limited by charring at about 300^{o}F)	wagon wheels and early automobiles	ca. 1897
Woven asbestos with brass and other wires for increased strength and performance	automobiles and trucks	ca. 1908
Molded linings with shorter chrysotile fibres, brass particles, and low-ash bituminous coal	" " "	ca. 1926
Dry-mix molded material to replace cast iron brake blocks that produced metallic dust that shorted electric train rails	London underground	ca. 1930
Flexible resin binders developed along with more complex formulations	brake drum linings	1930's
Resin-bonded metallic brake linings	industrial and aircraft applications	1950's
Glass fibers, mineral fibers, carbon and synthetic fibers to provide semi-metallics with higher performance than asbestos (beginning of safety issues with asbestos)	automotive and trucks	1960's
Non-asbestos (fiberglass) materials	brake drums on original equipment cars	1980's
Suggested use of carbon fibers	automotive brakes	1991

kernel and coconut shells used as the base materials have high strength, are resistant to wear and non poisonous. They are easily reducible to granular form and can be compounded with many of the known additives to form the friction linings.

2.0 Materials and Methods

2.1 Materials and Formulation

The base material selection was based on the following physical and mechanical properties: moisture content, apparent porosity, coefficient of friction, rupture strength, water and oil soak potentials, thermal conductivity, true density, specific heat capacity, sieve analysis, thermal degradation and compressibility. The other materials used are carbon dust charcoal, rubber dust from shoe, coconut shell dust, zirconium oxide, epoxy resins, copper dust and aluminium dust. The base material was collected and cleaned thoroughly to remove impurities. It was crushed and ground to a fine powder and subsequently sieved using 125 μm sieve. The sieved base material was mixed with the other materials in different proportions so as to determine the optimum friction lining formulation for manufacturing of the brake pad. Their mechanical property (hardness) and tribological properties (wear and coefficient of friction) were investigated from where the optimum manufacturing parameters and consequently the optimum friction lining formulation was obtained as Araldite® 0.05 kg, Epoxy resin 0.025 kg, Carbon 0.0025 kg, Aluminium 0.0015 kg, Copper 0.0015 kg, Zinc 0.0025 kg, Palm Kernel shell 0.025 kg, Coconut shell 0.025 kg, Rubber 0.012 kg using the analysis of variance (ANOVA) test. Different trial formulations were initially made before the preliminary tests which enabled the determination of some of the manufacturing parameters like the moulding pressure, curing time and heat treatment time. Some of the operations and the durations as determined are shown in Table 2.

The major laboratory equipment used in the production of the brake pad and its test are the Brake Pad Mould, Hydraulic Press for compressing the brake materials, Durometer for determining the hardness of the material, Inclined Plane for determining friction coefficient, Bondness machine for determining how the material is bonded to the back plate and brake pad Tribor test machine for determining the brake pad wear and braking time under different braking conditions.

2.2 Brake Pad Tests

2.2.1 Wear rate: The specimen has a groove so that it can be fitted firmly into the flywheel. After the specimen is firmly fitted to the flywheel, the electric motor is put on and allowed to drive the flywheel. While the flywheel is in motion the required brake load is added manually by loading the cantilever of the flywheel until the pad begins to wear out.

2.2.2 Bondness: The specimen is put into the Bondness testing machine and the electric motor is switched on to drive the hydraulic pump that moves the plate and compresses the pad material together.

2.2.3 Scratch hardness: The scratch hardness apparatus is placed on top of the specimen to determine the hardness of the material by pressing it on top of the specimen that indicates the required hardness.

2.2.4 Coefficient of friction: The specimen is put on an inclined plane and then allowed to slide. This is subsequently used to determine the friction co-efficient.

3.0 Result and Discussion

Table 2 shows a summary of results obtained from the tests conducted using the specimen produced. From these results, it is evident that the standard

Table 2: Some operations performed and their durations

Operation	Duration at room temperature
Matting stage (exposed under sun)	25 hours
Pot-life of gel coat resin with 30% solution of a medium	10 minutes
Gel point of the resin	22.4 minutes
Hardening time of the composite	42 minutes

brake pad produced from asbestos, which served as control, has better bonding and higher value of coefficient of friction. In fact specimen 1, 2 and 3 have coefficient of friction of 0.38, 0.39, and 0.37, respectively while that of asbestos was 0.41. The scratch hardness test results reveal that both the specimen and control are of about the same hardness. However specimen 3 presented a much lower hardness value of 80 as against the values of between 84 – 85 recorded by specimen 1 and 2 and the control. Despite the observed lower coefficient of friction values for the specimen, they are still within the typical value range of 0.3 – 0.6 (Anderson, 1980) for most automobile materials. These performances of the specimen may be attributed to the following factors:

i. Compacting Pressure: A compacting machine with a heating rig was not available as at the time of production of the specimen. In its stead, a G – clamp was used. This resulted to the problem of improper bonding of the specimen and thus the difference of 3 – 5 kg/cm3 recorded between the specimen and the standard one made of asbestos.

ii. The resin that was designed for was phenolic resin. However, due to its scarcity in the local market, an alternative, called epoxy resin which has approximate characteristics was used as the binding agent. Epoxy resin is associated with inferior thermal characteristics, since it decomposes at a temperature of 269oC compared to the Phenolic resin which decomposes at a temperature of about450oC. This poor thermal characteristic make the material separate from each other, thereby resulting in the reduced bonding strength of the brake pad material, especially at elevated operating temperature.

Figure 1 shows the wear characteristics of the specimen and control. It can be seen from this figure that between 0 – 240 sec, the specimen had generally lower wear rate. However, it presented an almost linear relation throughout the test period as against the control which was almost linear from 0 – 120 seconds. Above 120 seconds, the wear was almost constant. On the average, the specimen presented wear rate of 0.25 – 0.27 mm/min while the control had an average wear rate of 0.26 – 0.50 mm/min. This result further shows that the specimen had an initially lower wear rate which increased with time while the asbestos used as control had an initially higher wear rate which reduced with time. The good thermal conductivities of the materials used as abrasive in the brake pads produced enabled fast dissipation of heat generated during operation. This protects the surface of the specimen from high temperature induced wear, hence the superior wear characteristics earlier observed. The overall near linear wear pattern of the specimen however, may be attributed to the poor bonding and the poor thermal characteristics of the epoxy resin used.

Though the brake pads produced did not display good bonding and coefficient of friction when compared with the asbestos brake pad used as control, its overall performance compared favourably well with standard brake pad produced using Asbestos.

4.0 Conclusion

The design and fabrication of an automobile brake pad using locally available materials have been undertaken. The materials used include palm kernel shell, coconut shell, Araldite, epoxy resin, carbon, aluminium, copper, and zinc and rubber dust from shoe. Results obtained from test conducted using the brake pad revealed that the coefficient of friction ranged over 0.37 – 0.39, the scratch hardness between 80 – 85, bonding strength in the range of 25 kg/cm3 – 27 kg/cm3, and an average wear rate

Table 3: Summary of test results conducted using the specimen brake pad produced.

Property	Specimen 1	Specimen 2	Specimen 3	Asbestos
Bonding (kg/cm^3)	27	25	27	30
Scratch hardness	84	85	80	85
Coefficient of friction	0.38	0.39	0.37	0.41

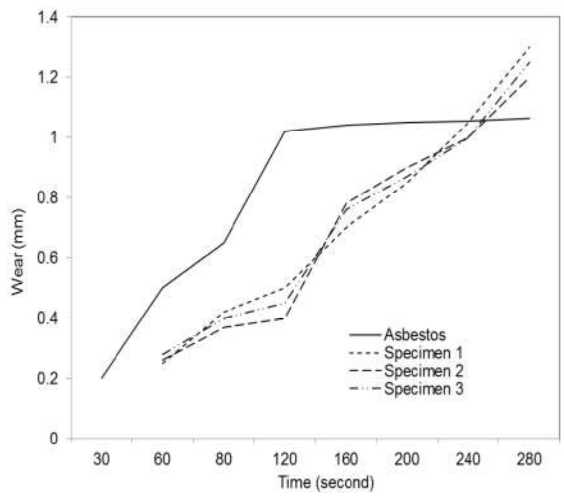

Figure 1: Wear pattern of the brake pads.

of 0.25 – 0.27 mm/min. Though these results appear impressive, there is room for further improvements, especially on the bonding and coefficient of friction.

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