OPEN ACCESS
World J of Engineering and Pure and Applied Sci. 2012;2(3):92 ISSN 2249-0582
Bashar et al., 2012. Production of Cold-Worked Brake Pad

Original Article
Basic Science

Material Selection and Production of a Cold-Worked Composite Brake Pad

Bashar DAN-ASABE [1], Peter B MADAKSON [1], Joseph MANJI [2]

ABSTRACT [ENGLISH/ANGLAIS]

This paper entails the selection and production of composite brake pad with varied constituent's composition. Series of tests were conducted that involved tensile, compressive, hardness, impact, wear and corrosion to ascertain composition with the best property as compared to a commercial Honda brake pad (Enuco) model widely used in Nigeria. The results shows that higher percentage of grounded coconut shell powder induces brittleness since compositions with lower percentage of it produced higher breaking strength and lower wear rate. It was also established from the tests results that compositions 4 and 5 have an overall better mechanical and corrosion resistance property than the model with composition 4 having the least wear rate effect.

Keywords: Material selection; cold-worked brake pad; mechanical tests

RÉSUMÉ [FRANÇAIS/FRENCH]

Ce document comporte la sélection et la production de plaquette de frein compositeavec une composition variée de constituant. Des séries de tests ont été effectués à la traction que parties concernées, à la compression, la dureté, l'impact, l'usure et la corrosion de la composition de vérifier avec le meilleur des biens par rapport à un padcommerciale Honda de frein (Enuco) modèle largement utilisé au Nigéria. Les résultats montrent que pourcentage plus élevé de la noix de coco en poudre à la terre enveloppeinduit une fragilité depuis compositions avec plus faible pourcentage de celui-ci produitune plus grande résistance de rupture et de baisse du taux de l'usure. Il a également étéétabli à partir des résultats des tests que les compositions 4 et 5 ont une propriété de résistance mécanique et une meilleure globale à la corrosion que le modèle avec la composition 4 ayant le moins d'effets taux d'usure

Mots-clés: La sélection des matériaux; écroui plaquette de frein, les tests mécaniques

Affiliations:

[1] Shell Chair Office, Department of Mechanical Engineering, Ahmadu Bello University, ZARIA

[2] Depa Department of Mechanical Engineering, Ahmadu Bello University, ZARIA

Address for Correspondence/ Adresse pour la Correspondance: bashar.danasabe@gmail.com

Accepted/Accepté: February, 2012

Citation: Bashar DA, Peter BM, Joseph M. Material selection and production of a cold-worked composite brake pad World Journal of Engineering and Pure and Applied Sciences 2012;2(3):92-7.

INTRODUCTION

Development of frictional composite brake pad of lighter weight, improved mechanical properties and corrosion resistance capability is essential in minimizing cost, material and wear while improving the safety on our high ways. The significance of brake pad is to transform the kinetic energy of a vehicle to heat energy via friction and ejecting the heat to the surrounding environment. Drum (shoe) brake and disk (pad) brakes are the major types of friction brakes.

Most of the brake pad material constituents are composites of varied material constituents. There are more than 2,000 different materials and their variants are used in commercial brake components [1]. The first frictional brake material composed of cotton material impregnated with bitumen solution was invented by Herbert Frood [2] in 1879. This led to the establishment of Ferodo Company that still supplies brake pad materials up till now. Table 1 lists some of the common brake pad materials.

Composite brake pad constituents' materials are composed of varied composition of abrasives, friction modifiers, binders, fillers and reinforcements. These are explained by Hooton [1], Spurr [3], Rhee [4], Hoeganaes [5], Nicholson [6], Gudmand-Hoyer et al [7], Borden [8] and Jang et al [9] as summarized in the Table 2.

Medical research has shown that asbestos usage can induce adverse respiratory conditions. Asbestos is still in use because of its high strength fibre and cheapness but its gradually phasing out due to respiratory problems it causes in the human lungs [1].

MATERIALS AND METHODS

This involves selection of constituents' materials, production of the brake pad with varying composition and carrying out mechanical and chemical test.

Material Selection

The main materials for this research are coconut shell powder, cast iron fillings, silica, epoxy (liquid resin), catalyst and accelerator. These are depicted in Table 3.

The coconut shell was obtained from a coconut trader in the market and dried in the sun for two weeks to drain moisture from the shell. The size was reduced using hammer and anvil, pounded with a pestle and mortar and finally grounded to powder with a grinding machine. A sieve of aperture of 710 µm (micrometer) was used to sieve the grounded product. The epoxy also known as polyepoxide, a thermosetting polymer was purchase from a chemical store in Jos central Nigeria. All the other materials were obtained from a chemical shop in Samaru, Zaria.

Production of the Brake Pad with Varying Compositions

The weights of the coconut shell powder and epoxy resin were varied while those of the abrasives, friction modifier, catalyst and accelerator were kept constant. The appropriate portion of epoxy resin was poured into a container followed by some small portions of the catalyst and accelerator and then thoroughly mixed. Powders of reinforcement, friction modifier and abrasives were mixed in a different container and then poured into the resin mixture and stirred further to obtain a homogenous mixture. The mixture was then poured into a mould of 100 ×50×10 mm to cure. . It takes about 30-40minutes to cure. Same process was followed to produce other samples in order to obtain composition with the best mechanical property. The percentage composition for each sample is given in Table 4.

Mechanical and Corrosion Test

Mechanical tests were carried out that includes tensile, compressive, hardness, impact and wear tests. The tensile test was carried out using Hounsfield extensometer with a specimen equal portion of 45×10×7 mm from the different compositions and model. The tensile strength indicates the ability of a material to stretch prior to failure.

The tensile stress, compressive stress and Young's Modulus are determined according to Hooke's Law as given below (11):

$$\sigma_t = \frac{F}{A}$$ ………………………………………equation 1

$$\sigma_c = \frac{F}{A}$$ … ……………………………………equation 2

$$E = \frac{\sigma_t}{e}$$ ……………………………………… equation 3

$$A = b \times t$$ ………………………………equation 4

Where σ_t = Tensile stress, σ_c = compressive stress, E = Young's Modulus, e = strain, A = surface area, b = breath and t = thickness

The compressive strength test was performed using the Enerpac universal hydraulic digital material testing machine with a specimen equal portion of 14×7×7 mm from the different composition and model. The compressive force or load is the load required to compress or crush material. The result is displayed in digital form.

The wear test was carried out using an adopted method with a specimen equal portion (of 14×7×8 mm) from the different the compositions and model. The method involves placing each sample (clamped rigidly in position) along the disc of a grinding machine for 5 seconds. The samples weights were taken before and after grinding. The weight difference from each sample indicates the lost in weight. The speed of the grinding machine and its disc diameter are 6600 rpm and 210mm respectively.

The wear rate is given by the following equation [12]:

$$\text{Wear rate} = \frac{\Delta w}{S} = \frac{\Delta w}{2\pi ND \times t}$$ (g/m)……… equation 5

Where Δw = weight loss (weight difference before wear e and after wear), S = sliding distance, D = diameter of disc, N = rpm and t = time it takes each sample (exposed) on the grinding machine.

The hardness test was carried out using Indentec Universal Hardness tester (model 8187 LVK) with a specimen equal portion (of 40×7×7 mm) from different compositions and model. Hardness is the ability of a material to resist plastic deformation. The impact test was conducted using the Charpy impact testing machine with a norch depth tip radius of 0.02mm at an angle of 45 degree with a sample equal portion (of 80×10×10 mm) machined from different composition and model. The machine impact energies ranges from 0 to 300J with a hammer of 22.7kg at striking velocity of 3.5m/s. The impact test gives an idea of the energy required to break a notch specimen under standard conditions.

Concentrated hydrochloric acid mixed with distilled water (in the ratio 0.5ml/2.5ml acid to distilled water concentration) was used for the corrosion test with a specimen equal portion (of 14×7×5 mm) taken from the different compositions and the model. The samples were cleansed with distilled water and inserted into the corrosion medium for 5 days with routine removal of the sample for analysis after every 24 hours. The samples were always cleaned before being reinserted back during the routine removal analysis. The lost in weight was noted and recorded during the five days period.

The corrosion rate was calculated as given below [13]:

$$\text{Corrosion rate} = \frac{kw}{\rho A t} \text{ (mm/yr)} \quad \ldots\ldots \text{ equation 6}$$

$$\rho = \frac{m}{v} \quad \ldots\ldots \text{ equation 7}$$

$$A = 2(l \times b) + 2(l \times h) + 2(b \times h) \quad \ldots\ldots \text{ equation 8}$$

$$V = l \times b \times h \quad \ldots\ldots \text{ equation 9}$$

Where k is constant = 87.6, w = weight (g), ρ = density, A = surface area, t = time (hrs), m = mass, v = volume of each sample.

RESULTS

All the different sample compositions have a fairly straight line trend for tensile tests (see the force-extension diagram in figure 1). Compositions 3, 4 and 5 have a steeper slope towards the y-axis and thus have higher Young's Modulus than other compositions and the model. All the compositions and model give a fairly elastic trend throughout i.e. the lines do not go into plastic deformation. The compressive and fracture (breaking) strengths are also higher than the model for compositions 2, 3, 4 and 5 as depicted in figure 3. Here the breaking load is very significant since it gives the ability of the materials to withstand higher elastic energy before breaking.

The various hardness and impact energies were (found to be) proportional for most of the compositions and the models (figure 4). However, compositions 4 and 5 are

Table 1: This table shows common brake pad materials [1]

S/N	Description of Material	Application/Approximate Year
1	Cast iron on steel	Railroad car brake blocks and tires. Prior to 1870's
2	Hair or cotton belting (limited by charring at about	Wagon wheels and early automobiles. ca. 1897
3	Woven asbestos with brass and other wires for increased strength and performance	Automobiles and trucks. ca. 1908
4	Molded linings with shorter chrysotile fibers, brass particles, and low-ash bituminous coal	Automobiles and trucks. ca. 1926
5	Dry-mix molded material to replace cast iron brake blocks that produced metallic dust that shorted electric train rails	London underground. ca. 1930
6	Flexible resin binders developed along with more complex formulations	Brake drum linings. 1930's
7	Resin-bonded metallic brake linings	Industrial and aircraft applications. 1950's
8	Glass fibers, mineral fibers, metal 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
9	Non-asbestos (fiberglass) materials	Brake drums on original equipment cars. 1980's
10	Suggested use of carbon fibers	Automotive brakes. 1991

Table 2: This table shows friction brake material composition with variety of material choice

S/N	Brake pad Materials	Material Choice
1	Binders (Matrix): holds all the other material in place	Phenolic resin, metallic alloys (of copper, iron etc) and modified resins (cresol, epoxy, cashew, PVB, rubber, linseed oil and boron)
2	Fillers and Reinforcements: maintains overall compositions, cheapens end products etc.	Anti-oxidants (i.e. graphite), asbestos, barium sulfate, calcium carbonate, cashew nut shell oil, cotton, fibres (mineral wool, alumina, calcia etc), lime, rubber scrap, zinc oxide etc.
3	Abrasives: increases friction and controls the build-up of friction film	Aluminium oxide, iron oxide, quartz, silica and zirconium silicate
4	Friction Modifiers: raises the friction and react with oxygen to control interfacial films	Antimony trisulfide, brass, carbon (graphite), copper, friction dust (processed cashew resin), friction powder, led oxide, metals (i.e. Pb, Sb, Mo etc), metal oxides (magnetite, zinc oxide, chromium oxide etc.), metal sulfides (i.e. lead sulfide, cupper sulfide etc), mineral fillers (i.e. mullite, kyanite, sillimanite, alumina, crystalline silica etc.), petroleum coke etc.

higher (better) than the model in both tests. The trends of the wear rate for the different compositions are shown in figure 5 with composition 4 having the least wear rate. The evenly distributed micro-structural distribution for Composition 4 is shown in figure 6.

Table 3: This table shows materials used in the production of the composite brake pad

S/N	Brake pad materials	Material	Reason for material choice
1	Binders (Matrix)	Epoxy	Rarely used in brake pad composition. Chosen to investigate its effects
2	Reinforcements	Iron	
	Filler	Grounded coconut shell	Cheapness and availability. Influences adhesion and dispersion of polymer composite fabrication (10)
	Catalyst	Methyl ethyl ketone peroxide	Less sensitive to shock and temperature
	Accelerator	Cobalt nephthanate	Speeds rate of reaction
3	Abrasives	Iron and silica	
4	Friction Modifiers	Brass	Improves wet friction and is non hazardous

Table 4: This table shows percentage compositions of the different brake pad samples

S/N	Constituents	Percentage Compositions (%)				
		Comp 1	Comp 2	Comp 3	Comp 4	Comp 5
1	Matrix	20.0	30.0	40.0	50.0	60.0
	Reinforcements	10.0	10.0	10.0	10.0	10.0
2	Filler	50.0	40.0	30.0	20.0	10.0
	Catalyst	0.5	0.5	0.5	0.5	0.5
	Accelerator	0.5	0.5	0.5	0.5	0.5
3	Abrasives:	10.0	10.0	10.0	10.0	10.0
4	Friction Modifiers:	9.0	9.0	9.0	9.0	9.0
	Total	100.0	100.0	100.0	100.0	100.0

Figure 1: This figure shows force-extension graph for the different compositions and model

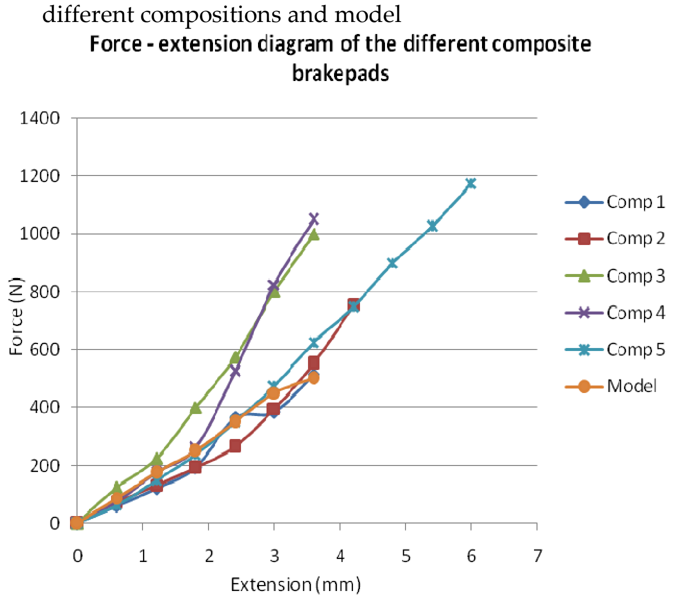
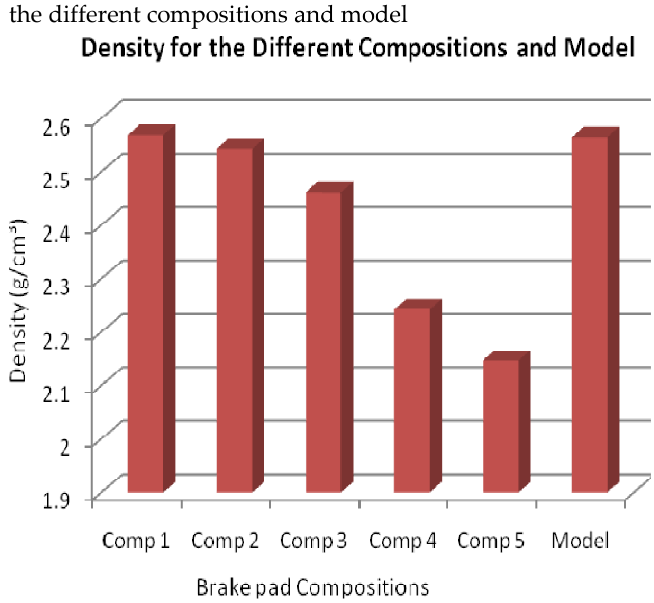


Figure 2: This figure shows comparison of density for the different compositions and model



DISCUSSION AND CONCLUSION

The developed composite brake pad has much better mechanical properties than the commercial Honda brake pad model. From the analysis of the results, the following conclusions were made:

- The higher the percentage of grounded coconut powder the lower the breaking strength, impact, hardness and compressive strength, and vice-versa respectively. Thus high percentage of grounded coconut powder induces brittleness. This corroborates the analysis that palm kernel nut shell incorporated into HDPE showed poor tensile properties i.e. the tensile - impact strength of treated and untreated Palm Kernel nut shells polymer composite decreases with increase in its filler (Palm kernel nut) content [14].

Figure 3: This figure shows comparison of compressive and breaking strength for the different compositions and model

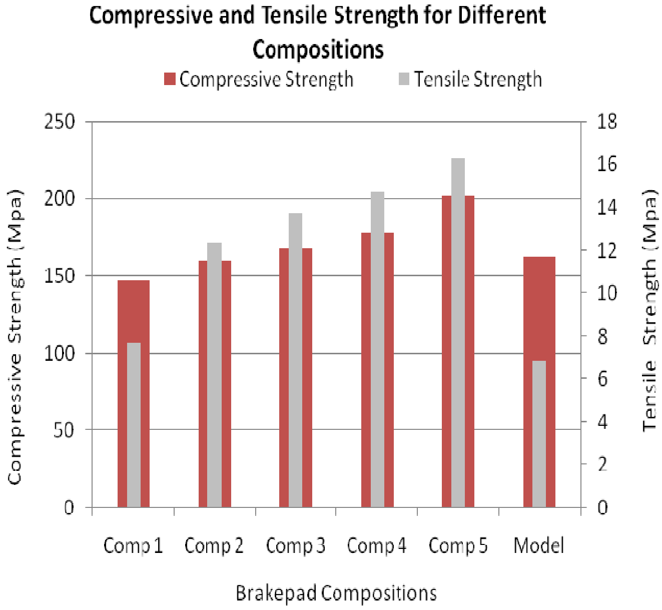


Figure 4: This figure shows comparison of hardness and impact energy for the different compositions and mode

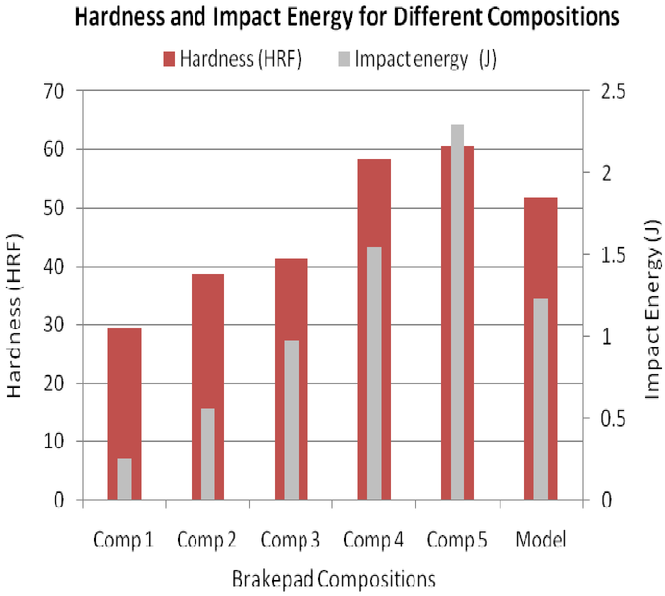


Figure 5: This figure shows comparison of wear rate for the different compositions and model

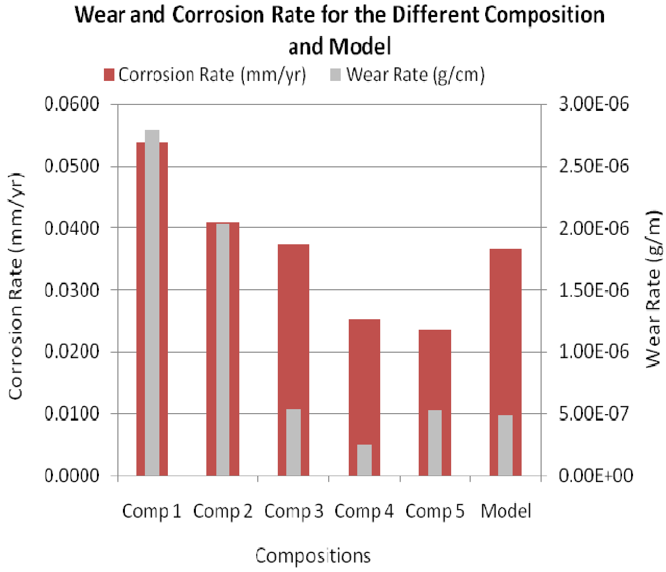
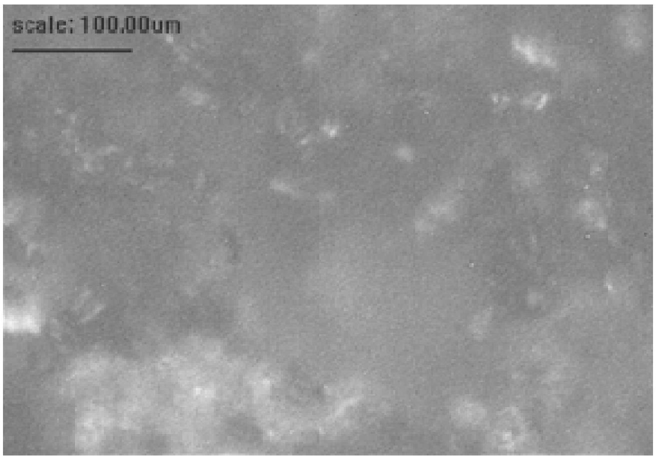


Figure 6: This figure shows microstructural distribution of constituents for composition 4



- Compositions 4 and 5 have overall better mechanical and corrosion resistance property than the model. Their tensile strength is much higher than that of the model.
- Compositions 4 and 5 can be adopted in the production of brake pads. They are far less dense (lighter) than the other compositions and model. However composition 4 may be a better alternative since it has the least wear rate resistance.

REFERENCES

[1] Blau PJ. Compositions, Functions, and Testing of Friction Brake Materials and Their Additives. Tennessee: Oak Ridge National Laboratory; 2001

[2] Nicholson G. Facts About Friction. Croydon, PA: P&W Price Enterprises. 1995.
[3] Hooton NA. Metal-Ceramic Composites in High-Energy Friction Applications. 1969,Bendix Technical Journal, Spring 1969;55-61
[4] Spurr RT. Fillers in Friction Materials. Birmingham Wear 1972;22:367-409
[5] Rhee SK. Wear Mechanisms for asbestos-reinforced automotive friction materials. Wear 1974;29:391-3
[6] Hoeganaes, Corp. Friction Powder Grades. New Jersy; Product literature. 1990.
[7] Gudmand-Hoyer L, Bach TG, Per M. Tribological properties of automotive disc brakes with solid lubricants. Wear 1999;232:168-175
[8] Borden Packing and Industrial Products, Inc. Literature on modified resin products. Louisville, KY. 1994.
[9] Jang H, Kim S J. The effects of antimony trisulfide and zirconium silicate in the automotive. Wear 2000;239:229-36.
[10] Ishidi EY, Kolawole EG, Sunmonu KO. Morphology and thermal property of alkaline treated palm kernel nut shell HDPE composite. Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS);2(2):346-350
[11] Khurmi, RS, Gupta, JK, Chand S. Machine Design. New Delhi: S Chan Publishers. 2005.
[12] Hanni AA, Khaira HS, Esthar MM. Effect of loads, sliding speeds and times on the wear rate.American Journal of Scientific and Industrial Research 2011;2(1):99-106
[13] Callister WD (Jr). Material science and engineering an introduction. New York: John Wiley and Son Inc. 1997.
[14] Ishidi E Y, Kolawole E G, Sunmonu K O, Yakubu M K, Adamu I K, Obele M C. Study of Physio-Mechanical Properties of High Density. Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS) 2011;2(6):1073-8.

ACKNOWLEDGEMENT / SOURCE OF SUPPORT
Nil

CONFLICT OF INTEREST
No conflicts of interests were declared by authors.